Interactive Music Science Collaborative Activities

Team Teaching for STEAM Education

Deliverable 2.6
Intermediate Educational Scenarios & Lesson Plans for iMuSciCA

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Executive Summary

With regard to the iMuSciCA's Framework for STEAM Education the pedagogical team has built upon the continuous communication with the technical team in order to analyse and implement improvements and adaptations the initially developed Educational Scenarios and Lesson Plans according to the evolving pedagogical needs of the project and the respective pilot sites.

In order to document the intermediate Educational Scenarios of the iMuSciCA project -and responding to the need to link learning approaches with the proposed interactive Digital Tools, the document commences with an assessment of the Workbench development. A summary of the contribution of teachers and students to the improvement of the objectives that the project deals with, is presented afterwards. References mainly to qualitative data collected so far are also included.

As an overall result for the teachers' evaluation the deliverable claims the following conclusions:

- Initial Educational Scenarios, Lesson Plans and Activities have been evaluated as positive.
- The project's extra-curricular activities imposed by the educational scenarios help teachers understand better its pedagogical framework and purpose.
- In terms of content, while authoring teams are encouraged to simplify the language and clarify the pedagogical objectives, teachers appreciate the diversity of tools that helps increasing students motivation in STEM and IBSE practices.

Except from France where piloting is scheduled to be initialized in May 2018, students gave the following feedback:

- In Belgium the digital environment was found to be exciting, but tools needed to be more stable allowing microphone recognition so as "hands on material" practices act complementary to digital.
- In Greece feedback from the interviewed students proved that digital tools encouraged them not only to meet the objectives but also allowed them to start exploring the opportunity of a concert with students from other piloting countries.

In the following introduction to these intermediate Educational Scenarios, the connection between the current scenarios and the project's pedagogical framework is briefly documented, according to the progress of the online platform and the qualitative feedback. Following the structure of the previous deliverable, all proposed Educational Scenarios are divided for Lower and Upper Secondary Education. References of the initial Educational Scenarios are included in the list of short descriptions along with the present intermediate ones. In each reference every Educational Scenario is briefly described along with the link to its corresponding online folder.

The following Educational Scenarios and their related Lesson Plans have been further or newly developed:

· Scenarios for Lower Secondary Education

1. Sound and tone: Sources of Sound and Music and What is Tone?
2. Standing waves and resonant frequencies: The sequence of natural tones, Natural Tones and Standing Waves, How do standing waves occur?
3. Synthesize the timbre of your preferred instrument
4. Build a musical piece using geometrical symmetry
5. Make your own string instrument

· Scenarios for Upper Secondary Education

1. Let's hear Thales' theorem
2. Investigating the monochord
3. Timbre and power spectra
4. Instruments of speech (Volume 1)
5. The house of chords
6. Let's play 'Sectio Canonis'
7. Instruments of speech (Volume 2)
8. Listen to your math

The document concludes with an assessment of the progress achieved on the strategy that secures the optimal implementation of the proposed scenarios in respect with the pedagogical needs adapted to the piloting conditions. The last update of the assessment for implementing this strategy will be included in the final version of learning scenarios (i.e. within D2.8 'Final Educational Scenarios and Lesson Plans for iMuSciCA').

This present Deliverable 2.6 is directly related to Deliverable 2.3 'Initial Educational Scenarios and Lesson Plans for IMuSciCA' and presents an update of the consolidated existing and newly co-created Educational Scenarios and Lesson Plans following the continuous technical progress of the interactive Digital Tools on the iMuSciCA Workbench.

The following Sections are furthermore utilising information from Deliverables 5.6 'First Version of Usability Validation of iMuSciCA Toolkits', 6.1 'Pilot Testing Action Plan' and 6.2 'Interim Report on Teacher's Feedback and Pilot Testing in Schools (Phase A)'.

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Disclaimer

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LIST OF ABBREVIATIONS

Abbreviation	Description
STEM	Science, Technology, Engineering and Maths
STEAM	Science, Technology, Engineering and Maths combined with Arts
PU	Public Report
WP	Work Package
ATHENA	ATHENA RESEARCH AND INNOVATION CENTER IN INFORMATION COMMUNICATION & KNOWLEDGE TECHNOLOGIES
UCLL	UC LIMBURG
EA	ELLINOGERMANIKI AGOGI SCHOLI PANAGEA SAVVA AE
IRCAM	INSTITUT DE RECHERCHE ET DE COORDINATION ACOUSTIQUE MUSIQUE
LEOPOLY	3D FOR ALL SZAMITASTECHNIKAI FEJLESZTO KFT
CABRI	Cabrilog SAS
WIRIS	MATHS FOR MORE SL
UNIFRI	UNIVERSITE DE FRIBOURG

1. Progress of the iMuSciCA Workbench

This Section introduces the improvements of the Digital Tools as contained on the iMuSciCA Workbench. It also gives a brief description of the improvements suggested by the educational partners UCLL and EA, in order to respond to the pedagogical requirements and to the structure of Educational Scenarios and their Lesson Plans.

Throughout the interaction the pedagogical partners asked the following improvements, which were implemented already:

- Make it possible to run all visualization and measurement tools next to all music and engineering tools.
- Improvement of the Athena Metronome: add metronome without tone; musicians need to have a metronome that makes a short 'hit' that contains no tone which could otherwise disturb the melody during performance.
- Make the sound coming out from the Engineering tool louder to make the measurement of the frequency possible: the technical team implemented a general volume regulator in the workbench.
- Allow the use of frequencies up to 7000 Hz in the Tone synthesizer: students can then synthesize the timbre of their preferred instrument. This has been implemented by the technical team by adding a drop-down menu that allows the user to select the maximum frequency.

The following are examples of requests currently under study or development by the technical team:

- Allow the use of the *microphone* for external sound input: the technical team will add a specific direct microphone input.
- In the *Engineering tool*, beside the monochord, create string instruments that look like a real string instrument like a guitar, a violin, a bass guitar so that the user can choose the form of the instrument body and the number of strings (e.g. 4 or 6 strings).
- Make it possible to copy the instruments created in the *Engineering tool* by the students (bass guitar, guitar, etc.: see point above) to the *3D Musical instrument performance tool* to play with them. This will be implemented through the clipboard.
- In the *Engineering tool* the sound produced needs some improvements in order to be be used in the pedagogical scenarios. These issues need some further investigation by the technical team:

    - If two different strings are initially set with identical parameters, they should emit the same sound.
    - By increasing the radius r of a string, the frequency f should decrease following the relation: $f \sim \frac{1}{r}$

    - By increasing the tension F of a string, the frequency f should increase according to the relation f ~ [$\sqrt{F}$].
    - The list of materials for the strings should be shortened, but the sounding properties of the strings with respect to the chosen string material should be checked to correspond with reality. In particular the sounds emitted by strings of typical materials used in string instruments should be harmonic.
- In Drawing Canvas for Music Creation there is an interesting feature which allows drawing tones in different colors. It would be useful if the different colors could be played separately by adding a play button for each color: this could be implemented e.g. in scenario 4. Build a musical piece using geometrical symmetry (for Lower Secondary Education).

