Interactive Music Science Collaborative Activities

Team Teaching for STEAM Education

Deliverable 6.4

Quantitative and qualitative results of learners - aspects of deeper learning with iMuSciCA

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Executive Summary

This document is about the final results of iMuSciCA as regarding the learners and it is complementary to *D6.3 Final Report on Teacher's Feedback & Pilot Testing in Schools*. It reports on the quantitative and qualitative data collected about the influence of iMuSciCA on the deeper learning competencies of students and about their motivation for STEAM studies. The data were collected in the three iMuSciCA piloting countries Belgium, Greece and France during piloting phase B. During phase B1 the data collected were mainly used to further develop the imuSciCA workbench and to improve the lesson scenarios and evaluation instruments in view of phase B2. This second phase was dedicated to the implementation of the project in both real classroom settings and in special settings (like e.g. the Summer Camp for students organized by Ellinogermaniki Agogi). In phase B2 the final evaluation instruments and some elements of comparative research were also applied. This allowed to draw the conclusions included in this deliverable (and in *D6.3*) about the piloting results. Generally speaking, if the STEAM pedagogy is well deployed in class, and if there is enough and good equipment, the combination of science with music seems to have a moderate but positive effect both on the learning of content as on the attitude and motivation of learners towards science and engineering.

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LIST OF ABBREVIATIONS

Abbreviation	Description
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
GSR	Galvanic Skin Response
EEG	Electroencephalography
AOI	Area of Interest

1. Introduction

This deliverable reports on the results of the iMuSciCA piloting in Belgium, France and Greece. The data collection was based on several qualitative as well as quantitative instruments developed in the previous deliverables included in WP2 (see D2.5 - Final Evaluation metrics for deeper learning with iMuSciCA). This document describes first how the piloting was organized in the three piloting countries and in which schools it was performed, including information about the number and the age of the students, the scenarios which were piloted, the period of the year. A description of the evaluation methods applied follows, including the implemented *comparative research elements*. We report then a summary and an analysis of the data collected. Given the differences between the piloting conditions in the three countries (different scenarios, different age-ranges of the students, different framework conditions) we performed a country related analysis, as a comparison among countries wouldn't be significant. Finally, some general conclusions about the piloting results are reported.

2. Description of piloting in the three pilot countries and evaluation methods

2.1 Pilot testing phase B1 in the three pilot countries

Piloting phase B1 was performed in the three piloting countries Belgium, Greece and France in the period January-June 2018. The aim of this piloting phase was in the first place to test and improve the scenarios, the ICT-workbench and even the evaluation methodology. A short description of the piloting in the three countries follows.

Pilot testing in Belgium

UCLL performed piloting phase B1 in 7 different schools: 4 schools with 'heavy implementation in classroom settings' (i.e. at least 8 lesson hours), 3 schools with 'light implementation in classroom settings' (i.e. 2-4 lesson hours). Four different scenarios for lower secondary were tested. In total 278 students were involved in the piloting: 145 pupils in the heavy implementation phase B1 and 133 pupils in the light implementation. The pupils performed the iMuSciCA activities foreseen in the 4 piloted scenarios. The pupils involved in the 'heavy implementation' also participated in focus groups and filled in the questionnaires according to the evaluation metrics.

Figure 1: Picture of pupils working in groups during the iMuSciCA piloting B1 in Belgium.

Teachers and observers also provided a summary of the field notes taken during the observation of the performed activities in the iMuSciCA lessons. The results of these evaluation methods were used for the further improvement of the piloting material in view of piloting phase B2.

Pilot testing in Greece

EA continued with two major events in Greece: a Student's Summer Camp for students in its premises and a Summer School for educators at the historical venue of Marathonas. Three major institutions: the Hellenic Mathematical Society, the Hellenic Physical Society and the Athens Conservatoire, co-organized along with Ellinogermaniki Agogi a five-day (June 25-29) course introducing the iMuSciCA platform to 19 registered students from all over Greece.

Pilot testing in France

In France, the pilot teaching took place in the collège Jules Vallès in a 9th grade class from May the 14th to May the 25th. A total of 8 hours was devoted to a scenario about the sources of sound and periodic sounds. The organisation of the activities was the following:

- identification of the sources of vibration for various instruments (on computer) ;
- experimenting about the transmission of vibrations by using a tuning fork, a ruler, a membrane;
- designing a vibrating instrument by using everyday material (cans, rice grains, elastics, pipe…);
- construction of the instrument;
- creation of a musical or rhythmic piece on the instrument;
- captation of various sounds with the visual analyser of the workbench
- analysis of the obtained curves, study of the changes in the curve when varying the pitch (on DrawMe)
- introducing the notion of periodicity and of frequency and calculations of frequency
- creation of a structured body music groove and then of a musical piece with DrawMe
- evaluation of the pilot teaching by the students by means of questionnaires.

A focus group of 12 selected students was devoted to exchanges between the observers and the students about the teaching pilot: what went well, what was complex, what could be improved.

Based on the results of this piloting the scenarios used in each country were improved in view of the next piloting phase B2. Furthermore during piloting phase B1 useful feedback was collected for the optimisation of the iMuSciCA workbench. The methods used for the evaluation of the deeper learning competencies and of the motivation and attitudes towards science learning of learners were also adapted in view of the data collection of piloting phase B2. In particular the methods were standardized among the three countries and *comparative research elements* were introduced as explained later (see 2.3).

2.2 Pilot testing phase B2 in the three pilot countries

The pilot testing in the three pilot countries is summarized in the table below. More details are reported in the following subsections.

	Light implementation in classroom settings: less than 8 lesson hours about iMuSciCA or more than 8 but without standard evaluation	***Heavy implementation in classroom settings: at least 8 lesson hours about iMuSciCA with standard evaluation***	***Heavy in depth implementation: more than 8 lesson hours about iMuSciCA with standard evaluation***
Belgium	Several schools: see further subsection Pilot testing in Belgium.	● IKSO Hoeselt ● Sint-Vincentiusmiddensc hool Lanaken	
Greece		● Ellinogermaniki Agogi, Pallini ● Evangelical School of Smyrni, Nea Smyrni	● Special Junior High School of Ilioupolis ● Summer Camp for Students ● iMuSciCA Day at MINT-EC Pallini Workshop
France		● Collège Jules Vallès	

Table 1: Implementation Scenarios of iMuSciCA in Belgium, France & Greece.

Pilot testing in Belgium

In Belgium the 'heavy implementation in classroom settings' piloting phase B2 and the related evaluation were performed in 2 different schools with 'standard scenarios'. Furthermore iMuSciCA was piloted in other schools in a 'light implementation form' using the standard scenarios but in one case also a scenario co-created by the school teacher together with the UCLL teacher educators. In the table below we report a summary of the 'heavy implementation in classroom settings' piloting in Belgium.

Name of school	Age range of pupils	Number of pupils	Piloting period and hours	Scenario’s	Evaluation instruments
IKSO Hoeselt	15-16 y.o.	16	February 2019 8 hours in total	Scenario 1: Sound and tone Scenario 2.1: The sequence of natural tones Scenario 5: Design and play a guitar in your own tuning	Deeper Learning Competencies (POST) Motivation and Attitudes towards Science Learning (PRE-PRE / PRE / POST) Knowledge Test (POST)
Sint-Vincentiusmidde nschool Lanaken	13-14 y.o.	33	March 2019 8 hours in total	Scenario 1: Sound and tone Scenario 2.1: The sequence of natural tones Scenario 6: Create Music with simple mathematical Proportions	Motivation and Attitudes towards Science Learning (PRE-PRE / PRE / POST) Knowledge Test (POST)

Table 2: Overview ‘heavy implementation’ schools phase B2 in Belgium.

In the piloting school of **IKSO Hoeselt** there were 16 pupils in total. However during piloting the class was divided into two groups of 8 pupils each. The groups followed the iMuSciCA lessons in parallel, with two different teachers. These pupils are in the 4th year of secondary school and they are studying within the 2nd year of the field of study TW (‘Techniek-Wetenschappen’ which stands for technology and sciences). The iMuSciCA lessons were held during the physics and biology hours, spread over a period of 2 weeks for a total of 8 hours. Each lesson lasted 2 lesson hours (in total 100 min). In this case we didn’t skip the basic scenarios but started with them: scenario 1: *Sound and tone* and scenario 2.1 *The sequence of natural tones*. Only after those, the students went to the more advanced scenario 5: *Design and play a guitar in your own tuning*. The organization of this piloting was very different from the previous one: the implementation of scenarios 1 and 2 turned out to be very supportive for the implementation of the more advanced scenario 5. Furthermore scenario 5 had been partly implemented during the previous piloting phase B1 and this had made it possible to improve it a lot. It is also worth mentioning that the iMuSciCA workbench was at this stage in a quite stable stage and many new features were added, which also contributed much to the success of this series of lessons. All the foreseen evaluation instruments were applied in this case. Therefore the evaluation performed in this school can be interpreted as a *normal case* of implementing iMuSCiCA: scenarios and workbench had no flaws.

In the piloting school of **Sint-Vincentiusmiddenschool Lanaken** there were 33 pupils divided into two groups of respectively 10 and 23. These pupils chose for a specific field of study including STEM hours: in total 2 hours STEM theory and 3 hours STEM practice (50 minutes per hour) per week. The iMuSciCA lessons were held during these STEM hours. The pupils are in the second year of secondary school. The piloting in each group lasted in total 8 lesson hours spread over a period of 2 weeks. Also in this case the piloting started with the introduction of the basic concepts included in scenario 1: *Sound and tone* and scenario 2.1: *The sequence of natural tones*, to end with the new developed advanced scenario 6: *Create Music with simple mathematical Proportions*. Only motivation and attitude related instruments were applied in this case. However the fact that a completely new scenario was implemented had an impact again on the results: indeed we did not have any possibility to improve the scenario in the same way it had been done with scenario 5. Furthermore we encountered some issues with the performance of the workbench: several activities were foreseen in the use of the tone synthesizer which in the days of this piloting did not work properly. This had a negative influence on the effective implementation of the foreseen activities. Because of all these reasons we decided to use this piloting in order to improve scenario 6 rather than for a final evaluation of iMuSciCA.

As above mentioned only the piloting in **IKSO Hoeselt** and in **Sint-Vincentiusmiddenschool Lanaken** has been used for the evaluation of the project. This choice has to do with the piloting conditions. Based on the issues reported above we can conclude that for a significant evaluation of the project would need to pilot a specific scenario at least two times. This would help to eliminate any source of unwanted 'noise effects'. This is for example the case for the piloting in the school IKSO Hoeselt. In 3.1 and in the conclusions we explain more in detail the results of the above described piloting.


Figure 2 and 3: Pictures of pupils working in groups during the iMuSciCA piloting B2 in Belgium.

It is also worth mentioning that some of the iMuSciCA scenarios were implemented in 'light implementation' schools (i.e. shorter implementation periods) and in other 'heavy implementation schools' in which it was not possible to implement the standard evaluation tools. Below a list of these pilotings:

- The first piloting held in **Sint-Franciscuscollege Heusden-Zolder** (November-December 2019) was in a class of 25 pupils in the 1st year of secondary school. The piloting of a total of 6 lesson hours was spread over a period of 2 weeks, with 3 hours per week and each lesson lasting 1 lesson hour of 50 minutes. iMuSciCA was piloted during lesson hours normally foreseen for math (2 hours per week) and music (1 hour per week). Indeed in this piloting we tried to connect maths (geometry) with music through the iMuSciCA advanced *scenario 4: Create a piece of music using geometric symmetries.* The fact that this was the first piloting of the series had an impact on the implementation. Nevertheless the experience of this first piloting was very useful for the improvement of the next ones. One of the problems was that the piloting started directly with advanced scenario 4, *without the preliminary introduction of the subject through the basic scenarios*. Skipping those basic scenarios turned out to be a problem. Pupils had a harder time to follow the content and had no real key to what the purpose was. Moreover, we noticed that the subject hour has an influence on the expectations of the pupils. E.g. if pupils are used to follow a math lesson during one specific hour, they would react rather negatively when the teacher would teach something about music or another subject in that hour. Therefore it is necessary to prepare students to *interdisciplinary* teaching when they are used to disciplinary teaching. Another issue to be reported is the fact that the iMuSciCA workbench was at this stage not yet fully ready and stable. For the above reported reasons we decided to skip this school from the final evaluation results. However useful information was collected in order to improve the scenario and the workbench.

- One lesson of 2 hours performed during STEM dedicated hours in the first year of secondary school (pupils of 12-13 y.o.) at the Sint-Gummaruscollege, Lier (scenario 1: *Sound and tone*).
- A total of 12 hours in a klas of the 1st year (pupils of 12-13 y.o.) of the secondary school Don Bosco Hechtel (scenario 1: *Sound and tone* and 2: *Standing waves and resonant frequencies*).
- A total of 4 hours of which 2 hours in a klas of the 3rd year (pupils of 14-15 y.o.) and 2 hours and 4th year (pupils of 15-16 y.o.) of the secondary school Heilig-Hartcollege Lanaken (scenario 2: *Standing waves and resonant frequencies*).
- A physics teacher participating in the workshops trajectory organized by UCLL in 2018-2019 also participated in the ‘heavy implementation’ by **co-creating** a scenario with the UCLL teacher educators. This piloting lasted several months (from January to June 2019 with a total of ~20 lesson hours) as the teacher decided to use his ‘seminary hours’ (2 hours per week) for the implementation of iMuSciCA. Seminary hours are lesson hours teachers can almost freely plan, usually by implementing projects to deepen or broaden the content studied during normal school hours. The school is the **Sint-Theresiacollege at Kappelle-op-den-Bos**. The pupils (23 in total) are in the third grade of secondary school (17-18 y.o.) and from different fields of study: 19 of the 23 learners has a strong math background, 9 of them has a strong physics background, 4 has also some music background. The teacher started with the implementation of the basic scenarios (scenario 1 *Sound and tone* and scenario 2 *The sequence of natural tones*), though slightly adapted to the age group. He built then further by focussing on the analysis and reproduction of the timbre of musical instruments (based on scenario 3 *Synthesize the timbre of your prefered instrument*) and on the investigation of the dependency of the frequency produced by string on the length, tension, radius (based on scenario 5 *Design and play a guitar in your own tuning*). Some observations by thy this teacher are reported in 3.2.