2. Evaluation of the iMuSciCA Platform and Educational Scenarios

This Section gives a brief summary on the feedback as well as suggestions for refinement and further improvement as collected from both end users i.e. teachers and students with regard to the initial Educational Scenarios, Lesson Plans and where relevant to the related Digital Tools as collated on the iMuSciCA Workbench.

2.1 Teachers' Evaluation of Educational Scenarios

The majority of the 38 participating European teachers in the first round of evaluation of the Educational Scenarios (and related Lesson Plans) were Science or Mathematics teachers, of which around 55% have a teaching experience of more than ten years. More than 80% of all teachers describe themselves as at least relatively experienced in applying Information and Communication Technologies (ICTs) and e-Learning applications in the classroom. On the flipside the participating teachers were at large not experienced in connecting STEM education with Music.

Overall the initial Educational Scenarios, underlying Lesson Plans and Activities have been evaluated as positive; however, the second Scenario on Standing Waves & Resonant Frequencies gained slightly lower scores as teachers perceived the concept as too sophisticated to be applied easily with students in junior high schools.

Experimenting with the Educational Scenarios within the classroom as well as during extra-curricular (i.e. afternoon) activities clearly helped teachers to understand better the pedagogical framework of iMuSciCA. The Scenarios are perceived of having high potential to improve the student's performance in STEM. They are furthermore helpful to i) increase the interest of students in STEM; ii) to implement Inquiry Based Learning (IBL) as well as; iii) to apply interdisciplinary approaches in the classroom. Thus, most educators are planning to the use the teaching and learning environment as well as the educational materials of in their daily teaching in the future.

However, the achievement of their educational objectives and their relevance for the STEM curriculum and beyond (e.g. through extra-curricular students' clubs or summer camps) should be further improved and reflected in the refined versions of the Educational Scenarios.

During the refinement phase, the original authors (i.e. experts of iMuSciCA) will be supported by teachers and external experts in refining the original Scenarios and in co-creating new Educational Scenarios.

The authoring teams are encouraged to pay special attention to express more accurately the educational objectives for each Educational Scenario. In addition, the language should be simplified as well as the educational content better adapted to the specific age group of students. It was also recommended to follow more closely an inquiry-based approach to teaching and learning.

Finally, a highly diverse range of Activity Environments (i.e. Digital Tools) have been successfully integrated within individual Educational Scenarios and the Workbench, both positively affecting the teachers' satisfaction in using the iMuSciCA service portfolio.

The evaluation of Educational Scenarios, Lesson Plans and related Digital Tools of iMuSciCA by teachers will continue throughout 2018 within the involved pilot sites in Belgium, France and Greece.

A prominent role in the assessment of the existing service portfolio of iMuSciCA will play the Summer School for teachers to be held in Greece in July 2018 involving science teachers from all around Europe.

The results will be summarised in deliverable D2.8-Final Educational scenarios and lesson plans for iMuSciCA.

2.2 Students' Feedback on Educational Scenarios

In **Belgium** the students of Agnetencollege at Peer were involved in the piloting. Below a summary of the student's feedback on the Educational Scenarios developed for Lower Secondary Education is provided.

In general students find the possibility to be working in a digital environment exciting. It is furthermore a well perceived change from the more classical, transmissive Educational Scenario between student, teacher, pen, paper and blackboard.

The animations provide a good alternative for them to visualize certain properties compared to more traditional drawings, which in certain cases have limitations as they cannot show what is really happening. In general, the reactions on the iMuSciCA workbench and scenarios were positive, however it was emphasized the necessity of having more stable digital tools (i.e. to make implementations straight forward), but also to implement even more digital tools in future Educational Scenarios.

Concerning the Digital Tools, the feedback centred primarily on the tools 'Drawing Canvas for Music Creation' and the 'Analyzer'. The first tool received unanimously positive reactions because it offers many options and it can be deployed in many different ways, e.g. to make drawings, portraits and sometimes short melodies. The teacher-students[1] and teachers emphasised the necessity of using earbuds to prevent a cacophony of sounds during lessons. Furthermore, rather strict guidance how and what students should perform with a tool should be provided in order to prevent gradual loss of concentration.

The 'Analyzer' offers support in acquiring insights regarding the properties of sound and waves. For example, when using instruments such as a whirly tube or a tin whistle, students discover how whirling harder or softer makes the waveform change and how playing louder or softer does the same. Overall the recognition power of the *Analyzer* was perceived as sufficient, but in some cases an external microphone was regarded necessary. Furthermore, some further precision in the tool in order to be able to read frequency values (e.g. between 880Hz and 1760Hz) would further improve its usability.

[1] Teacher-Students in Belgium are university students in the third (and last) year of their Bachelor studies for becoming teachers in physics. They attend an internship in a specific school of approximately eight weeks.

In addition, the understanding of lesson content naturally impacted on students - despite the relative complexity of the content for students of this age range.

During the focus groups with students it also became clear that the general ideas and concepts of the study materials were understood. Students were able to explain in simple words these concepts. Quite understandably explaining the links between theoretical concepts in their own words remained difficult for students of this specific age range. Nonetheless the test results showed that they understood the general ideas - mostly better than expected - and could even solve short related problems.

Finally, 'hands on materials' are still considered a good complement to the proposed digital tools. This lifts spirits and can be a wake-up call when attention is dwindling. Whilst many instruments and experiments can be digitalised, having the actual item or performing the experiment in real life creates an alternative and complementary way of learning: the interaction with real instruments sometimes offers something that can't be achieved by looking at an animation or digital performance.

In **Greece** initial feedback from students has been collected at the end of each session of the iMuSciCA Student's Club at Ellinogermaniki Agogi. The students have been and are meeting from February to May every Friday afternoon to experience different Educational Scenarios and the corresponding Digital Tools.

Concerning the use of Digital Tools within the Educational Meta-Scenario 'Instruments of Speech' the involved students provided encouraging results.

The students reported that they haven't been facing major difficulties because the instructions of the sessions were clear and thus it was easy to respond to them and to realise the requested tasks and activities.

Furthermore, the iMuSciCA tools helped them to meet the objectives of the Educational Scenario, while the interaction with both teachers and their classmates was described as enjoyable and supportive.

"What we liked most about the lesson was our engagement with the second computer where we played a virtual instrument and telling us that we could make such an instrument ourselves."

"I liked that we will play a piece of music in the end."

"I liked the interaction with the hand recognition and the ability to 'paint' a melody."

"I liked both instruments, but I liked more the idea that you can make a score with little practice."

The students also mentioned ideas on how the Student's Club could be further improved:

"When we well understand what we do with the instruments, we will be able to promote our activities even further and beyond our own school. We should start advertising iMuSciCA for the world to learn. "

Finally, the interviewed students promoted the idea of having a concert at the end of the Student's Club in order to show other students at Ellinogermaniki Agogi what they have been experimenting and achieving.