Pilot testing in Greece

In Greece, the final phase of implementation of the project focused mainly on the implementation of control group conditions in two schools and on adapted heavy implementation in a special school.

For the heavy implementation needs, a customized scenario was developed based on pre-existing data in existing scenarios, as well as on new elements that involve specific Geometry material. This material was in line with the current needs of covering a particular teaching field on geometric symmetries. The adaptation of the iMuSciCA course plans to the needs of the special school focused on the practical use of Leap Motion and was completed to the extent that school conditions allowed it.

The general implementation plan for heavy implementation was as follows:

- Phase A: a) Completing three student questionnaires prior to the courses (one for the Science lesson, the Motivation and Attitudes towards Science Learning questionnaire and a Knowledge Acquisition one (Knowledge Test) which is a small, multiple answer questionnaire tailored to the objectives of the course); b) Two lessons without iMuSciCA; c) Completion of the same above questionnaires after the lessons.
- Phase B: a) Completion of all the above mentioned questionnaires before the courses; b) Two courses with iMuSciCA; c) Completion of the above mentioned questionnaires after the lessons; d) Teacher's questionnaire completion.

Ellinogermaniki Agogi

EA followed the general implementation plan with the lessons that took place at the Computer Lab in the school. Students were invited to recognize the parallels that can be observed between symmetrical constructions of geometric shapes as they are designed in a common geometry lesson, in correspondence with musical patterns as they are formed in a melodic sequence with motifs of sounds and frequencies. Two lessons, with a total duration of 4 classroom hours, with the above content were dedicated without the use of iMuSciCA. After an elapsed time of approximately 2 months, another 4 classroom hours teaching with the Workbench and integrated Educational Scenarios of iMuSciCA about the same subject of symmetries took place.

Evangelical School (Nea Smyrni)

The Evangelical School of Nea Smyrni adapted the objectives of an existing scenario to the needs of conducting a course on the parallelogram. The students attended the four-lesson program distributed under the control groups scheme. Assessment papers were provided to students who attended two custom lessons without and with using iMuSciCA in order to draw conclusions. The assessment papers were prepared by the iMuSciCA implementation team in collaboration with the teacher.

Special Junior High School of Ilioupolis

Lesson plans were adapted from their school teachers for the needs of special school and learning abilities of students and applied during special courses. Three teachers of the school with specializations in Computer Science, Mathematics and Music were interested in the iMuSciCA project. Particular importance was noted in the use of haptic hardware like Leap Motion, which was appreciated by teachers because of the possibility of developing specific scenarios that encourage the above perspective.

Summer Camp for Students

A heavy in-depth implementation was performed during the iMuSciCA Summer Camp at Ellinogermaniki Agogi, Pallini in July 2018. A group of 17 students aged between 14 and 16 years old learned and experimented with the iMuSciCA workbench and scenarios. The camp had a duration of 5 days with an overall 20 hours of teaching and learning activities.

Pilot testing in France

The environment of the school

In France the 'heavy implementation in classroom settings' of 8 hours took place in the collège "Jules Vallès", a secondary school (the same as for piloting B1) with 11 to 15 year-old student from January 28th to February 8th in 2019. The school is located in a suburb of Grenoble with a very mixed socio-cultural level population. It can be difficult for many students to project themselves in the future. Therefore the teaching of science may not be very attractive for them. It was interesting to test the iMuSciCA pedagogy in such a students' population in order to investigate to what extent it may raise the interest of students for science.

The school

The school devotes a lot of efforts for motivating the students. The computer equipment is good and the teachers are very committed and involved in several innovation projects. The school has an agreement with the music school of the town and part of the students learn to play an instrument half a day in this music school.

The class and the teachers

The pilot teaching took place in two classes of 14 to 15 year-old students (last year in the school), each of them with 15 students. The music teacher and the maths teacher collaborated with us in order to design a scenario adapted to the state of the students' knowledge end of January when the pilot began. In addition of the maths and the music teachers, physics, technology and biology teachers were monitoring the sessions of the pilot teaching.

The scenario

The scenario, co-created with the teachers and adapted for phase B2 based on the results of piloting B1, began with parts of basic scenarios. In the first session, students performed physics experiments about the notion of sound as a vibration and listened to various instruments in a Cabri activity book in order to determine the source of the vibration (air, membrane, string, massive body). Then the notion of frequency and of Hertz was introduced with the visual analyser and the study of periodic curves in a Cabri activity book.

The other sessions of the pilot teaching were based on the scenario 'Let's hear Thales Theorem'. It addressed the notions of octave, the relationship between the length of a string and the frequency of the tone played by the string. After watching a video showing the geometrical construction of the subdivision of a segment into congruent parts, students had to justify it. They also had to determine how to change the tension of a string (without changing its length) in order to obtain a tone separated with an octave from a first tone. They also had to create melodies with Draw Me, the Performance Sampler and an instrument of the 3D Virtual Instrument Design.

Physical, mathematical and musical activities were intertwined in the sessions. They were carried out in the workbench in Draw Me, the Performance Sampler, the 3D Virtual Instrument Design, Algebra and Geometry, by using the tools : the Recorder, the 2D and 3D Sound Visualizations as well as the Snail.

2.3 Evaluation methods

The evaluation data during the iMuSciCA piloting were collected according to the evaluation framework reported in *D2.5 Final Evaluation metrics for deeper learning with iMuSciCA* supported by *D6.1 Pilot Testing Action Plan*. Several methods were applied, both qualitative and quantitative: the methods applied during piloting phase B2 are an optimized version of the methods used during phase B1. The data collected can be divided into two groups according to the targeted subjects: students (dealt with in this deliverable) and teachers (dealt with in D6.3). In this deliverable we focus on the data concerning students. All evaluation instruments were developed based on the classification of Deeper Learning Competencies by the Hewlett Foundation (https://www.hewlett.org/programs/education/) [Warkentien, Charles, Knapp, Silver, 2017] and consist of:

- **qualitative data** by observations and focus groups
- **quantitative data** based on students questionnaires
- **biometric data:** these are reported in annex 1

The qualitative and quantitative data collected give us information about the Deeper Learning Competencies, organized into the following three groups (see D2.5):

- Cognitive competencies;
- Interpersonal competencies;
- Intrapersonal competencies;
- Science education and music.

For the purposes of iMuSciCA the *quantitative* evaluation instruments were deployed in the form of two questionnaires - one on 'Deeper Learning Competencies'[1] and one in 'Motivation and Attitudes towards Science Learning' - and one 'Knowledge Acquisition Test' (see annex 1 and 2). The two questionnaires were standardized in order to collect the same data in the three piloting countries. On the other end the Knowledge Acquisition Test was country specific as different scenarios were piloted in the three countries. This quantitative evaluation was complemented by *qualitative*

[1] Adapted from the original questionnaire as developed by Hsiao-Lin Tuana, Chi-Chin Chin & Shyang-Horng (2005).

instruments, i.e. class observations and focus groups.

Furthermore during piloting phase B2 *comparative research elements* (e.g. control group designs) were introduced. Each piloting country implemented such elements in different ways, depending on the local possibilities. The types of comparative research elements applied are the following:

1. **Within one class with one subject teacher**. This approach was followed in **Belgium**, **France** and **Greece**. It consists of a **longitudinal approach** according to the following sequence: PRE-PRE questionnaire followed by one or two weeks of traditional teaching of STEM subjects (i.e. control scenario); break plus PRE questionnaire; STEM teaching with the support of iMuSciCA (i.e. experimental scenario); final POST questionnaire.
2. **Teaching the same subject twice**; i) traditional teaching of STEM subjects (i.e. control scenario); ii) elapse time (= pause); iii) STEM teaching with the support of iMuSciCA (i.e. experimental scenario).
3. **Comparison between different Schools.** This approach was followed in **Greece**. In-classroom implementation in different schools; longitudinal approach following the curriculum; control of independent variables e.g. curriculum, school background etc; Teacher Training before the intervention; comparison between schools applying the same curriculum without (i.e. control group) or with the support of iMuSciCA (i.e. experimental group).
4. **Comparison between Students' Clubs** running throughout the school year i.e. comparison between purely scientifically/STEM oriented Students' Clubs (i.e. control groups) with Student Clubs' of iMuSciCA (i.e. experimental group).
5. **Comparison between dedicated Students' Camps** i.e. comparison between purely scientifically/STEM oriented Students' Camps and (i.e. control groups) with Student Clubs of iMuSciCA (i.e. experimental group).

In table 3 we report the specific way in which the **longitudinal approach** was implemented in the three piloting countries. Because the application of the questionnaires for students is a time expensive operation, Belgium and France decided to focus on the Motivation and Attitudes towards Science Learning questionnaire for the purpose of comparison research, while the other questionnaire and the Acquisition Test were only applied after the piloting.

Target	Instrument	Belgium	France	Greece
Students	Deeper Learning Competencies Questionnaire	POST WITH	POST WITH	PRE-POST WITHOUT & PRE-POST WITH
	Motivation and Attitudes towards Science Learning Questionnaire	PRE-PRE WITHOUT & PRE / POST WITH *In one case only PRE / POST*	PRE-PRE WITHOUT / PRE WITH / POST WITH	PRE-POST WITHOUT & PRE-POST WITH

	Knowledge Tests	POST WITH	POST WITH	PRE-POST WITHOUT & PRE-POST WITH
Teachers	Summary Evaluation	POST WITH	POST WITH	POST WITH
	Software Usability Scale (SUS)	POST WITH	POST WITH	POST WITH

Table 3: Overview of iMuSciCA Piloting Phase B2 showing the target groups vs the *quantitative* evaluation instruments deployed per country. Note: WITH stands for teaching using iMuSciCA (Experimental Group) and WITHOUT for traditional teaching without iMuSciCA (Control Group).

3. Summary of data collected

3.1 Analysis of quantitative data (questionnaires and knowledge test)

We report below a summary of the most relevant results of the analysis of the quantitative data, while a more detailed analysis is reported in *D6.3 Final Report on Teacher's Feedback & Pilot Testing in Schools.*

3.1.1 Deeper Learning Competencies and Motivation and Attitudes towards Science Learning: results of students

The analysis of the collected data is reported per country, given the differences in piloting conditions and in material implemented during piloting. However some general conclusions about iMuSciCA will be reported too. The analysis of the data was done for each school separately and it was performed by calculating the average and standard deviation of the scores over all students of a given school and over all questions related to a given topic, i.e. motivation, cognitive competencies, interpersonal competencies, intrapersonal competencies and science education and music.

Belgium

The Deeper Learning Competencies were only measured after the piloting at the IKSO school: therefore no comparison is possible with a reference value. However, the average values of the scores of the post evaluation are in all cases positive (cognitive competencies: 3,76±0,48; interpersonal competencies: 3,86±0,27; intrapersonal competencies: 3,92±0,29; science education and music: 3,68±0,75).

Concerning the evaluation of Motivation and Attitudes towards Science Learning, we report below the results of the IKSO school, which we can consider as a *normal case* of implementing iMuSciCA (see section 2.2). In this case we see some indication of potential increase in motivation of the learners thanks to the piloted iMuSciCA lessons: the score on motivation increases from an average of 4,03 in the PRE-PRE and of 4,01 in the PRE test to an average of 4,11 in the POST test (see figure

4). We observe therefore an indication of improvement due to iMuSciCA, while classical teaching does not have any effect. We also have to mention that the starting average values measured with the PRE-PRE and PRE test are already quite high: the reference point was in this case an already quite good situation. In the case of Sint-Vincentiusmiddenschool Lanaken we don't see any effect (neither positive or negative), as the motivation remains the same before and after the piloting. As mentioned already in section 2.2 these results are strictly linked with the piloting conditions: in IKSO indeed the success of the piloting has to do with the structure of the foreseen activities (gradually growing in complexity starting from basic scenarios up to more advanced ones) and with the fact that the implemented scenarios had been piloted in the previous phase B1.
We could expect that a longer intervention than 8 lessons could result in even more positive effect. At least the data collected in the Greek Summer Camp (which lasted much longer) give indication for an even greater positive effect (see below under the Greek results).

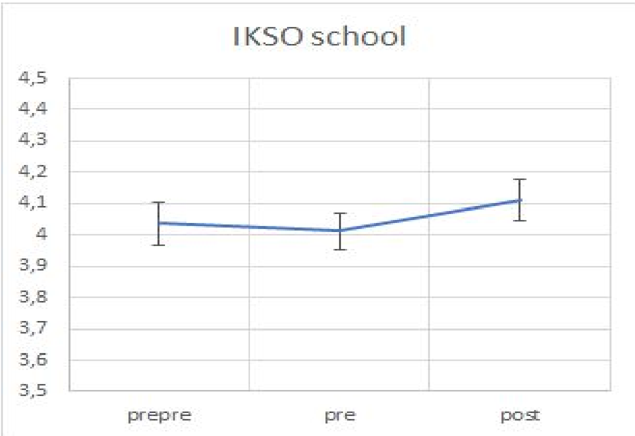
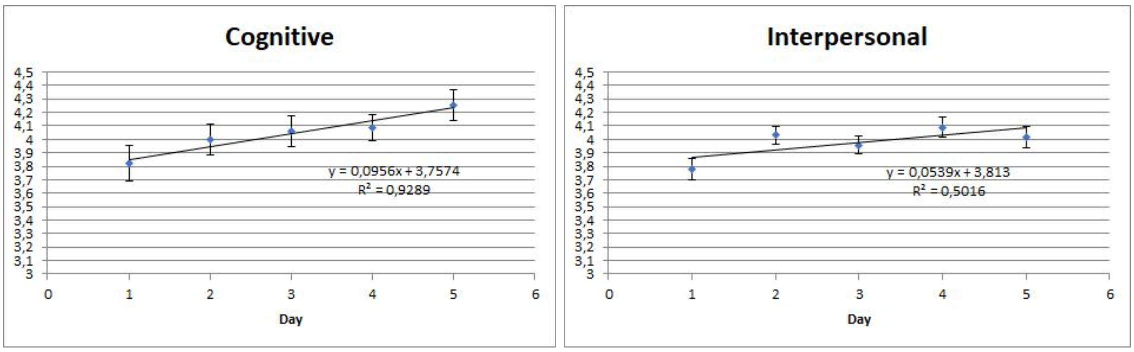
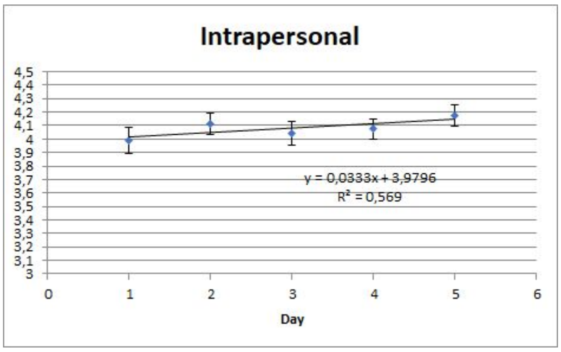


Figure 4: Graphics of Motivation and Attitudes towards Science Learning as measured at the IKSO school during PRE-PRE, PRE and POST evaluation.