They also suggested to start interacting with pupils from other schools in other countries in order to exchange expressions and impressions.

"We could socialize with other students and organise something like a competition (for the best music event) or some inter-school games."

In **France** the experimentation of the Educational Scenarios and related Digital Tools of iMuSciCA by students will start in May 2018.

As with the evaluation of the iMuSciCA solutions by teachers, further feedback from students will be collected throughout 2018 e.g. through in-classroom experimentations in the three piloting countries (i.e. Belgium, France, Greece) and especially during the dedicated iMuSciCA Summer Camp for students to be held in Greece in June 2018.

All results will be again summarised in Deliverable 2.8 'Final Educational Scenarios and Lesson Plans for iMuSciCA'.

3. The Intermediate iMuSciCA Educational Scenarios

3.1 Introduction

The Educational Scenarios of iMuSciCA are based on the developed Pedagogical Framework combining the Inquiry Based Science Education (IBSE) model with the integration of three fields of STEAM: Science-Mathematics, Music and Engineering.

Following these developments, with alongside the continuous technical development of the iMuSciCA Workbench, the pedagogical team has refined the existing initial Educational Scenarios and co-created new Educational Scenarios and by these means articulates an 'iMuSciCA Curriculum', which is defined as a full sequence of Educational Scenarios, which in turn will be applicable to all national curricula either directly implemented in classroom settings during science lessons or in the framework of Project Based Learning (PBL) e.g. in the afternoon or even extra-curricular.

These presented Educational Scenarios should be viewed together with deliverable D2.3-Initial Educational scenarios and lesson plans for iMuSciCA as it is a development or continuation of what has already been described previously. The evolution of the Digital Tools of iMuSciCA according to the observations of the pedagogical team are the necessary priority to their use in developing advanced Educational Scenarios and included Lesson Plans. The present Educational Scenarios respect the above information, which define their complexity and serve a dual role against their intermediate development stage. On the one hand, they exploit the existing capabilities of Digital Tools as they evolve up to the date, on the other hand they give an outline of the possibilities that need to be developed towards their final version. As a result, the approaches presented follow the potentials of the iMuSciCA Workbench at its current stage.

The architecture of the iMuSciCA Educational Scenarios have been designed taking into account the following factors:

- Pedagogical Framework of iMuSciCA;
- Provisions for students to achieve Deeper Learning of STEM;
- Flexibility to adapt the Educational Scenarios and Digital Tools to the reality in classroom as well as for extra-curricular activities.

Following the Pedagogical Framework, the Educational Scenarios describe all inquiry phases and STEAM fields at the same time. The pedagogical phases of iMuSciCA can be applied linearly or iteratively, allowing students space to engage effectively both in a structured and in a free fashion.

To address the need to provide the means for students to achieve Deeper Learning of STEM through iMuSciCA, a long-term exposure (where applicable) is preferred for students involved in iMuSciCA implementation activities. As a result, the minimum level of student engagement has been defined as the time needed to complete an educational scenario, the duration of which is at least four school hours, with a desired estimated time of eight school hours. No upper time limit is defined per scenario.

The variations between the participant countries' National Curricula, the structural differences between the public schools, music schools and private schools as well as the everyday classroom reality provide a landscape which requires flexibility and adaptability in

the architecture of iMuSciCA Educational Scenarios. Taking into account these factors their design should be such that it can adapt in long term project-based work that can be carried out e.g. in school clubs, in medium term regular classroom interventions dedicated to iMuSciCA or in short termed classroom interventions which go on par with the school curriculum, the last two depending on the school's flexibility and availability.

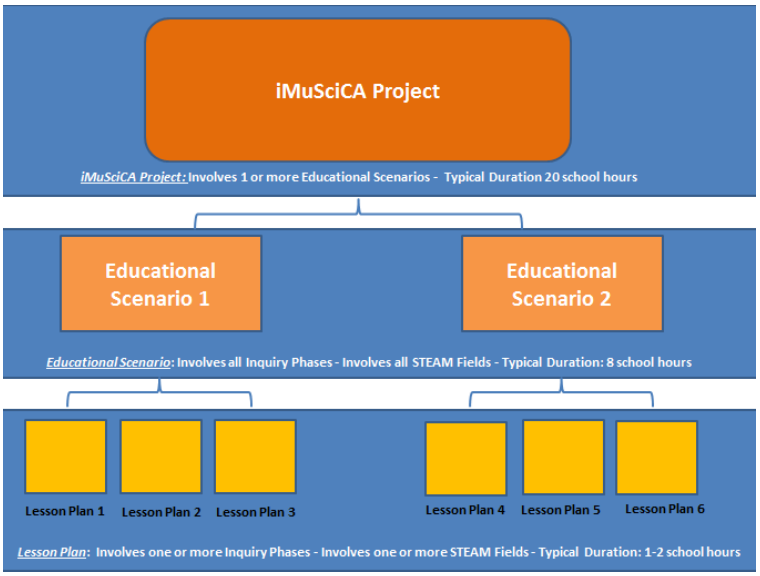

Figure 3.1.1: Modular Architecture of iMuSciCA Educational Scenarios

This structure allows not only flexibility with respect to the implementation setting, curriculum and time availability but also in the scenario design. As a scenario consists of Lesson Plan modules which involve one or more Inquiry Phases and STEAM fields, lesson plans can be combined, varied and rearranged in order to provide different educational scenarios.

3.2 iMuSciCA Long and Short Term Projects with their Educational Scenarios

The present document can be used as a reference that provides the links to all Educational Scenarios that have been posted in special folders on the project repository. Their main feature is the possibility of enriching their content according to the pilot requirements as outlined in Deliverable 6.1 'Pilot Testing Action Plan', in close cooperation with the teachers participating in the implementation phase in three European countries.

The Educational Scenarios presented in the following Sections are either adapted or newly developed in co-creation with a group of iMuSciCA teachers by UCLL in Belgium for Lower Secondary Education and Ellinogermaniki Agogi in Greece for Upper Secondary Education. They are designed according to the new strategy for implementing pedagogical innovation in Educational Scenarios of iMuSciCA as reported in the previous deliverable D2.3-Initial Educational Scenarios and Lesson Plans for iMuSciCA.

The collaborating teachers in all implementation countries will be invited to continue to further develop these scenarios until their final release in the forthcoming deliverable D2.8-Final Educational scenarios and lesson plans for iMuSciCA.

3.3 Scenarios for Lower Secondary Education

This Section commences with an overview of the major changes that were implemented by UCLL in Belgium within the Educational Scenarios developed for Lower Secondary Education based i) on the results of the pilot testing and ii) on the co-creation work with the science teachers.

The core idea is that teachers can start working from an 'open' scenario (i.e. serving as an 'entrance point' to the iMuSciCA pedagogy) and go to the basic scenarios whenever this is needed in order to deepen the knowledge on the used basic concepts.

In Figure 3.3.1 a detailed scheme with the new structure of the Educational Scenarios dedicated to Lower Secondary Education is provided:

- In the center Scenarios 1 and 2 are ***Adapted Basic Scenarios***: these contain basic concepts of music, physics and mathematics like what are the sources of sound and tone, what is tone, what are natural tones and how they occur etc. These two scenarios are based on Cabri files, which contain full lessons including link to the appropriate tools on the iMuSciCA workbench. These scenarios were adapted following the strategy for the scenarios development reported in the reviewed version of D2.3 *Initial Educational Scenarios and Lesson Plans For iMuSciCA* and based on the feedback received during Piloting Phase A. The main adaptations consist in a better and direct implementation of the Digital Tools inside the Cabri files and in the 'position' of these scenarios within the general structure. Furthermore, during adaptation several requests were advanced to the iMuSciCA technical team in order to fit the pedagogical requirements, which lead to a general improvement of the iMuSciCA Workbench.

  Many detailed suggestions of teachers were implemented: reformulation of some questions, some lesson phases were totally worked over to make concept building more clear or to remove flaws that were still in the first versions.

- Around the Basic Scenarios are the ***'Open' Scenarios*** 3, 4, 5, 6 which can be best described as 'entrance' Scenarios into the iMuSciCA pedagogy: these are creative scenarios containing a description of activities to be implemented by students directly on the iMuSciCA workbench. Scenarios 3, 4, 5 are newly developed together with the iMuSciCA teachers from UCLL, while Scenario 6 is currently in the planning stage. These are not based on Cabri files as the Basic Scenarios, but consist of a description of the activities to be performed directly on the iMuSciCA Workbench following the usual scenario synopsis. These Scenarios leave therefore more degree of freedom in the executions of the activities by students. According to the new strategy, teachers gave many concrete suggestions that were implemented right away.

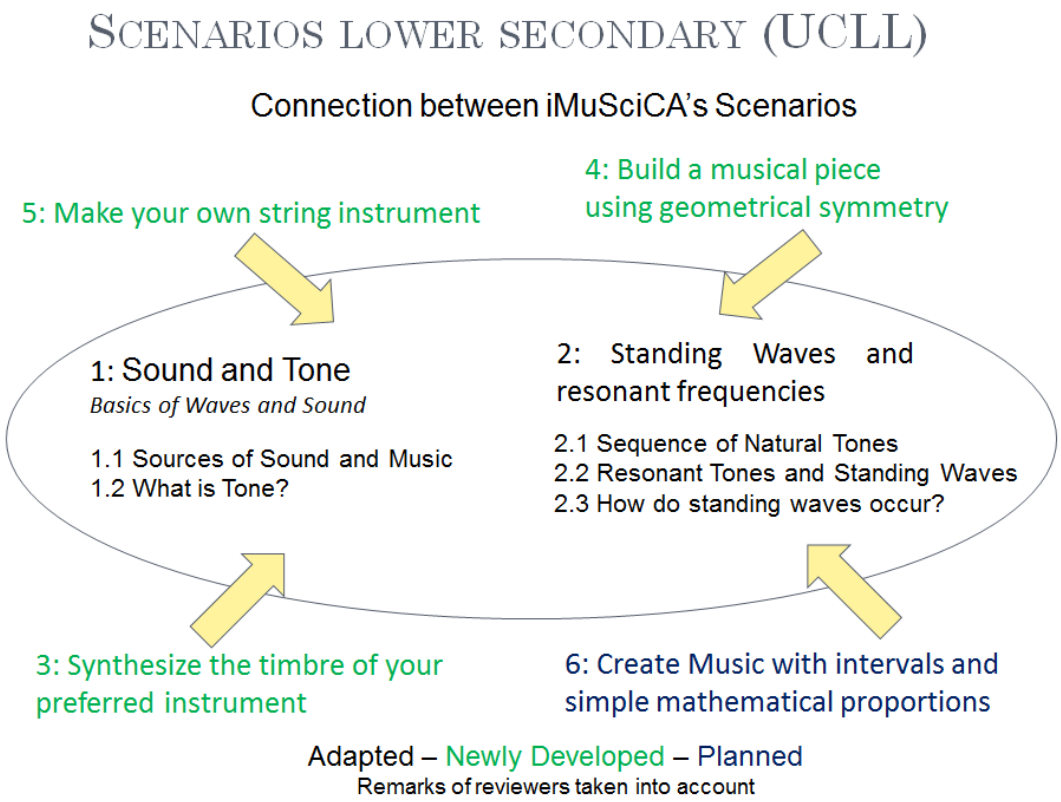

Figure 3.3: Structure of Educational Scenarios for Lower Secondary Education

These above depicted Scenarios suggest teachers how they can use innovative Digital Tools of iMuSciCA directly on the Workbench. In the Table below, you find a summary of the iMuSciCA tools used in the Educational Scenario for Lower Secondary Education.

Scenario 1: **Sound and tone**	**DrawMe Analysers** to analyse the different waveforms of external sounds **DrawMe canvas**: create tone and sound **Tone.js: sampler**: virtual keyboard -> la, do etc **Athena music tools**: measure the actual hz (not working for external though) **Metronome** for musical exercises **Athena sampler**: which are sounds vs tones; build a soundscape
Scenario 2: **Standing waves and resonant frequencies**	**Drawme Analysers**: measure whistle frequencies **Drawme canvas** natural tones
Scenario 3: **Synthesize the timbre of your preferred instrument**	**Tones Synthesizer**: this scenario is centred around this tool. How simple waves sum up to form more complex waves **Sound visualizers drawme** **Frequency meters** to discover overtones, reproduce them on the synthesizer

Scenario 4: **Build a musical piece using geometrical symmetry**	**Performance sequencer**: create a composition **Cabri express**: transformations, rotations and reflections of figures in relation with music **Drawme canvas**: reproduction of imuscica melody, reflection and transformation once possible (clipboard)
Scenario 5: **Make your own string instrument**	**3D Musical Instrument Design**: work with the monochord, radius, length, tension **Sound visualizer**: discover the difference whilst playing with above tool

Table 3.3: List of Digital Tools of iMuSciCA used in Educational Scenarios for Lower Secondary Education

In the following a brief description of the i) initially developed and adapted as well as of the ii) newly developed Educational Scenarios for Lower Secondary Education and their corresponding are presented.