Greece

The Deeper Learning Competencies were measured in three cases: during the Summer Camp lasting 5 days, at Ellinogermaniki Agogi, and in the Special School of Ilioupolis. In the case of the Summer Camp competency levels were measured every day. The results per day and for each competency are reported in figure 5 where a clear growing trend is visible in all cases but for their perception of the connection between Science Education and Music.





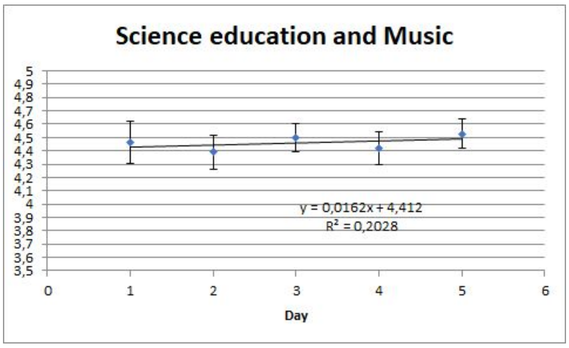


Figure 5: Graphics of Deeper Learning Competencies as measured every day during the summer camp.

Indications of a growing trend is also visible in the case of the Special School of Ilioupolis when comparing PRE to POST results for all competencies, but for the interpersonal competencies which remain stable. In the case of Ellinogermaniki Agogi an increasing trend is visible when comparing PRE and POST test results concerning science education and music, while in the other cases no clear effect (nor positive, nor negative) can be observed.

Motivation and Attitudes towards Science Learning was measured in the cases of Ellinogermaniki Agogi and of the Special Junior High School of Ilioupolis. In the first case no significant increase is observed (see figure 6), while an increasing positive trend (about 7%) is visible in the case of the Special Junior High School as shown in figure 7.

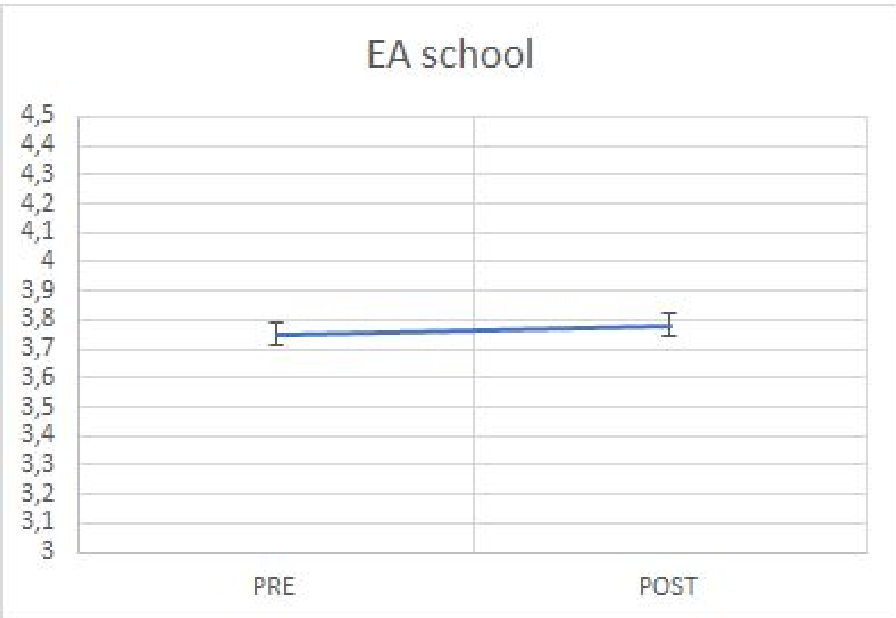


Figure 6: Graphics of Motivation and Attitudes towards Science Learning as measured at the Ellinogermaniki Agogi during PRE and POST evaluation.

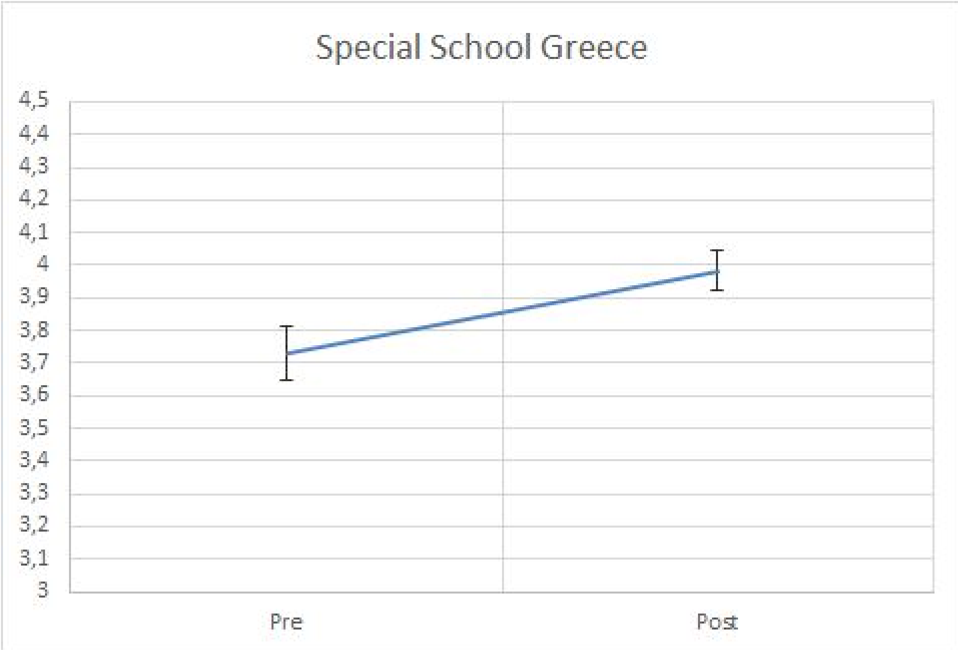


Figure 7: Graphics of Motivation and Attitudes towards Science Learning as measured at the Special Junior High School of Ilioupolis during PRE and POST evaluation.

We can conclude in general that both the results on motivation and on deeper learning competencies give indications of a positive effect of the iMuSciCA lessons. In particular the increasing trends on the Deeper Learning Competencies in the summer camp can be associated with a longer term intervention (5 days entirely dedicated to iMuSciCA).

France

Similarly to the case of Belgium, the Deeper Learning Competencies were only measured after the piloting: therefore no comparison is possible with a reference value. Also for France the average values of the scores of the post evaluation are in all cases positive (cognitive competencies: 3,62±0,49; interpersonal competencies: 3,70±0,73; intrapersonal competencies: 3,62±0,72; science education and music: 3,1±1,2).

Concerning Motivation and Attitudes towards Science Learning, in this case we don't see any clear effect as the average score remained unchanged before and after the piloting. However the average scores on motivation are positive (3,3). It has to be mentioned that there were some issues with the proper working of some features of the iMuSciCA workbench during the piloting lessons, which probably had a negative impact on the evaluation results. However positive effects of the iMuSciCA implementation in France were observed too: these are described in detail in section 3.2, where the qualitative results are presented. It is worth to be mentioned that the pupils for example became aware of the power of the mathematical method and that half of them claimed that iMuSciCA changed their view of physics and maths. Furthermore students recommended that a scenario should preferably be implemented during a longer time frame, in order to have enough time to process the studied content.

Generally we can conclude that through the piloting we got good indication of the potential of iMuSciCA concerning the increase of Deeper Learning Competences and Motivation and Attitudes towards Science Learning of students for STEM disciplines. Positive results were obtained especially the cases in which the scenarios had been tested during phase B1 and further improved and in which the iMuSciCA workbench worked in a stable way. Some more clear indication has been obtained during long term implementations (like e.g. during the Summer Camp in Greece), while no indication (neither positive or negative) has been observed during short term interventions (e.g. 2-4 hours). These elements indicate that in order to really observe effects on the learners we need simultaneously:

- time and possibility to preliminary test the produced material and optimize it based on the collected feedback;
- a long implementation period in the classroom;
- everything should be working smoothly during the lessons;
- engaged teachers have a crucial role in bringing iMuSciCA, like any other subject, to their students.

The above reported conclusions are in line with the expectations when we consider the available literature: we discuss this point further in the conclusions (see section 4). Last but not least we have to remind the positive feedback received from the teachers involved in iMuSciCA which are reported in deliverable *6.3 Final report on teacher's feedback and pilot testing in schools (B-Cycle)*.

3.1.2 Knowledge Acquisition Test

Belgium

In Belgium several knowledge tests were applied, related to the different scenarios piloted. In annex 1 some examples of knowledge tests are reported. In this section we report the results of the knowledge tests performed.

- At **IKSO Hoeselt** the Knowledge Test was performed after piloting scenario 2.1 The sequence of natural tones. Twelve of the 16 students were present on the day of the test. The average score was 90% with a standard deviation of 8%. One student got a score of 70% (the lowest value), two students got 100%.
- At **Sint-Vincentiusmiddenschool Lanaken** three Knowledge tests were performed, respectively after piloting scenarios 1, 2.1 and 6. In total 31 students were present for the test on scenario 1 and the average score was 80% with a standard deviation of 15%. The test on scenario 2.1 was performed by 32 pupils, with an average score of 90% and a standard deviation of 17%. The test on scenario 6 was performed by all 33 pupils resulting in an average score of 81% and a standard deviation of 17%.

The knowledge tests were performed immediately after seeing the related scenario in the class. Students didn't have time to study before performing the tests: so these are a measure of the immediate understanding of the included concepts during the iMuSciCA lessons.

Conclusions

In general all participating students got good scores in the Knowledge tests applied, which is a positive signal. These results indicate that the students understood the main concepts included in the scenarios already during the iMuSciCA lessons, as they did not have time to study at home.

Greece

The Knowledge Acquisition Test used for the iMuSciCA pilot process was adapted to the needs of the courses in which it was applied. Two Geometry teachers in upper secondary, one at Ellinogermaniki Agogi and the other at the Evangelical School of Nea Smyrni, responded to the invitation to conduct tests with a control group in the classes where they teach. After consulting the professors, the Knowledge Acquisition Test was adapted to Ellinogermaniki Agogi's chapter on "Symmetry," in the case of the Evangelical School of Nea Smyrni, which deals with the chapter of the “Parallelograms”.

The structure of the Knowledge Acquisition Test consists of four questions that derive from the content of the course and four with content that is directly related to both the Music and the particular lesson. Each question is multiple choice with four answers with one of which is the right one.

For conducting control groups, the same subject was taught in one case without the use of iMuSciCA and on the other using the platform. In teaching without the use of iMuSciCA, the teacher followed the teaching practice according to the curriculum (on teacher's official curriculum guide) as well as with examples available on the internet. By associating and paralleling the course content with Music, targeted examples were used such as:

- Horizontal thematic mirroring (inverse) and retrograde music notation examples
- The “Sectio Canonis” steps, up to division by 4 (1/2,2/3,3/4)
- The grades of Harmony (Tonic, Dominant, Subdominant)

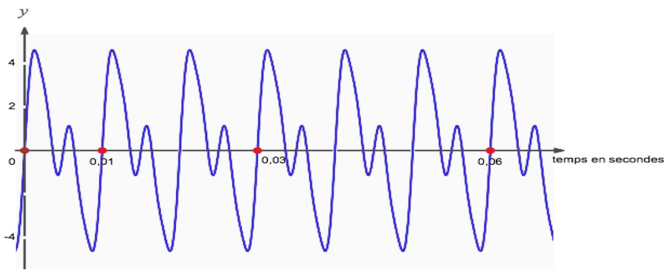
The Knowledge Acquisition tests used can be accessed on http://connect.ea.gr/imuscicakbq-ea/. In general an increase in content knowledge was registered at the Ellinogermaniki Agogi (10% overall). See deliverable *D6.3 Final Report on Teacher’s Feedback & Pilot Testing in Schools* for more details.

The Knowledge Acquisition was also monitored throughout the summer camp in July 2018: in general an order 10% systematic increase in students’ overall content knowledge was observed (more information is contained in *D6.3 Final Report on Teacher’s Feedback & Pilot Testing in Schools* for further detail).

France

The Knowledge Test consisted of 5 questions.

1. Why does propagate the sound when pinching the string of a guitar?
2. If a string of a monochord is extended, does become the sound deeper or higher?
3. How to change the length of a string to make it sound an octave higher?
4. Here is represented the curve of a periodic sound. Color with another colour the smallest pattern which is repeated in the curve.



5. Calculate the frequency of that sound.

Below are given the numbers of correct and incorrect answers (only 24 of the 30 students were present when the Knowledge Test was deployed).