3.3.1 Scenario 1: Sound and tone

The students investigate the vibrations as sources of sound. By means of the iMuSciCA visualisation tools they measure sounds and recognise that some are periodic, and others aren't. They learn to connect this insight with what they can hear: some sounds have more tone, some others less or no tone at all. This scenario consists out of two lesson plans:

1.1 Sources of Sound and Music

1.2 What is Tone?

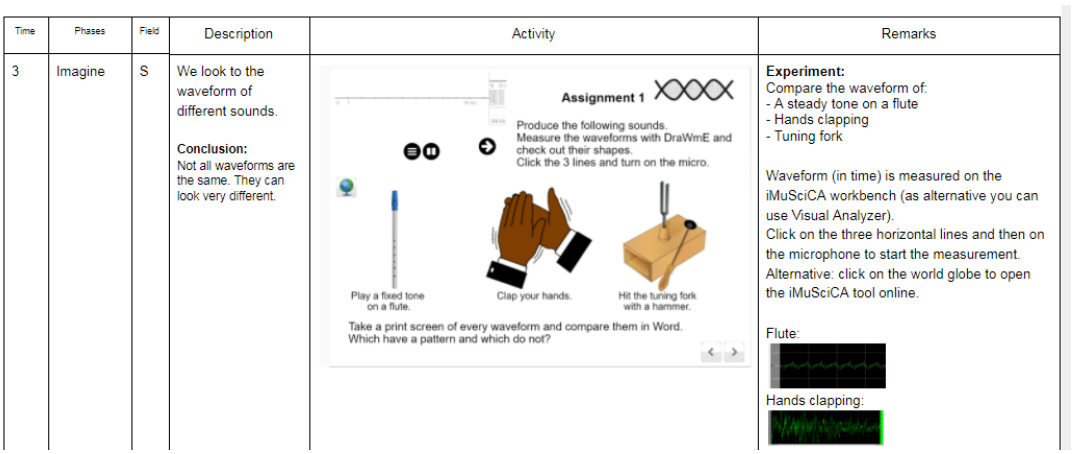

Figure 3.3.1: Excerpt from Scenario 1 'Sound and tone'

3.3.2 Scenario 2: Standing waves and resonant frequencies

The students investigate the natural sequence of tones that do occur on string instruments and aerophones. With the iMuSciCA analyser tools on the workbench they measure the frequencies and discover their mathematical relation. Moreover, they try to understand how a specific sequence of tones can occur on an instrument where you don't change anything. This scenario consists of three lesson plans:

2.1: The sequence of natural tones

2.2: Natural Tones and Standing Waves

2.3 How do standing waves occur?

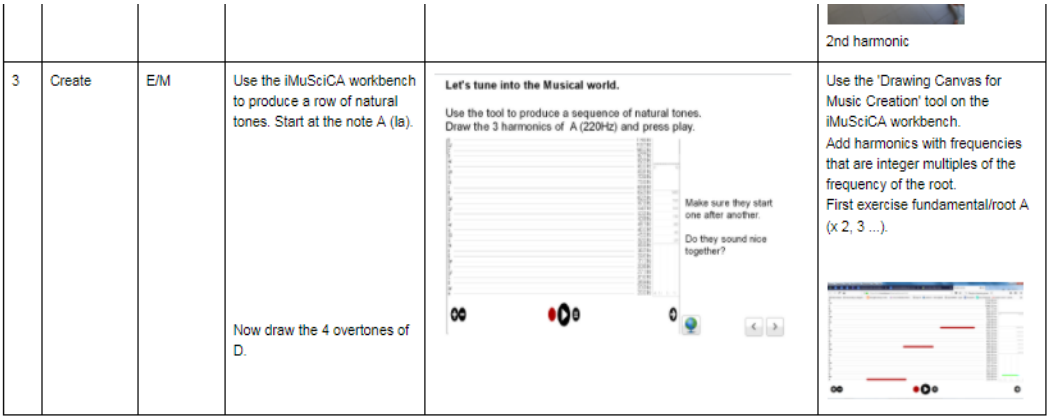

Figure 3.3.2: Excerpt from Scenario 2 'Standing waves and resonant frequencies'

3.3.3 Scenario 3: Synthesize the timbre of your preferred instrument

The scenario 'Synthesize the timbre of your preferred instrument' is built around the workbench tool 'Tones Synthesizer'. In this scenario the student has the task to recreate the timbre of his or her favourite instrument. It was developed according to the new strategy in co-creation with iMuSciCA teachers in Belgium by UCLL. The Scenario 'Synthesize the timbre for your preferred instrument' can be accessed through this link.

Observe the result of the sum of the different harmonics: which form has the sum? Does it looks like the form of a pure tone or is it more complex?
[ans: it is a complex form, therefore waves can sum up and form a more complex wave.]

Figure 3.3.3: Excerpt from Scenario 3 'Synthesize the timbre of your preferred instrument'

3.3.4 Scenario 4: Build a musical piece using geometrical symmetry

The scenario 'Build a musical piece using geometrical symmetry' uses various iMuSciCA tools on the workbench like the 'Performance Sample Sequencer', the 'Drawing Canvas for Music Creation', the Geometry and Algebra tools in order to teach students to recognize patterns, transformations and combination of transformations in music and geometry. The Dutch version of this scenario can be found at the following link and it is in the process of translation into English.

	Creëren	M	Zelf een muziekstuk ontwerpen met een ostinaat in verwerkt	**Opdracht:** Maak zelf een muziekstuk in de DrAwMe-tool waarbij een zelf ontworpen motief verschoven wordt. **Mogelijke oplossing:**  Waarbij het roze motief herhaald wordt (do - re - mi - do)	Gebruik de iMuSciCA werkbank DrAwMe-tool https://imusicca-platform.unifr.ch/drawme/first/canvas.html
	Aangrijpen/ Voorstellen	M	We starten in de muzikale wereld en kijken naar motiefverwerkingen in muziek: de gevarieerde herhaling	Bekijk het volgende muziekstuk. 	

Figure 3.3.4: Excerpt from the Scenario 4 'Build a musical piece using geometrical symmetry'

3.3.5 Scenario 5: Make your own string instrument

The Scenario 'Make your own string instrument' is built around the iMuSciCA workbench tool '3D Musical Instrument Design'. The aim of this scenario is that the students create their own virtual string instrument like a violin, a (bass) guitar or a cello. It was developed

according to the new strategy in co-creation with iMuSciCA teachers in Belgium by UCLL. The Scenario 'Make your own string instrument' is available via this link.

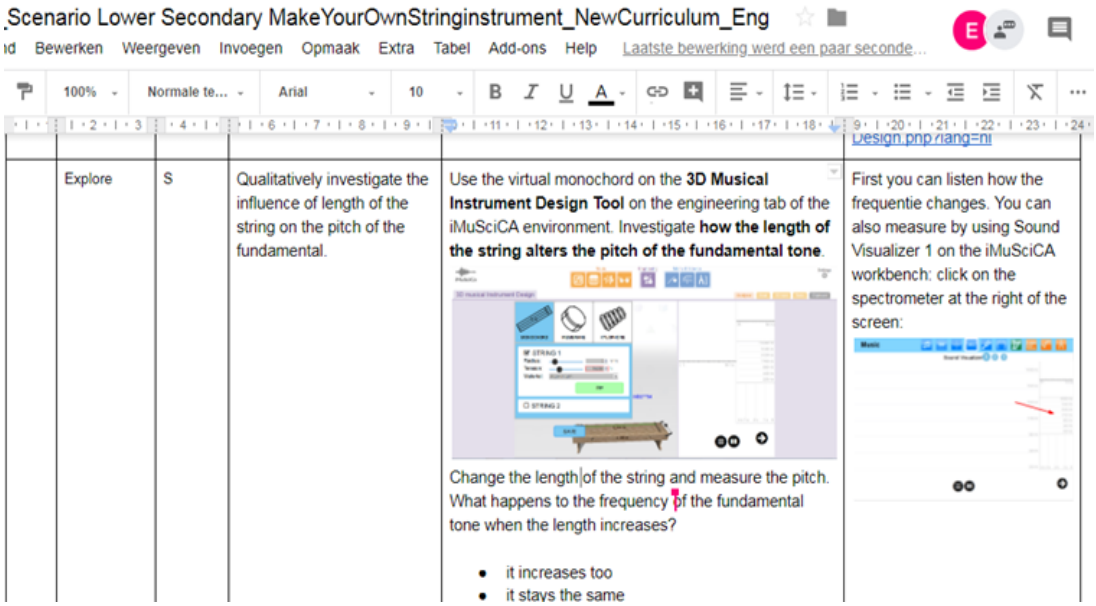

Figure 3.3.5: Excerpt from Scenario 5 'Make your own string instrument'

3.4 Scenarios for Upper Secondary Education

The Educational Scenarios presented in this Section have been developed by Ellinogermaniki Agogi (EA) and are designed for students in Upper Secondary Education. As mentioned in the introduction, these Scenarios have been enriched, enhanced, interlocked and continue the corresponding initial Educational Scenarios based on the feedback received from educators and students.

Following the recommendations of the strategy for the implementation of pedagogical innovation in Educational Scenarios as described in the revised version of deliverable D2.3, the presented Educational Scenarios encapsulate three fundamental needs for the implementation of the iMuSciCA's pedagogical innovation:

- Need for co-creation with teachers and students;
- Need to harness the potential of the tools of the iMuSciCA Workbench both in terms of variety and of in-depth engagement;
- Need to create Educational Scenarios, which can be adapted to both the corresponding curricula in the piloting countries and beyond, including the possibility of applying them in informal (e.g. extra-curricular) teaching and learning settings.

Within this framework, the iMuSciCA pedagogical at EA team has developed four initial Educational Scenarios (i.e. 1 through 4), refined and further developed a meta-scenario for a long-term project (i.e. Scenario 4 and 7) and developed three new Educational Scenarios (i.e. 5, 6 and 8) for students of Upper Secondary Education.

3.4.1 Scenario 1: Let's hear Thales' theorem

Within the Scenario 'Let's hear Thales' theorem' students use the tools of iMuSciCA to divide a string length (or membranophone area) in equal parts keeping tension (and radius in case of string) in constant value and then listening to its different corresponding lengths (or areas). They select a number of string-lengths (or surfaces) to form their own 'scale' in a

polychord (e.g. bichord, trichord, tetrachord etc) or in more than one in case of membranophones. With the help of their music teacher, they use this scale to compose motifs (i.e. sets of notes) making brief rhythmical patterns. By altering the tension, students then experiment with new instruments, achieving the same frequencies used in their above scale. They compare their scientific results in table format and perform the same composition with their new models. The full Scenario can be obtained here.

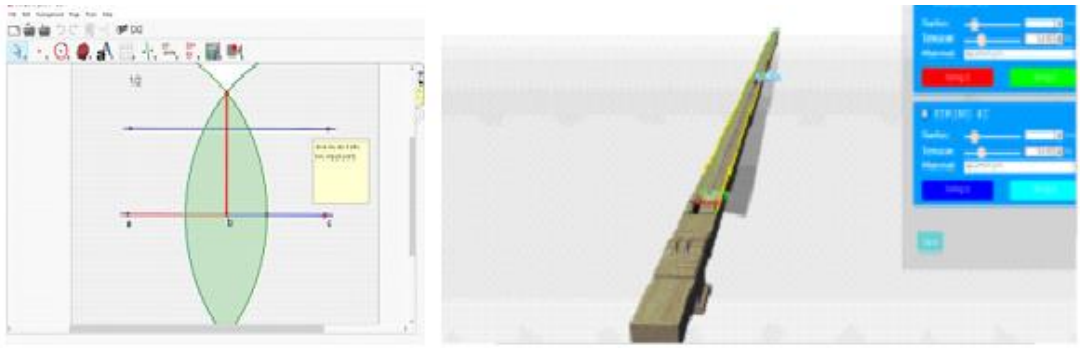

Figure 3.4.1: Excerpts from Scenario 1 'Let's hear Thales' theorem'

3.4.2 Scenario 2: Investigating the monochord

This seven-hour-long Educational Scenario introduces students to the science behind the sound produced by the simplest stringed instrument, the monochord. Students will investigate and verify Mersenne's laws on the dependencies of the frequency of the sound produced by a virtual monochord on several parameters, such as the string tension, radius and length. To do that, they will produce a virtual monochord using '3D Design Environment' in the iMuSiCA Workbench and will experiment in a hands and minds on fashion with the relevant parameters and investigate the aforementioned dependencies using simulated data produced by the performance of the virtual instrument. The Scenario 'Investigating the monochord' is available via this link.

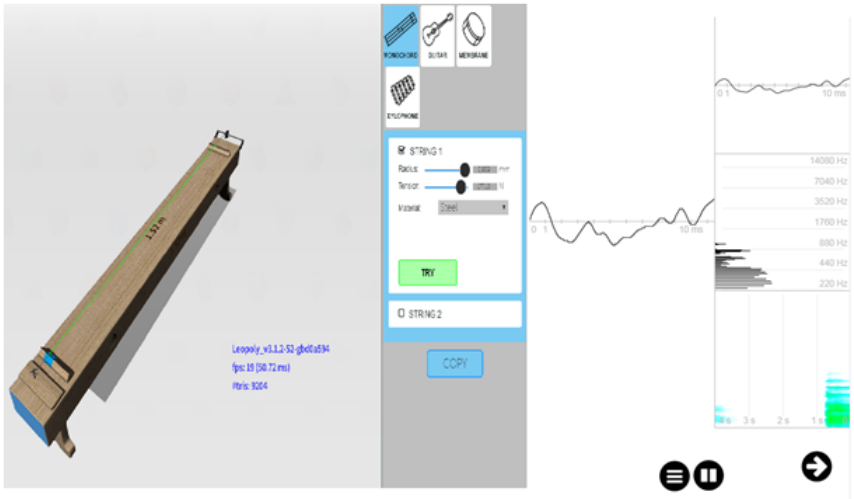

Figure 3.4.2: Excerpts from Scenario 2 'Investigating the monochord'

3.4.3 Scenario 3: Timbre and power spectra

The Educational Scenario 'Timbre and power spectra' lasts 12 teaching hours in total and addresses students of Upper Secondary Education and beyond, aiming to introduce them to the physics of wave interference and the investigation of the harmonic content of sound. Students will experiment with different virtual musical instruments and investigate why

different instruments sound differently. They will analyse different sounds and comprehend the connection of the timbre of a musical instrument with the harmonic content of the produced sound. In order to achieve that, students get acquainted with the powerful analysis tools of the power spectrum and the spectrogram. This scenario is a continuation of the Scenario 'Investigating the Monochord' and is available here.