	Correct answers	Incorrect answers	No answer
Question 1	24 (100%)		
Question 2	21 (~87%)	2 (~8%)	1 (~4%)
Question 3	1 (~4%)	14 (~58%)	9 (~38%)
Question 4	13 (~54%)	7 (~29%)	4 (~17%)
Question 5	2 (~8%)	11 (~46%)	11 (~46%)

Table 4: Results of the Knowledge Test in France.

These results show that almost all students understood that a sound is a vibration and acquired a qualitative idea of the relationship between the frequency of a sound and the length of a string. However they did not perceive the quantitative relationship. Half of the students were able to identify the smallest pattern in the curve but almost no students were able to calculate the frequency from the graph of the sound. One could conclude that students got a qualitative idea of the physical concept of sound and of propagation of sound as well as of the notion of pitch of a sound.

3.1.3 Biometric data

In order to infer some indications concerning motivation and engagement of students biometrical data was collected in a study group. The study group was a group of students of the Summer Camp organised by EA during the summer 2018. You can find more details on the data collected in *Annex 3 - Biometric data of learners' behaviour*. We give here a summary of the methodology and main results.

The group of students was divided into a group with a stronger musical background ('did you follow a musical conservatoire course?') and a group with a weaker musical but rather a science background. In our sample there were 18 students categorized as 'science' and 12 as 'music'. Both groups performed the same tasks. Some of those tasks were typical 'musical' other 'scientific'.

A science task was for example:

Double the string tension and observe the fundamental frequency of the note produced when you pluck the chord.Explore what happens to the fundamental frequency of the note produced by the chord when changing its tension.

A music task was for example:

Move the bridge of the one string to the point that creates a fifth with respect to the fundamental of the other string when you pluck either of the two segments.

During these tasks the students were monitored with the deployment of various biometric sensors (eyetracker, camera recordings of facial expressions, galvanic skin response-GSR and electroencephalography-EEG). Of course participation of the students to this was voluntary and written consent was provided by the parents.

Figure 8: Example of analysis of the eye gaze data (above) and respective heat maps (below).

We give here the conclusions that can be inferred based on this data (details on what basis this was done see *Annex 3 - Biometric data of learners' behaviour*). It was observed that:

- the group of Music students was 'sweating emotionally' less than the group of Science students in all tasks.
- students with music background show more engagement during the tasks, while students with science background show more interest.

- the female Music students have a positive attitude and motivation for the music-oriented tasks while they show a rather negative attitude and withdrawal in motivation for the science oriented tasks
- the group of Science students have a generally more positive attitude and motivation for the tasks compared to the Music students. For specific tasks we saw within the group of music students a withdrawal in motivation. This happened especially in tasks where quantitative investigations were at stake.

These results can be expected given that iMuSciCA was developed for science education. It is normal that students expecting more musical tasks can be a bit disappointed ('too much science in it'). This phenomenon was also observed in the classroom piloting: students who had to perform 'scientific inquiry' during a music lesson for instance, had a less positive attitude than students in a science class 'where music was used within scientific tasks'.

3.2 Analysis of qualitative data (observations etc.)

Belgium

In Belgium the qualitative data were collected through observation instruments: during each iMuSciCA lesson external observers (other teachers of the same school and project partners) were present and took notes on a provided form including some guiding questions and space to write down own field notes.

We list below some general comments which arise from these observations:

- It appears to be very important to start each new lesson with a short summary of the previous lesson, in order to create a common starting point in the class. The best way to do this is by letting students explain the content of the previous lesson in own words.
- It is also of fundamental importance to conclude each lesson with a common reflection moment for all the students. During a typical iMuSciCA lesson students work in groups of 3 - 4 quite independently, with the support of 1 or 2 teachers. However a common reflection moment is needed to be sure that the students really understood the content of the lesson. This moment can be based e.g. on questions posed by the teacher to the students about the content and let them discuss until the expected answer is given. The teacher will need in some cases to give the word to different groups and sometimes to intervene in order to guide them in the right direction.
- Such kind of reflection moments appear to be needed even during a lesson, after finishing a specific part of the scenario dealing with a specific subject.
- Another point to deal with at the beginning of each lesson is the clear statement of the aim of that lesson: this should be clearly formulated in order for the students to correctly place and understand the content and in order to enhance their motivation.
- In general students appear to be interested in the subjects and to be ready to work in order to carry out the proposed activities. They can generally cooperate in groups too.

Some interesting observations were collected by the teacher of the **Sint-Theresiacollege at Kappelle-op-den-Bos** (see 2.1). This teacher had the initiative to prepare some *extra questionnaires* for his students which are complementary to the standard ones. After each lesson, students had to fill in a short questionnaire on a Likert scale with 5 points: they had to indicate their level of understanding of the concepts seen during iMuSciCA and/or their level of improvement in the related skills. They also had to indicate how much they could use the tools and the environments on the iMuSciCA workbench in order to perform the proposed tasks.

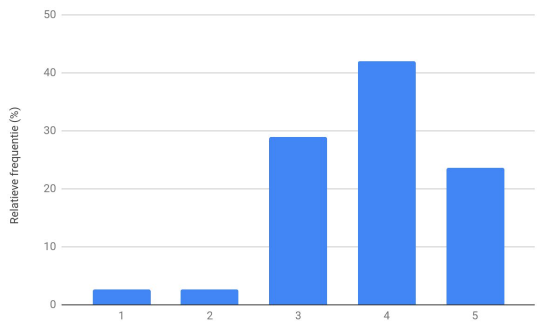


Figure 9: ***"The iMuSciCA workbench was useful in view of the learning goals".*** *For instance: I could use the tone synthesizer tool in the workbench to superimpose to simple tones to a more complex one. (Answers of the learners at St.-Theresiacollege, Kapelle-op-den-Bos - likert scale 1 negative - 5 positive; extra questionnaire prepared by the teacher).*

In general the results were quite positive as well concerning the understanding of the concepts as concerning the improvement of skills: for example the majority of the students admitted that they had *improved their communication skills* thanks to the group activities, that *their creativity benefited from the project* and that *they learned to motivate others*.

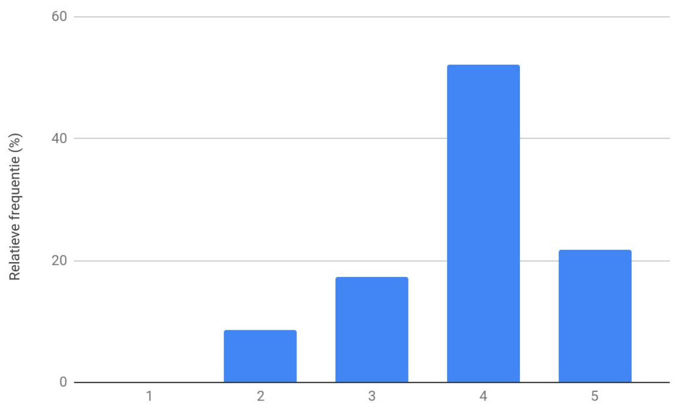


Figure 10: ***"The iMuSciCA project taught me to motivate others, to stimulate other student's engagement".*** *This falls in the category of interpersonal competencies of deeper learning (Answers of the learners at St.-Theresiacollege, Kapelle-op-den-Bos - likert scale 1 negative - 5 positive; extra questionnaire prepared by the teacher).*

The teacher confirmed that in general the positive answers of the pupils correspond to his own observations. The students also answered positively to the questions related to the use of the workbench, a fact that confirms the good usability this instrument in the classroom. It is also interesting to mention that this teacher plans to use the iMuSciCA workbench and scenarios next school year in a similar way, but with some more improvements in the organisation of his lessons. He also would like to implement some features of the workbench he could not implement yet, such as the 3D Instrument Interaction with the Leap Motion.

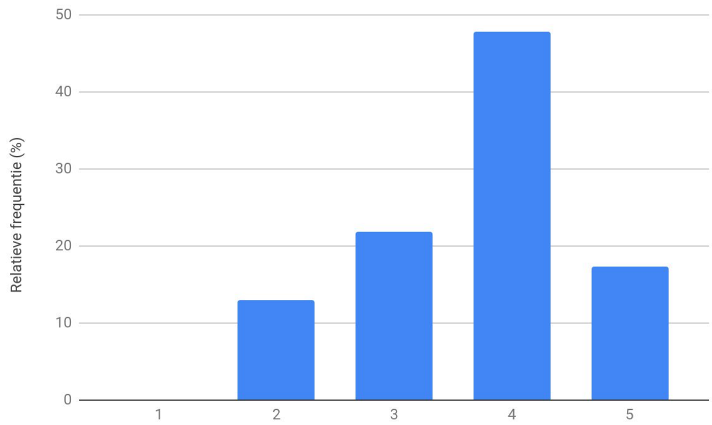


Figure 11: ***"The iMuSciCA project stimulated my verbal skills to make clear ideas, views and decisions in a scientific language"***. *This falls in the category of intrapersonal competencies of deeper learning (Answers of the learners at St.-Theresiacollege, Kapelle-op-den-Bos - likert scale 1 negative - 5 positive; extra questionnaire prepared by the teacher).*

Greece

In Greece, the observation of the learning process using the iMuSciCA platform was carried out by two teachers (Music and Physics) for Ellinogermaniki Agogi, as well as by the teachers who carried out the action at the Special School of Ilioupoli and the Evangelical School of Nea Smyrni.

In both EA and the Evangelical School of Nea Smyrni, the students found the interest of correlating a Geometry course with Music as this is something that is not expected in a traditional Geometry lesson. For EA, particular interest was expressed in the ability of acoustic interaction with both virtual instruments, sonification of geometrical figures and drawing. It is characteristic that after analysing the correlation between the symmetrical projection of the triangle over the x horizontal axis and the concept of the mirroring melodic sequences, a student asked if the sound of the shape he constructed "can be used in Music". The visualization capabilities of acoustic stimuli from either each student via the microphone or by testing the potential workbench tools encourage students to perceive parallels and correlations particularly useful in teaching science with an emphasis on their association with daily audio and personal impulses and perceptions such as the human voice itself.

France

Focus group

The students told that the pilot experiment did not change their view of music but half of them claimed that it changed their view of physics and maths. They mentioned

- that they could relate the notion of octave to the subdivision of a string into congruent parts;
- that they discovered that mathematical calculations must be performed to find the

frequency of a sound;
- that a musical sound is a vibration which is a phenomenon in physics.

A nice example was the surprise of a student when she learned that there is a mathematical construction for subdividing a segment into congruent parts based on Thales theorem or similarity of triangles. She asked us whether the industrial way of subdividing a string was based on this method: "Is it used in industry?". It must be explained that students became aware of the power of the mathematical method because, before being introduced to the mathematical method, they were requested to subdivide a piece of string into two congruent parts and then into three congruent parts without trial and error. They discovered that they could not succeed without trial and error in the subdivision into 3 congruent parts of the string.

Some activities were appreciated by the students but there was no consensus on the preferred activities. Some students liked the experiments in physics. They found that it is important not to work only on virtual objects but to work both in a material and a virtual environment.

Some other students liked the musical activities and a third group liked the fact to justify a geometrical construction that they could watch in a video. An advantage of STEM pedagogy lies in the fact the activities resort to various domains of knowledge and as such can attract a diversity of students.

When asked to propose modifications for a future iMuSciCA scenario, the students suggested to use better sounds in DrawMe (particularly to improve the timbre of the sounds), to add more strings in the monochord and to repair remaining bugs, related in particular to the absence of sound or to the low quality of sound in the Performance Sampler and in the 3D Virtual Instrument Design. They also suggested to add help on line in the workbench.

Finally they recommended that a scenario takes place over a longer period of time, for example one session per week. This a very sensible proposal. A longer period of time gives time for interiorizing the new notions introduced in the teaching.

The final word was said by one student who described the pilot by two adjectives: enriching and instructive.

4. Conclusions

In general, based on the results of the qualitative and quantitative data collected during the iMuSciCA piloting, we can conclude that the project can potentially positively affect the motivation of learners towards science learning. Also positive indications were obtained concerning the Deeper Learning Competencies.

The Deeper Learning Competencies and Motivation and Attitudes towards Science Learning results, and in part the Knowledge Test results, arise from the comparative research approaches presented in section 2.2. In general we observed indications of positive effects on Deeper Learning Competencies and Motivation and Attitudes towards Science Learning when compared to the previous situation (longitudinal approach within the same students group) or to other approaches to teach the same subjects in other groups.

We have to mention here that the results are quite encouraging given the rather small amount of statistical data collected during piloting and the rather short piloting periods. These conditions have to do with the nature of the iMuSciCA project: indeed it was not our aim to prove that iMuSciCA is better than other approaches to science, math and technology, but rather to develop a completely new approach to teach these disciplines in the class.

As a matter of fact, it was often based on the piloting results that the workbench and the scenarios were further improved till their final versions.

Given the innovative nature of the project, it wasn't possible to deliver bigger amounts of pilot lessons within the project lifetime. In order to be able to measure a clear effect, one should concentrate all the efforts in delivering such an innovative approach and for a much longer amount of time in a given class. Compare for example the effects of inquiry learning reported e.g. in [Minner, Levy & Century, 2010]: they stated a positive effect of inquiry learning based on a collection of findings across 138 analyzed studies! In [Furtak, Seidel, Iverson & Briggs, 2012] it is also reported that the effect of an intervention lasting between five and seven weeks had a higher impact on student learning than those that lasted up to one week. Hattie also reports that the effect size decreases with age [Hattie, 1999].

Therefore we can be satisfied of the results obtained compared with literature since we were dealing with students of secondary schools (13-18 y.o.). It is also worth mentioning that the teachers feedback was very positive (see deliverable *6.3 Final report on teacher's feedback and pilot testing in schools (B-Cycle)*).

Finally in France Cabrilog won, with the iMuSciCA activity books, Lot 6 «Autres enseignements scientifiques» (dedicated to STEM) within the French high school tender *Banque des ressources Numériques des lycées des Régions*.

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Annex 1 - Questionnaires

Deeper Learning Competencies Questionnaire

Please tell us what you think. There are no 'right' or `wrong' answers. We just want to hear your opinion. Draw a circle around:
1. if you strongly disagree; 2. if you disagree; 3. if you have no opinion; 4. if you agree; 5. if you strongly agree

	Strongly disagree		No opinion	Strongly agree	
1. I understood the study material during class.	1	2	3	4	5
2. I could easily solve the theoretical questions.	1	2	3	4	5
3. I could easily solve the exercises.	1	2	3	4	5
4. Which score do you expect?			/ 10		
5. I provide my team members with constructive feedback.	1	2	3	4	5
6. My team members provide constructive feedback.	1	2	3	4	5
7. I am willing to incorporate someone else's feedback into my own way of thinking.	1	2	3	4	5
8. I am part of the team. This means I cooperate actively, but also do not want to do everything alone.	1	2	3	4	5
9. My team members and I share and distribute tasks in view of adequate problem-solving.	1	2	3	4	5
10. My team works individually.	1	2	3	4	5
11. My team has achieved good results through teamwork.	1	2	3	4	5
12. I reflect about the subject.	1	2	3	4	5
13. We try solving a problem in group first before asking the teacher for help.	1	2	3	4	5
14. I can easily refocus after distractions and concentrate on my goal.	1	2	3	4	5
15. I care about the result and put in extra effort to accurately execute the exercise.	1	2	3	4	5
16. I understand the importance of school for my life and interests.	1	2	3	4	5

17. I see that the iMuSciCA lessons continue to build upon what I already know.	1	2	3	4	5
18. I see the work I do now will benefit my future life.	1	2	3	4	5
19. I like learning science connected to music.	1	2	3	4	5
20. The connections between music and science interest me.	1	2	3	4	5

Motivation and Attitudes towards Science Learning questionnaire

Please tell us what you think. There are no ‘right ‘or `wrong’ answers. We just want to hear your opinion. Draw a circle around the number:
1. if you strongly disagree; 2. if you disagree; 3. if you have no opinion; 4. if you agree; 5. if you strongly agree

	I strongly disagree		No opinion	I strongly agree	
1. I have pleasure when learning science.	1	2	3	4	5
2. Even if scientific concepts are difficult, I still try to learn and understand them.	1	2	3	4	5
3. I am sure about my capabilities and competencies in science subjects.	1	2	3	4	5
4. I am personally responsible if I do not understand science well.	1	2	3	4	5
5. I employ different approaches (e.g. finding resources, discuss with others) to ensure that I learn science well.	1	2	3	4	5
6. Learning science is valuable for me because I can use it in my daily life.	1	2	3	4	5
7. Learning science will help me in the future to build my career.	1	2	3	4	5
8. I am confident that I can achieve high grades in science subjects.	1	2	3	4	5
9. I am trying to achieve excellent results in science tests.	1	2	3	4	5
10. Receiving good grades in science tests is not as important as the learning about science as such.	1	2	3	4	5
11. I am satisfied when I can solve a difficult scientific problem.	1	2	3	4	5
12. I feel fulfilled when others (e.g. teachers, students) accept my ideas.	1	2	3	4	5
13. I like learning science when the content is exciting and inspiring.	1	2	3	4	5
14. It helps me to learn science when the teacher uses different teaching methods.	1	2	3	4	5
15. I like to learn science together with others.	1	2	3	4	5

Annex 2 - Knowledge Acquisition tests used in Belgium

Scenario 1

Test scenario 1: Sound and tone

1. Fill in using one of the following words:
Wave-string-vibration-air-membrane-lichaam
Points: _ /4

· Sound is originated by a …………………………………….

· This vibration propagates in the form of a ……………………………….

· In an aerophone what vibrates is ………………………….

· In a string instrument the source of the vibration is ……………………………………

2. Are the following statements correct or wrong? Amend the incorrect statements.
Points: _ /4

A) By clapping in your hands, you produce a tone and you can thus measure a repeating pattern.

B) We call the vertical deviation of the waveform 'amplitude'.

C) The frequency indicates how many times the pattern is repeated.

D) The unit of frequency is the centimeter.

Scenario 2.1

Test scenario 2.1: The sequence of natural tones

1) Are the following statements correct or wrong? Amend the incorrect statements.
Points: _ /2

	Statement	Correct	Incorrect
1)	When you play a tone with a certain pitch on an instrument you can always play a new tone a bit higher or lower, even without changing anything to the music instrument (don't change the length, don't open or close the holes, etc.). ____		
2)	The first natural tone is also called the fundamental tone. ____		

2) Solve the following exercises. Points: _ / 8

The frequency of the first two natural tones of an aerophone are given. Complete the table further. (__ / 4)

	f (Hz)	Frequency difference (Hz)
	12	-
	24	

What is the frequency of the 12th harmonic of this instrument? write down the formula you have used. (__ / 2)

____

The third harmonic of another aerophone has a frequency of 99Hz. What is the frequency of the fundamental tone of this instrument? (Write down the calculations too) (__ / 2)

____

Scenario 6

Test scenario 6: Create Music with simple mathematical Proportions

Question 1. Points: _ /3

A) Explain when two tones which sound together are consonant.

B) Explain when two tones which sound together are dissonant.

C) Listen to the following musical piece. Do you hear mostly consonant or dissonant tones? https://www.youtube.com/watch?v=nLMvjGS9XiA

Question 2. Points: _ /3

Write down whether the following statements are correct or wrong? Amend the incorrect statements.

A) When you hit a tuning fork with a frequency of 220 Hz and simultaneously one with a frequency of 221 Hz, you can hear a beat. *(0.5 points)*

B) Consonant tones are often used in horror movies. *(1 points)*

C) When we take 2 strings and the lengths relate like simple integer numbers, they start to sound like a dissonant two-tone. *(1 points)*

D) If the frequencies of 2 tones relate as simple integers, then they are consonant. The frequencies of 2 tones that are not related as simple integers, are dissonant. You can experience how beauty in music is connected with simple proportions in mathematics. *(0.5 points)*

Annex 3 - Biometric data of learners' behaviour

Introduction

During the summer camp for students organized by EA we have conducted an experiment of learners' behaviour while interacting with the iMuSciCA workbench for completing certain music or science tasks. In particular, the students attending the summer camp (see Section 2.1) were categorized as 'music-background' and 'science-background' depending on whether they have been exposed to formal music education (e.g. by attending conservatoire courses) and were exposed to 'science tasks' or 'music tasks'. Each student was monitored with the deployment of various biometric sensors (eyetracker, camera recordings of facial expressions, galvanic skin response-GSR and electroencephalography-EEG). The participation of the students was voluntary and written consent was provided by the parents selecting the allowed sensors.

Students participated in the pilot study

Students with science background were 18 (7 males and 11 females), whereas students with music background were in total 12 (8 males and 4 females). In addition, 2 students we measured without eye tracker, resulting in total 32 students (16 males/16 females).
The table below summarizes the number of participants carried out the tasks above categorized in two groups, namely, music and science.

Task Label	Music	Science	Total
MT1(F1)	6	9	15
MT2(F2)	5	9	14
MT3_0(F3)	6	10	16
MT3_1(F4)	6	10	16
ST1_0(F5)	6	11	17
ST1_1(F6)	6	11	17
ST2_0(F7)	6	11	17
ST2_1(F8)	6	11	17
ST3_0(F9)	6	11	17
ST3_1(F10)	6	11	17

In the table above note that one student of the Music group didn't perform task MT2 as he answered it in MT1 and one student of the Science group asked not to perform tasks MT1 and MT2 as she didn't have any knowledge.

Tasks performed by students

Science Tasks

Label	**Description**
ST1_0	Create a monochord with the following chord features: length 0.30 m, tension 50 N, radius 0.235 mm and steel as material. Observe the fundamental frequency of the note produced when you pluck the string.
ST1_1	Double the chord length and observe the fundamental frequency of the note produced when you pluck the string. Explore what happens to the fundamental frequency of the note produced by the chord when changing its length.
ST2_0	Restore the chord to its original length of 0.30 m.
ST2_1	Double the string tension and observe the fundamental frequency of the note produced when you pluck the chord. Explore what happens to the fundamental frequency of the note produced by the chord when changing its tension.
ST3_0	Return the chord to its original length of 0.30 m and its initial tension of 50 N. Observe the fundamental frequency of the note produced when you pluck the string. Then, triple the length of the string.
ST3_1	Try to find the value of the tension that produces the same as the original fundamental frequency of the note produced.

Music Tasks

Label	**Description**
MT1	Create a chord based on the E note.
MT2	Create a MAJOR chord based on the E note.

MT3_0	Create a two-string instrument with the following chord features: length 1.20 m, tension 95 N, radius 0.2 mm and steel as material. Observe the fundamental frequency of the note produced when you pluck one of the strings.
MT3_1	Move the bridge of the one string to the point that creates a fifth with respect to the fundamental of the other string when you pluck either of the two segments.

Statistics on the time required for each task

The table below shows the statistics of the time required to complete each of the tasks above.

Row Labels	Average of Stimulus / Marker Duration (ms)	StdDev of Stimulus / Marker Duration (ms)	Min of Stimulus / Marker Duration (ms)	Max of Stimulus / Marker Duration (ms)
MT1	26544	13261	8633	61600
MT2	25767	21507	7300	89634
MT3_0	41371	9170	26733	58667
MT3_1	45948	34736	8800	135733
ST1_0	62661	11772	43300	83000
ST1_1	65766	30962	27500	124833
ST2_0	12555	2731	8066	17100
ST2_1	48941	25966	21167	125333
ST3_0	24263	6279	11600	38300
ST3_1	90776	45938	38933	216300

By considering only the science students:

Row Labels	Average of Stimulus / Marker Duration (ms)	StdDev of Stimulus / Marker Duration (ms)	Min of Stimulus / Marker Duration (ms)	Max of Stimulus / Marker Duration (ms)
MT1	28292	16383	8633	61600
MT2	30426	24811	12600	89634
MT3_0	42923	11024	26733	58667

MT3_1	50153	37438	17300	135733
ST1_0	65130	11171	43300	83000
ST1_1	59406	28417	32133	124833
ST2_0	12733	2837	8066	17100
ST2_1	43748	13558	22666	67100
ST3_0	24915	6765	11600	38300
ST3_1	104442	50541	39466	216300

By considering only the music students:

Row Labels	Average of Stimulus / Marker Duration (ms)	StdDev of Stimulus / Marker Duration (ms)	Min of Stimulus / Marker Duration (ms)	Max of Stimulus / Marker Duration (ms)
MT1	23922	7013	14100	35100
MT2	17380	11638	7300	37333
MT3_0	38783	4544	29666	41700
MT3_1	38939	31663	8800	97666
ST1_0	58133	12484	49233	79400
ST1_1	77428	34648	27500	111600
ST2_0	12228	2750	9234	16267
ST2_1	58461	40272	21167	125333
ST3_0	23067	5655	16767	31467
ST3_1	65722	21910	38933	99933

Affect measures based on facial expression analysis

Affect measures of average percentage of time with facial expressions above the threshold of the prototypes using the Affectiva engine for each group.

Music												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Engagement**	**Attention**	**Positive**	**Negative**	**Neutral**
MT1	0.00	1.95	0.68	6.21	0.00	0.00	8.80	11.75	66.30	5.79	0.38	78.21

MT2	0.00	0.00	0.00	6.90	0.71	0.53	1.73	18.72	83.33	7.34	0.90	86.94
MT3_0	0.00	0.00	0.08	2.32	1.40	0.00	0.57	16.29	92.84	1.28	3.70	89.68
MT3_1	0.00	0.00	0.06	0.35	1.50	0.22	0.53	9.97	90.13	0.26	0.55	93.45
ST1_0	0.44	0.00	0.24	0.21	0.69	0.00	0.54	8.82	87.70	0.23	0.42	91.63
ST1_1	0.33	0.00	0.04	0.51	0.59	0.00	0.05	8.82	87.62	0.41	0.96	90.26
ST2_0	0.00	0.00	0.00	0.54	0.00	0.42	0.00	5.89	92.56	0.54	1.36	91.77
ST2_1	0.05	0.16	0.07	0.05	0.09	0.12	0.83	10.61	82.33	0.12	1.71	91.27
ST3_0	0.08	0.00	0.06	0.46	0.81	0.00	0.00	15.84	82.58	0.31	9.40	75.22
ST3_1	0.00	0.00	0.07	0.29	0.88	0.03	1.17	12.68	90.17	0.40	1.87	90.40
Grand Total	**0.09**	**2.11**	**0.13**	**1.70**	**0.67**	**0.13**	**1.42**	**11.82**	**85.59**	**1.57**	**2.15**	**87.90**

Science												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Engagement**	**Attention**	**Positive**	**Negative**	**Neutral**
MT1	0.00	0.76	0.52	0.18	2.94	0.24	1.06	15.80	54.51	0.15	0.88	88.53
MT2	2.13	0.00	2.63	5.16	1.15	0.00	2.39	15.91	60.02	5.03	3.83	88.02
MT3_0	0.04	0.00	0.69	0.00	2.41	0.10	3.88	11.11	87.99	0.01	3.20	92.25
MT3_1	0.24	0.00	2.66	1.21	2.38	0.00	2.24	16.63	91.91	1.09	5.25	92.77
ST1_0	0.88	0.30	0.24	2.04	2.10	1.23	1.69	13.73	89.73	1.81	2.82	91.32
ST1_1	0.07	0.00	0.39	1.62	4.63	0.23	2.27	21.14	92.55	1.67	4.40	89.72
ST2_0	0.00	0.00	0.00	0.00	0.04	0.00	1.11	12.20	91.53	0.00	7.18	90.03
ST2_1	0.39	0.00	0.32	0.86	2.53	1.33	1.57	13.93	87.40	0.62	4.29	86.27
ST3_0	0.87	0.00	0.46	2.15	2.35	2.50	2.12	22.88	92.60	2.05	8.88	84.64
ST3_1	0.17	0.00	0.53	1.93	1.98	2.53	2.34	16.40	85.70	1.71	4.09	83.47
Grand Total	**0.46**	**1.06**	**0.80**	**1.49**	**2.26**	**0.86**	**2.06**	**16.02**	**84.27**	**1.39**	**4.57**	**88.65**

All												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Engagement**	**Attention**	**Positive**	**Negative**	**Neutral**
MT1	0.00	2.71	0.58	2.59	1.77	0.14	4.15	14.18	59.23	2.41	0.68	84.40

MT2	1.37	0.00	1.69	5.78	1.00	0.19	2.15	16.91	68.35	5.85	2.78	87.64
MT3_0	0.03	0.00	0.46	0.87	2.03	0.06	2.64	13.05	89.81	0.48	3.39	91.28
MT3_1	0.15	0.00	1.68	0.89	2.05	0.08	1.60	14.13	91.24	0.78	3.49	93.03
ST1_0	0.73	0.30	0.24	1.39	1.60	0.80	1.28	11.99	89.01	1.25	1.97	91.43
ST1_1	0.16	0.00	0.27	1.23	3.20	0.15	1.49	16.79	90.81	1.22	3.18	89.91
ST2_0	0.00	0.00	0.00	0.19	0.03	0.15	0.72	9.97	91.90	0.19	5.12	90.64
ST2_1	0.27	0.16	0.23	0.58	1.67	0.90	1.31	12.76	85.61	0.44	3.38	88.03
ST3_0	0.59	0.00	0.32	1.55	1.81	1.62	1.37	20.40	89.07	1.43	9.06	81.31
ST3_1	0.11	0.00	0.37	1.35	1.59	1.65	1.93	15.09	87.28	1.25	3.31	85.92
Grand Total	**0.33**	**3.17**	**0.56**	**1.56**	**1.68**	**0.59**	**1.83**	**14.50**	**84.75**	**1.45**	**3.69**	**88.37**

Affect measures of average percentage of time with facial expressions above the threshold of the prototypes using the Emotient engine for each group.