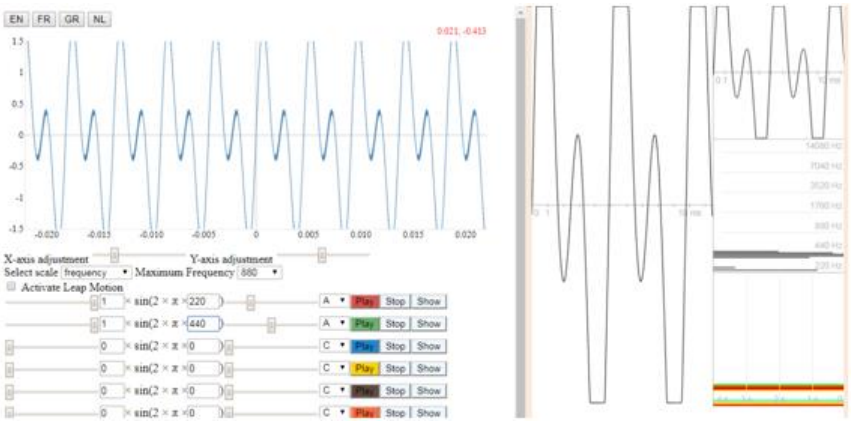

Figure 3.4.3: Excerpts from Scenario 3 'Timbre and power spectra'

3.4.4 Scenario 4: Instruments of speech (Volume 1)

This meta-scenario is an early investigation for utilising all possible existing digital tools of the iMuSciCA Workbench in the form of a unified Educational Scenario. Through the study, analysis and experimentation around the sound properties of their own voice, students create virtual monochords meeting certain requests and measurements. At the end of the scenario the monochords interpret a series of variations around a melodic sequence. The first version of the Scenario 'Instruments of speech' is available via this link.

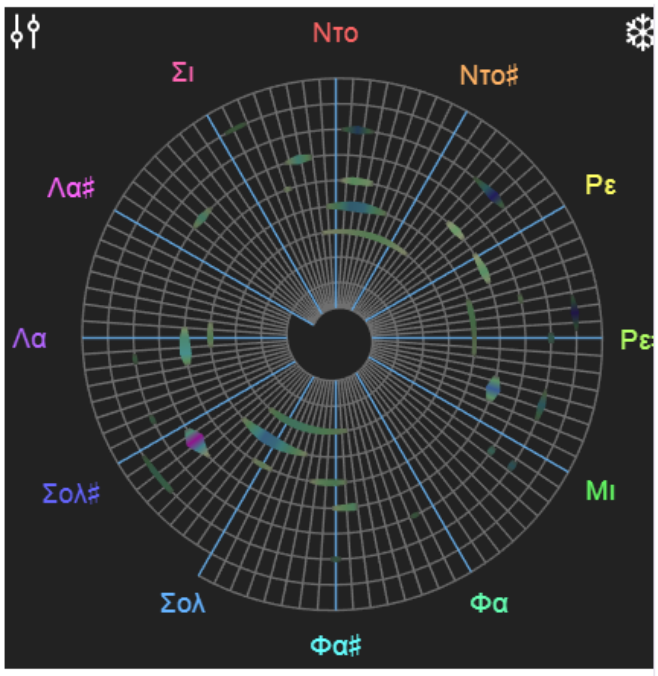

Figure 3.4.4: Excerpts from Scenario 4 'Instruments of speech'

3.4.5 Scenario 5: The house of chords

In the Educational Scenario entitled 'The house of chords' students will understand how the idea of chords is being produced and how the combination of chords leads to harmonic sequences. They investigate given consonances and dissonances of different tones according to ear and data analysis. Students experiment with the compilation of two, gradually three, tones produced in the tone synthesizer and analyze their observations using their ear in combination with the measurements taken from the workbench analyzing toolkit. With the help of their Music teacher, they draw a score of consonances or dissonances as a result of building chord sequences and finally they record it using the virtual instruments produced to play it. The scenario link is accessible through this link.

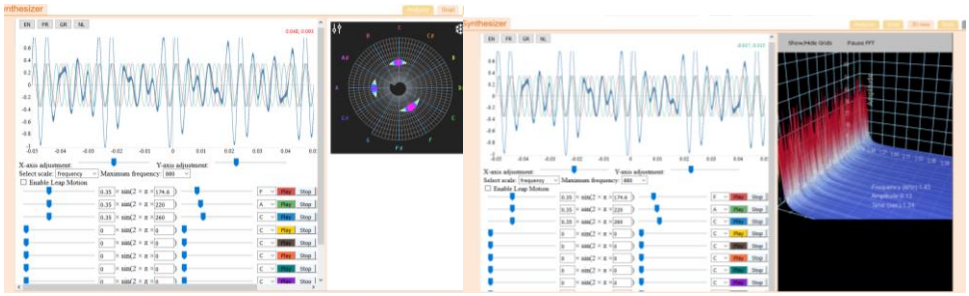

Figure 3.4.5: Excerpts from Scenario 5 'The House of Chords'

3.4.6 Scenario 6: Let's play 'Sectio Canonis'

Within the Scenario 'Let's play Sectio Canonis' students take the division of the string using the intercept theorem as described in the 'Let's Hear Thales' theorem' and start investigating synergies of consonances and dissonances derived by the similar triangles produced in each section. Students experiment with their own similar triangles by composing sequences of tones derived from their sides and eventually by constructing the virtual instruments to play them. This scenario can be found here.

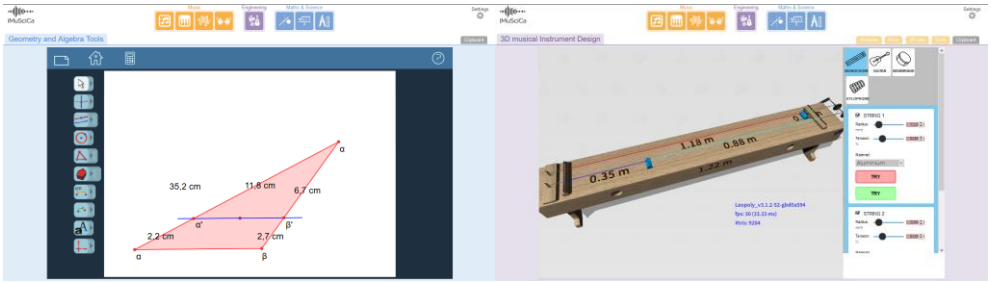

Figure 3.4.6: Excerpts from Scenario 6 'Let's play sectio canonis''

3.4.7 Scenario 7: Instruments of speech (Volume 2)

In the refined second version of the Educational Scenario 'Instruments of speech' students identify and analyze the harmonic content of their voices and subsequently create virtual musical instruments aiming to produce sound with similar power spectrum to that of their voice. Throughout the course of this educational scenario, students are taught about musical notes and scales, about the design of virtual monochords and the crucial parameters affecting their performance, about wave interference and the creation of beats and about

the power spectrum and its use to identify the harmonic content of a sound. The scenario lasts 20 school hours. The scenario can be accessed through this link.