Music												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Confusion**	**Frustration**	**Positive**	**Negative**	**Neutral**
MT1	0.82	1.78	0.23	9.50	0.92	0.00	7.51	0.00	0.00	1.72	0.27	41.54
MT2	1.70	3.44	0.05	0.00	0.00	0.00	7.79	0.00	0.00	0.00	0.28	53.61
MT3_0	1.09	0.02	2.73	1.61	1.61	0.01	10.89	0.00	0.00	0.00	0.14	70.76
MT3_1	2.34	0.11	0.90	0.12	2.78	0.12	3.70	0.00	0.00	0.00	0.00	52.80
ST1_0	2.19	6.73	0.90	0.54	4.08	0.00	4.23	0.00	0.00	0.04	0.02	78.49
ST1_1	1.23	9.24	0.67	1.06	3.78	0.00	10.34	0.00	0.00	0.00	0.44	70.51
ST2_0	3.13	13.05	0.05	0.42	0.29	1.37	12.15	0.00	0.00	0.00	0.00	67.42
ST2_1	4.87	5.89	1.12	0.48	3.42	0.07	4.14	0.00	0.00	0.00	0.10	72.95
ST3_0	7.30	12.66	0.00	0.28	1.81	0.21	11.43	0.00	0.00	0.00	0.00	62.26
ST3_1	4.92	7.79	1.33	2.32	3.12	0.13	8.85	0.00	0.00	0.11	0.47	71.52
Grand Total	**2.98**	**6.12**	**0.81**	**1.66**	**2.22**	**0.20**	**8.11**	**0.00**	**0.00**	**0.19**	**0.17**	**64.36**

Science												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Confusion**	**Frustration**	**Positive**	**Negative**	**Neutral**

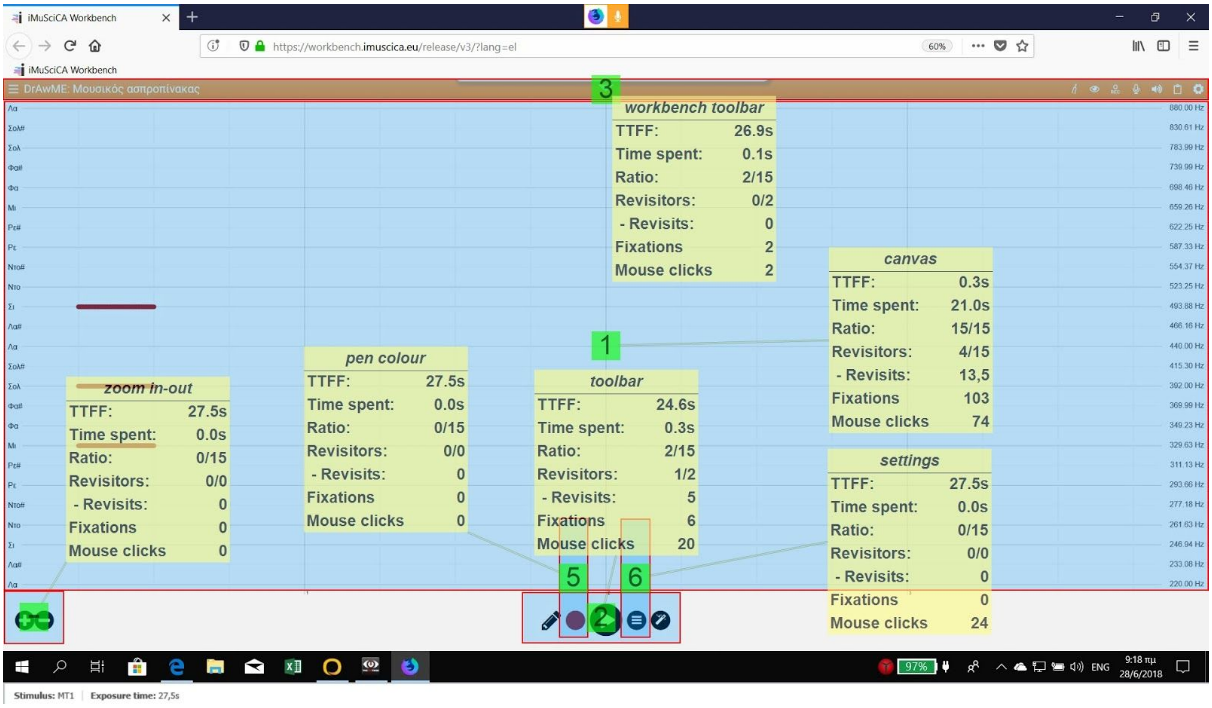
MT1	3.23	0.01	6.14	0.22	16.38	0.00	13.92	0.00	0.00	0.00	3.37	48.02
MT2	3.61	0.10	7.03	7.60	7.38	0.00	12.38	0.00	0.00	1.61	1.24	45.35
MT3_0	6.98	0.08	0.70	2.40	6.63	0.00	18.88	0.00	0.00	0.00	2.46	74.32
MT3_1	14.61	0.01	2.21	1.58	11.48	0.00	7.99	0.00	0.00	0.19	0.43	69.71
ST1_0	3.00	0.00	0.51	2.96	11.52	0.00	9.74	0.00	0.00	0.23	0.42	74.62
ST1_1	1.26	0.19	1.06	3.22	9.44	0.13	16.12	0.00	0.00	0.45	1.25	67.61
ST2_0	0.23	0.00	0.02	1.01	10.50	0.00	18.04	0.00	0.00	0.00	9.25	68.20
ST2_1	2.25	0.10	0.52	2.15	10.55	0.01	9.83	0.00	0.00	0.31	0.90	71.85
ST3_0	2.43	0.01	0.10	3.56	8.22	0.00	11.83	0.00	0.00	1.29	1.25	74.87
ST3_1	0.89	0.09	1.88	3.56	7.33	0.06	10.48	0.00	0.00	1.13	1.53	65.16
Grand Total	**3.73**	**0.06**	**1.85**	**2.80**	**9.89**	**0.02**	**12.90**	**0.00**	**0.00**	**0.52**	**2.22**	**66.60**

All												
Task Labels	**Anger**	**Sadness**	**Disgust**	**Joy**	**Surprise**	**Fear**	**Contempt**	**Confusion**	**Frustration**	**Positive**	**Negative**	**Neutral**
MT1	2.26	0.72	3.78	3.94	10.20	0.00	11.36	0.00	0.00	0.69	2.13	45.43
MT2	2.93	1.29	4.54	4.89	4.75	0.00	10.74	0.00	0.00	1.04	0.90	48.30
MT3_0	4.77	0.06	1.46	2.10	4.75	0.01	15.89	0.00	0.00	0.00	1.59	72.99
MT3_1	10.01	0.05	1.72	1.03	8.22	0.04	6.38	0.00	0.00	0.12	0.27	63.37
ST1_0	2.72	2.38	0.64	2.11	8.90	0.00	7.79	0.00	0.00	0.16	0.28	75.99
ST1_1	1.25	3.38	0.92	2.45	7.44	0.08	14.08	0.00	0.00	0.29	0.96	68.63
ST2_0	1.25	4.61	0.03	0.81	6.89	0.48	15.96	0.00	0.00	0.00	5.99	67.92
ST2_1	3.17	2.14	0.73	1.56	8.04	0.03	7.82	0.00	0.00	0.20	0.62	72.24
ST3_0	4.15	4.48	0.07	2.40	5.95	0.08	11.69	0.00	0.00	0.84	0.81	70.42
ST3_1	2.31	2.80	1.69	3.12	5.84	0.09	9.90	0.00	0.00	0.77	1.15	67.40
Grand Total	**3.46**	**2.25**	**1.48**	**2.39**	**7.11**	**0.08**	**11.17**	**0.00**	**0.00**	**0.40**	**1.48**	**65.79**

Eye gaze analysis

Areas of Interests (AOIs) are defined for each task and per respondent as they have different duration for each respondent. The analysis of the eye gaze data per task is shown in the following figures.

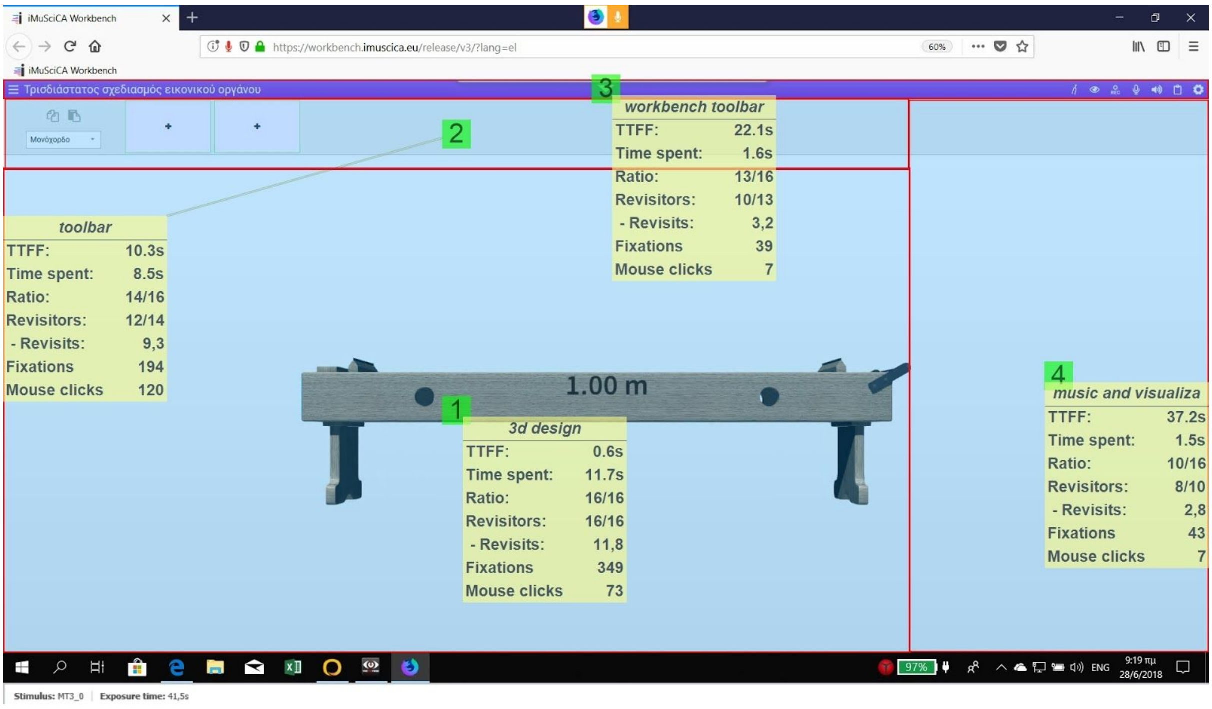
MT1



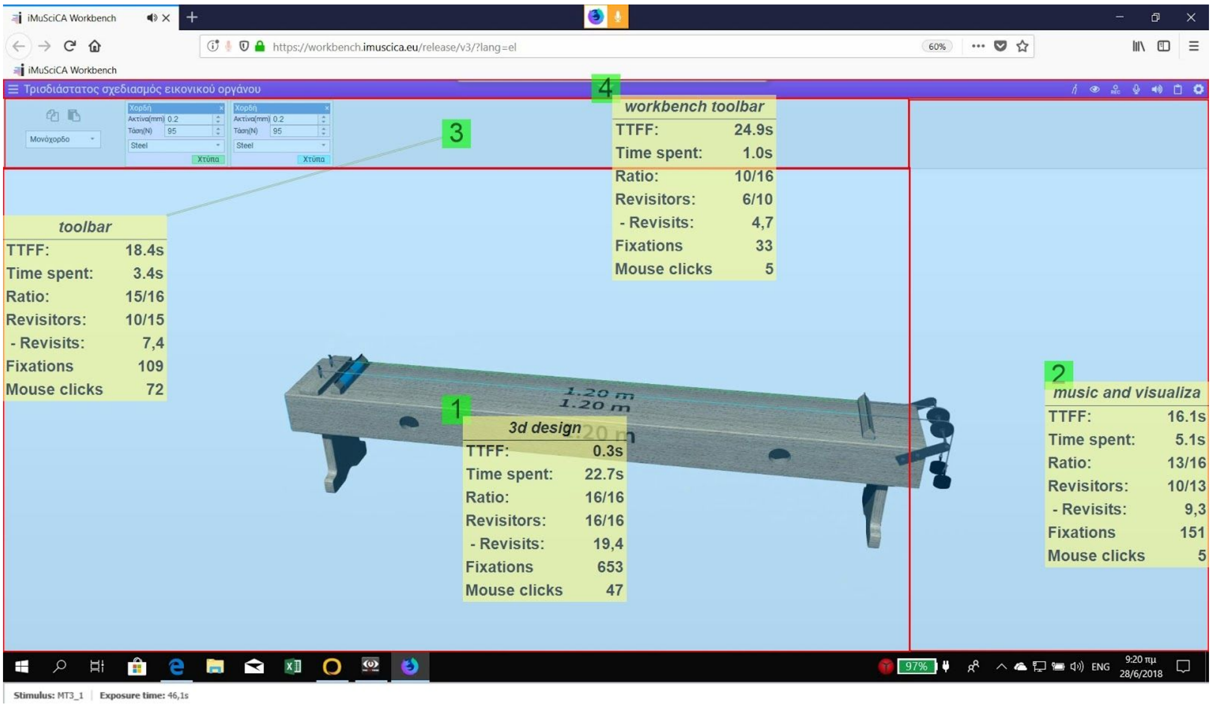
MT2


iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
DrAwME: Μουσικός ασπροπίνακας
workbench toolbar
TTFF: 26.5s
Time spent: 0.0s
Ratio: 0/15
Revisitors: 0/0
- Revisits: 0
Fixations 0
Mouse clicks 0
canvas
TTFF: 0.7s
Time spent: 10.1s
Ratio: 15/15
Revisitors: 15/15
- Revisits: 14,8
Fixations 384
Mouse clicks 66
pen colour
TTFF: 19.7s
Time spent: 0.2s
Ratio: 8/15
Revisitors: 2/8
- Revisits: 2
Fixations 10
Mouse clicks 0
settings
TTFF: 22.2s
Time spent: 0.4s
Ratio: 6/15
Revisitors: 2/6
- Revisits: 2,5
Fixations 9
Mouse clicks 13
zoom in-out
TTFF: 23.1s
Time spent: 0.0s
Ratio: 2/15
Revisitors: 0/2
- Revisits: 0
Fixations 2
Mouse clicks 0
toolbar
TTFF: 15.4s
Time spent: 1.1s
Ratio: 12/15
Revisitors: 6/12
- Revisits: 3,5
Fixations 31
Mouse clicks 18
Stimulus: MT2 | Exposure time: 26,5s

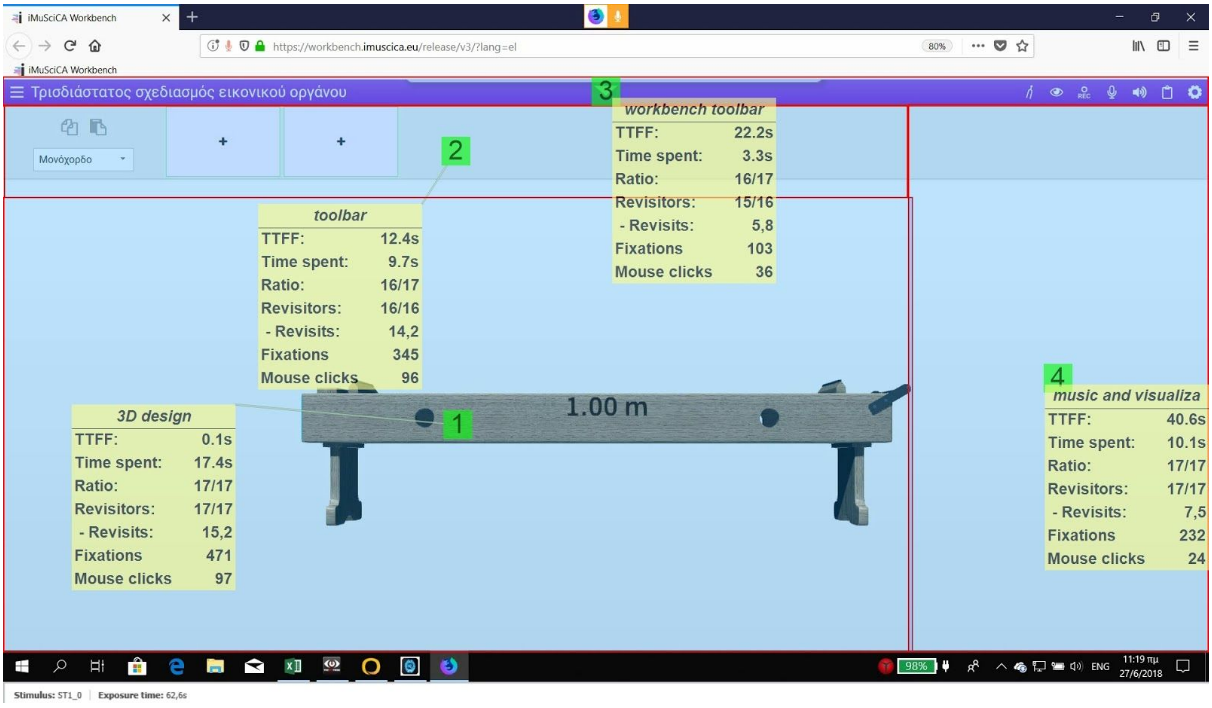
MT3_0


iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
workbench toolbar
TTFF: 22.1s
Time spent: 1.6s
Ratio: 13/16
Revisitors: 10/13
- Revisits: 3,2
Fixations 39
Mouse clicks 7
toolbar
TTFF: 10.3s
Time spent: 8.5s
Ratio: 14/16
Revisitors: 12/14
- Revisits: 9,3
Fixations 194
Mouse clicks 120
1.00 m
3d design
TTFF: 0.6s
Time spent: 11.7s
Ratio: 16/16
Revisitors: 16/16
- Revisits: 11,8
Fixations 349
Mouse clicks 73
music and visualiza
TTFF: 37.2s
Time spent: 1.5s
Ratio: 10/16
Revisitors: 8/10
- Revisits: 2,8
Fixations 43
Mouse clicks 7
Stimulus: MT3_0 | Exposure time: 41,5s

MT3_1

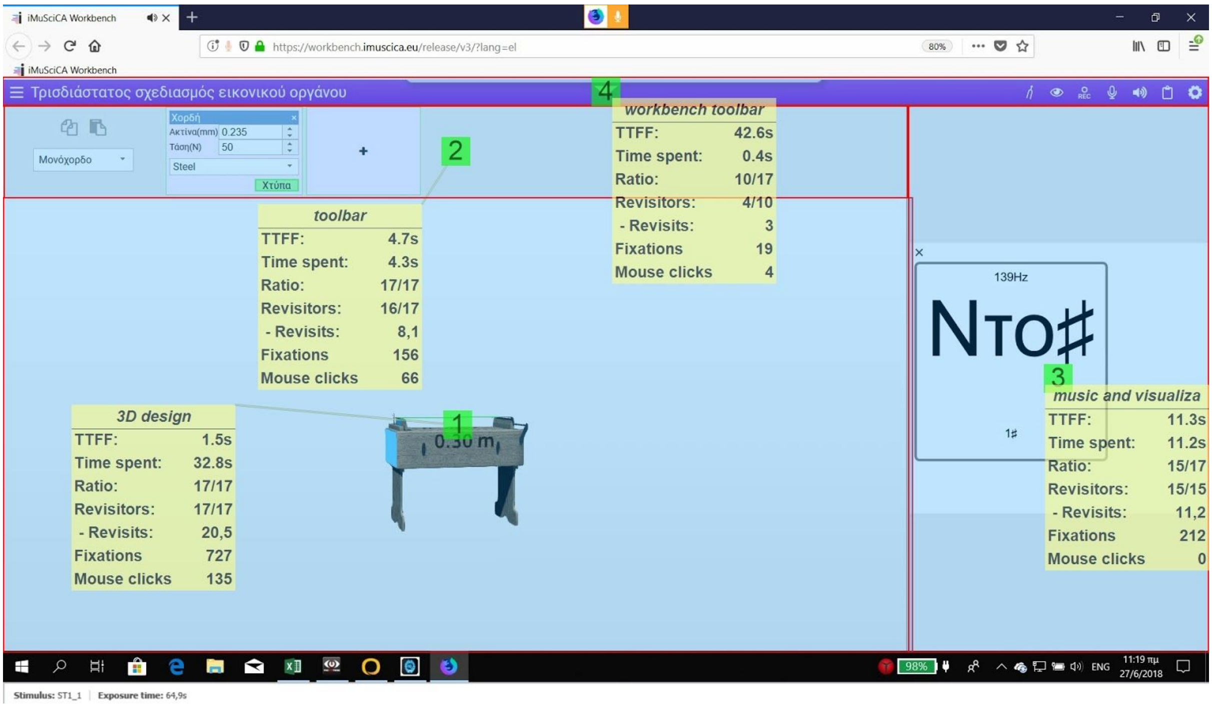

workbench toolbar
TTFF: 24.9s
Time spent: 1.0s
Ratio: 10/16
Revisitors: 6/10
- Revisits: 4,7
Fixations 33
Mouse clicks 5
toolbar
TTFF: 18.4s
Time spent: 3.4s
Ratio: 15/16
Revisitors: 10/15
- Revisits: 7,4
Fixations 109
Mouse clicks 72
3d design
TTFF: 0.3s
Time spent: 22.7s
Ratio: 16/16
Revisitors: 16/16
- Revisits: 19,4
Fixations 653
Mouse clicks 47
music and visualiza
TTFF: 16.1s
Time spent: 5.1s
Ratio: 13/16
Revisitors: 10/13
- Revisits: 9,3
Fixations 151
Mouse clicks 5
Stimulus: MT3_1
Exposure time: 46,1s

ST1_0



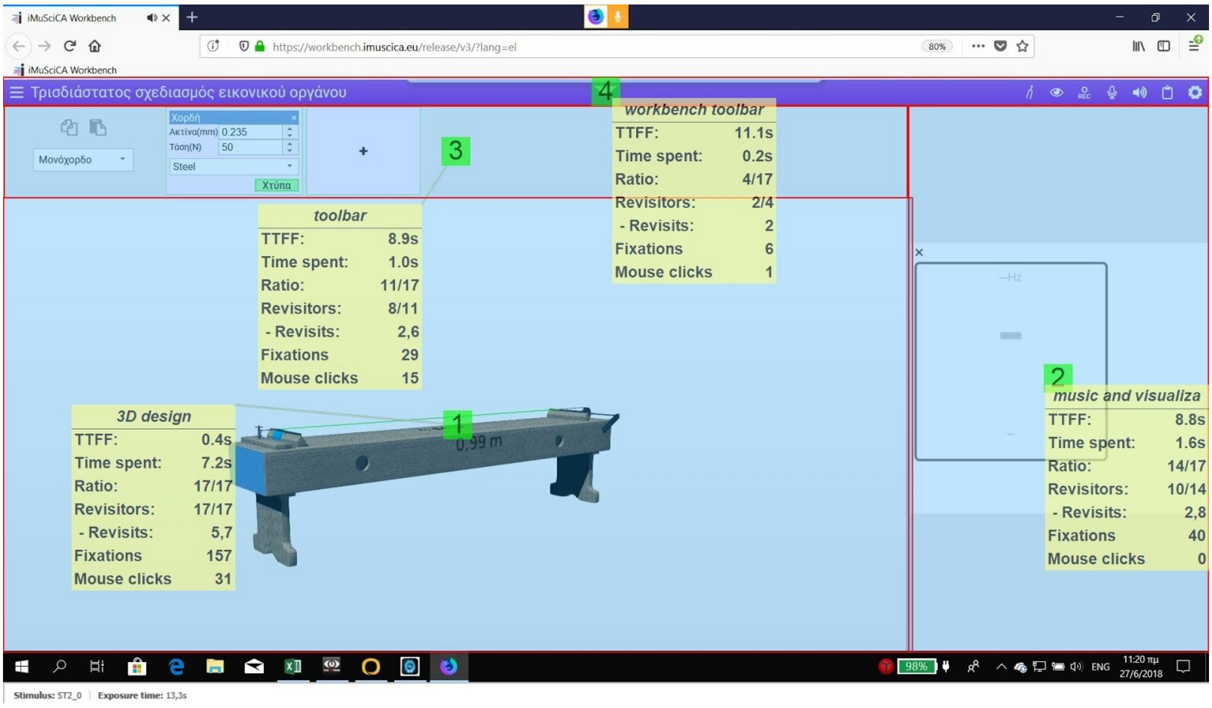
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
workbench toolbar
TTFF: 22.2s
Time spent: 3.3s
Ratio: 16/17
Revisitors: 15/16
- Revisits: 5,8
Fixations 103
Mouse clicks 36
toolbar
TTFF: 12.4s
Time spent: 9.7s
Ratio: 16/17
Revisitors: 16/16
- Revisits: 14,2
Fixations 345
Mouse clicks 96
3D design
TTFF: 0.1s
Time spent: 17.4s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 15,2
Fixations 471
Mouse clicks 97
1.00 m
music and visualiza
TTFF: 40.6s
Time spent: 10.1s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 7,5
Fixations 232
Mouse clicks 24
Stimulus: ST1_0 | Exposure time: 62,6s