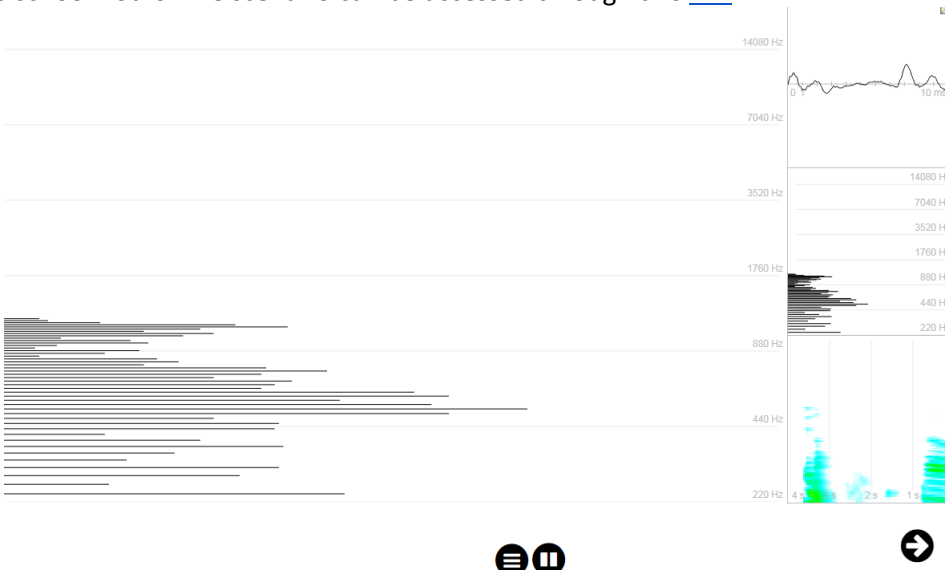

Figure 3.4.7: Excerpt from Scenario 7 'Instruments of speech' (Volume 2)

3.4.8 Scenario 8: Listen to your math

The Educational Scenario 'Listen to your math' introduces students to the techniques of sonification. Combining the teaching of mathematical functions with music, students utilize the sonification tool of the iMuSciCA workbench to sonify different mathematical functions relevant to their curriculum and create a soundscape. Then, they identify the notes of the sound produced and reproduce them with virtual musical instruments of their own design. The preliminary Educational Scenario can be found at this link.

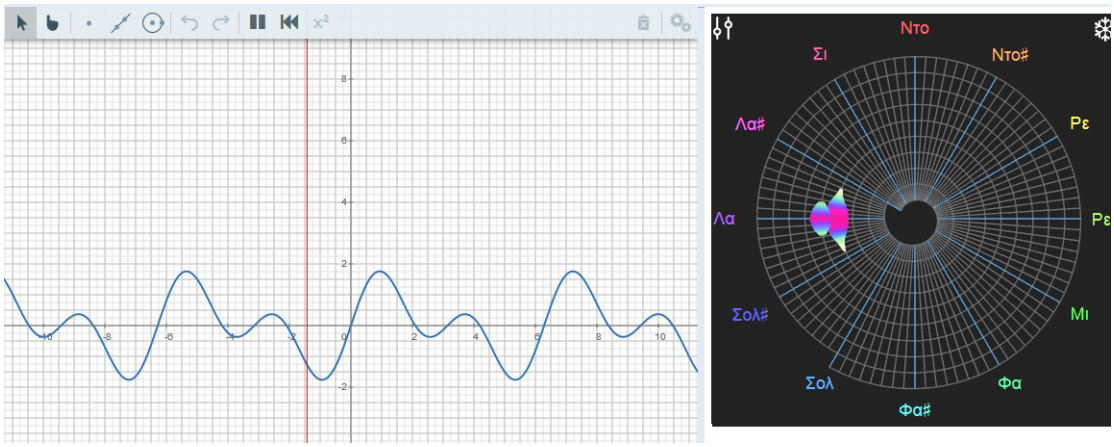

Figure 3.4.8: Excerpt from Scenario 8 'Listen to your math'

4. Keeping the strategy for implementing pedagogical innovation in the final version of educational scenarios

Building upon the strategy for implementing pedagogical innovation in the Educational Scenarios as detailed in deliverable D2.3-Initial Educational Scenarios and Lesson Plans for iMuSciCA the project opens the way for integrating piloting scenarios not only by presenting them as part of the piloting procedures, but also by making them available digitally allowing permanent accessibility and adaptability by teachers, students and other educational stakeholders after the consolidation of this Deliverable. In this way and as teachers of the piloting process will become more familiar with the approach of iMuSciCA, the philosophy of the described strategy will be fulfilled, which can be described best with the terms Inquiry Based Science Education (IBSE), Project Based Learning (PBL) and Deeper Learning (DL), all under a perspective of interdisciplinarity and (largely) self-controlled learning experiences of students building upon their inspirations, aspirations and study design.

Addressing the particular objectives of this strategy, the following aspects can be additionally noted:

- The described Educational Scenarios are providing a concrete outline of the content covering a variety of subjects, while respecting the particularities of the curricula.
- The accessibility and openness to adaptations ensures the further shaping of the final format of Educational Scenarios.
- The interaction between formal and informal learning and teaching environments is increased as pupils are already actively involved in the use of tools, both at school and at home.
- Advanced Educational Scenarios encourage students to use the Digital Tools of iMuSciCA as ways of developing non-conventional school events such as performing a concert based on mathematical concepts.
- The continuous improvement of the digital tools ensure the further involvement of teachers as their observations and recommendations are valued and systematically taken into account.
- The formation of student groups (such as e.g. the Students Club in Greece) and other Communities of Practice (CoP) ensures continuous monitoring of the interest and the degree of participation of students in the educational process proposed by iMuSciCA.
- Applying the Educational Scenarios in three pilot countries (and hopefully beyond on a voluntary basis) encourages the interaction and exchange of educational practices amongst them to the extent that teachers contribute to the continuous improvement of scenarios in open cooperation with their colleagues.
- As the communication between educational communities and project stakeholders is encouraged by iMuSciCA, this spirit and philosophy is also extended to their students.

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