ST1_1

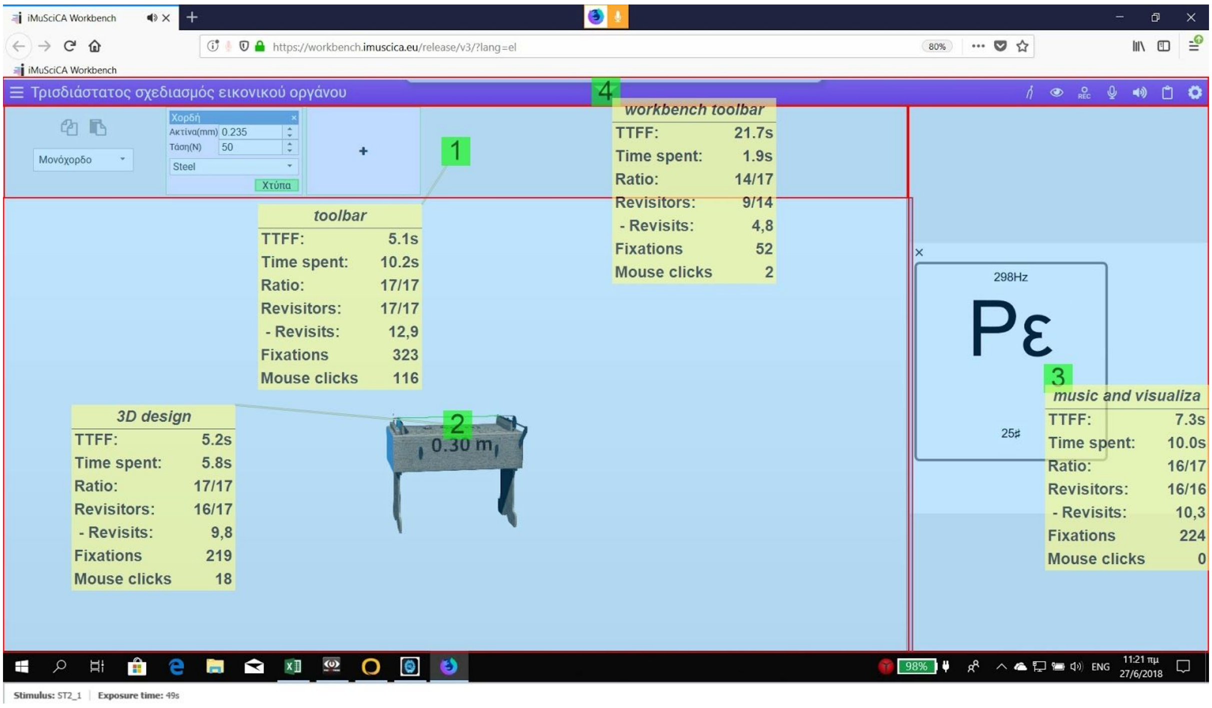


Τρισδιάστατος σχεδιασμός εικονικού οργάνου
workbench toolbar
TTFF: 42.6s
Time spent: 0.4s
Ratio: 10/17
Revisitors: 4/10
- Revisits: 3
Fixations 19
Mouse clicks 4
toolbar
TTFF: 4.7s
Time spent: 4.3s
Ratio: 17/17
Revisitors: 16/17
- Revisits: 8,1
Fixations 156
Mouse clicks 66
3D design
TTFF: 1.5s
Time spent: 32.8s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 20,5
Fixations 727
Mouse clicks 135
139Hz
Ντο#
music and visualiza
TTFF: 11.3s
Time spent: 11.2s
Ratio: 15/17
Revisitors: 15/15
- Revisits: 11,2
Fixations 212
Mouse clicks 0
Stimulus: ST1_1 | Exposure time: 64,9s

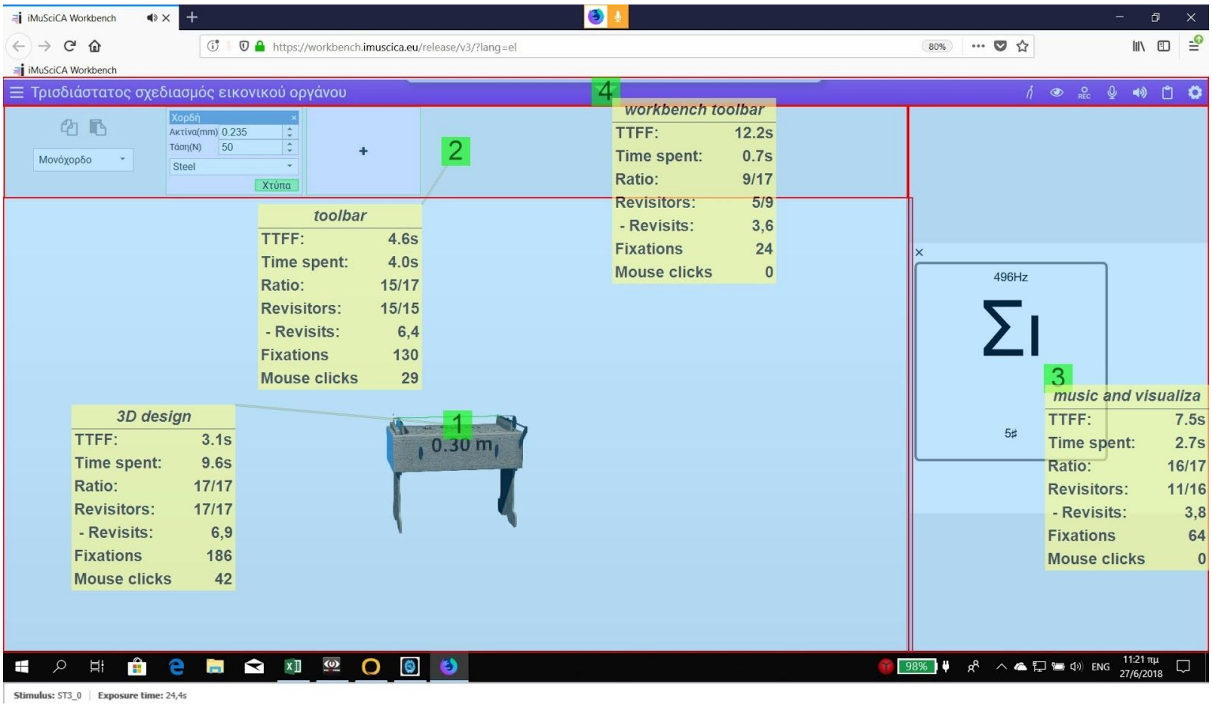
ST2_0


Τρισδιάστατος σχεδιασμός εικονικού οργάνου
workbench toolbar
TTFF: 11.1s
Time spent: 0.2s
Ratio: 4/17
Revisitors: 2/4
- Revisits: 2
Fixations 6
Mouse clicks 1
toolbar
TTFF: 8.9s
Time spent: 1.0s
Ratio: 11/17
Revisitors: 8/11
- Revisits: 2,6
Fixations 29
Mouse clicks 15
3D design
TTFF: 0.4s
Time spent: 7.2s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 5,7
Fixations 157
Mouse clicks 31
music and visualiza
TTFF: 8.8s
Time spent: 1.6s
Ratio: 14/17
Revisitors: 10/14
- Revisits: 2,8
Fixations 40
Mouse clicks 0
0.99 m
Stimulus: ST2_0 | Exposure time: 13,3s

ST2_1

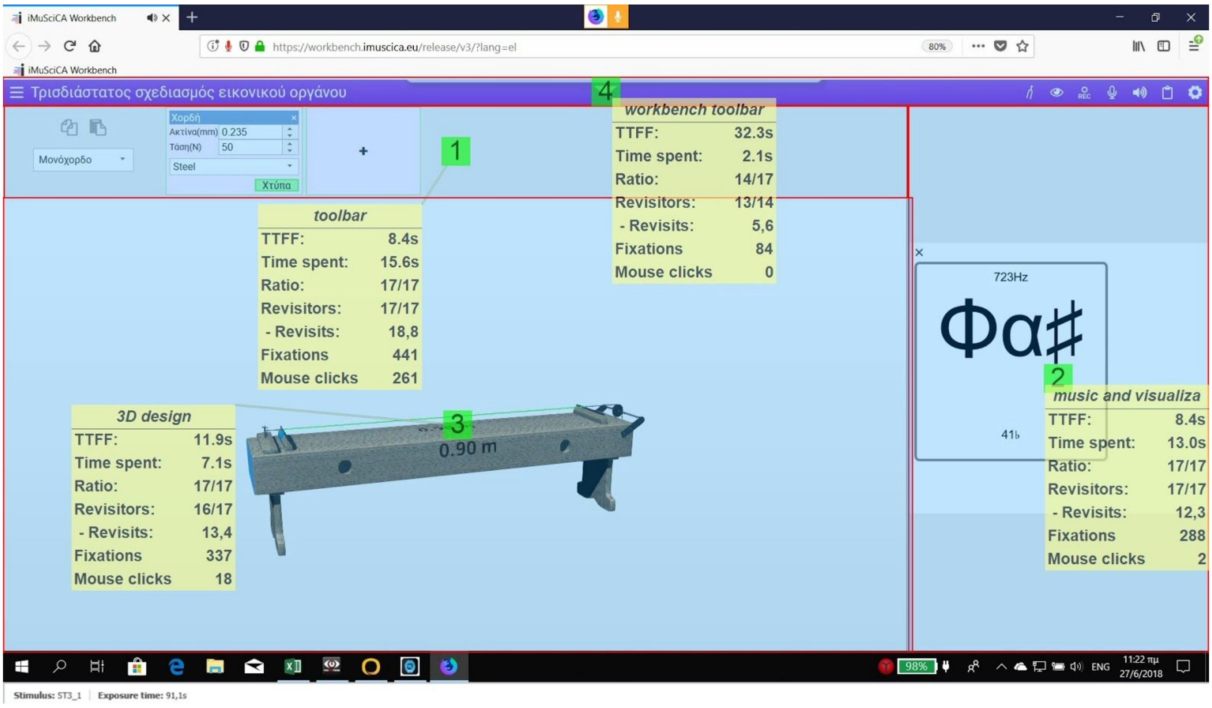

Τρισδιάστατος σχεδιασμός εικονικού οργάνου
workbench toolbar
TTFF: 21.7s
Time spent: 1.9s
Ratio: 14/17
Revisitors: 9/14
- Revisits: 4,8
Fixations 52
Mouse clicks 2
toolbar
TTFF: 5.1s
Time spent: 10.2s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 12,9
Fixations 323
Mouse clicks 116
3D design
TTFF: 5.2s
Time spent: 5.8s
Ratio: 17/17
Revisitors: 16/17
- Revisits: 9,8
Fixations 219
Mouse clicks 18
music and visualiza
TTFF: 7.3s
Time spent: 10.0s
Ratio: 16/17
Revisitors: 16/16
- Revisits: 10,3
Fixations 224
Mouse clicks 0
298Hz
Pε
0.30 m
Stimulus: ST2_1 | Exposure time: 49s

ST3_0



iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
Μονόχορδο
Χορδή
Ακτίνα(mm) 0.235
Τάση(N) 50
Steel
Χτύπα
workbench toolbar
TTFF: 12.2s
Time spent: 0.7s
Ratio: 9/17
Revisitors: 5/9
- Revisits: 3,6
Fixations 24
Mouse clicks 0
toolbar
TTFF: 4.6s
Time spent: 4.0s
Ratio: 15/17
Revisitors: 15/15
- Revisits: 6,4
Fixations 130
Mouse clicks 29
3D design
TTFF: 3.1s
Time spent: 9.6s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 6,9
Fixations 186
Mouse clicks 42
0.30 m
496Hz
Σι
5♯
music and visualiza
TTFF: 7.5s
Time spent: 2.7s
Ratio: 16/17
Revisitors: 11/16
- Revisits: 3,8
Fixations 64
Mouse clicks 0
Stimulus: ST3_0 | Exposure time: 24,4s

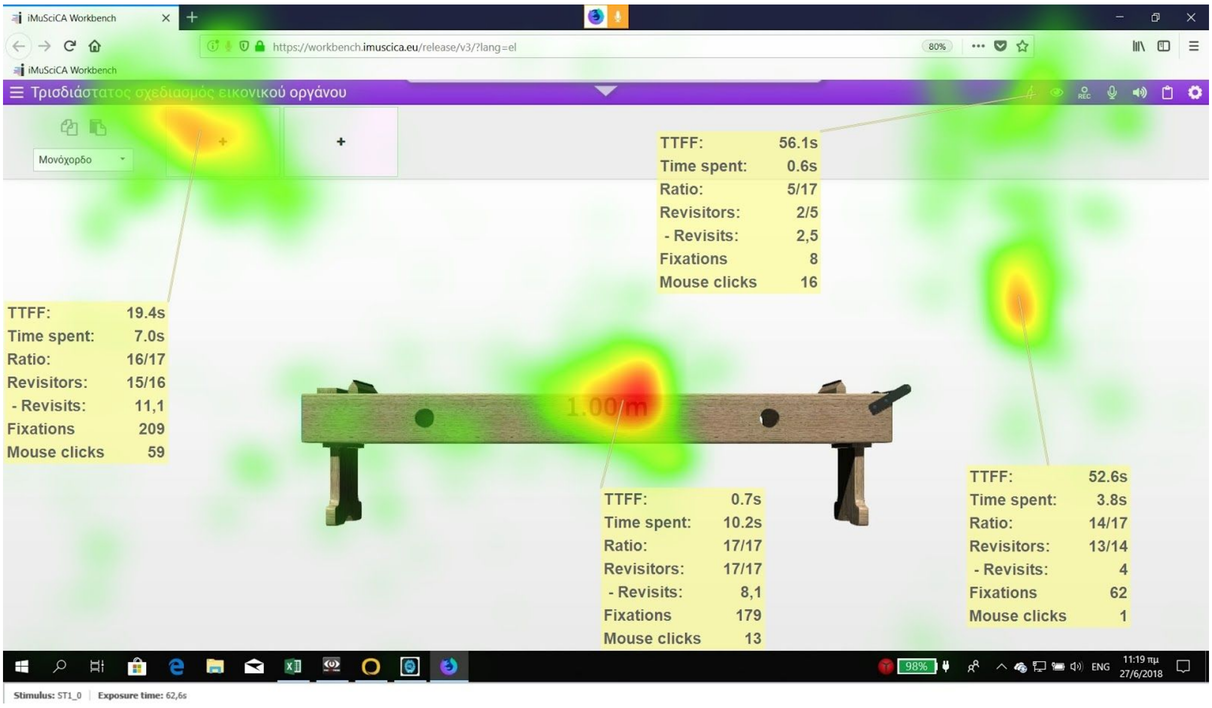
ST3_1



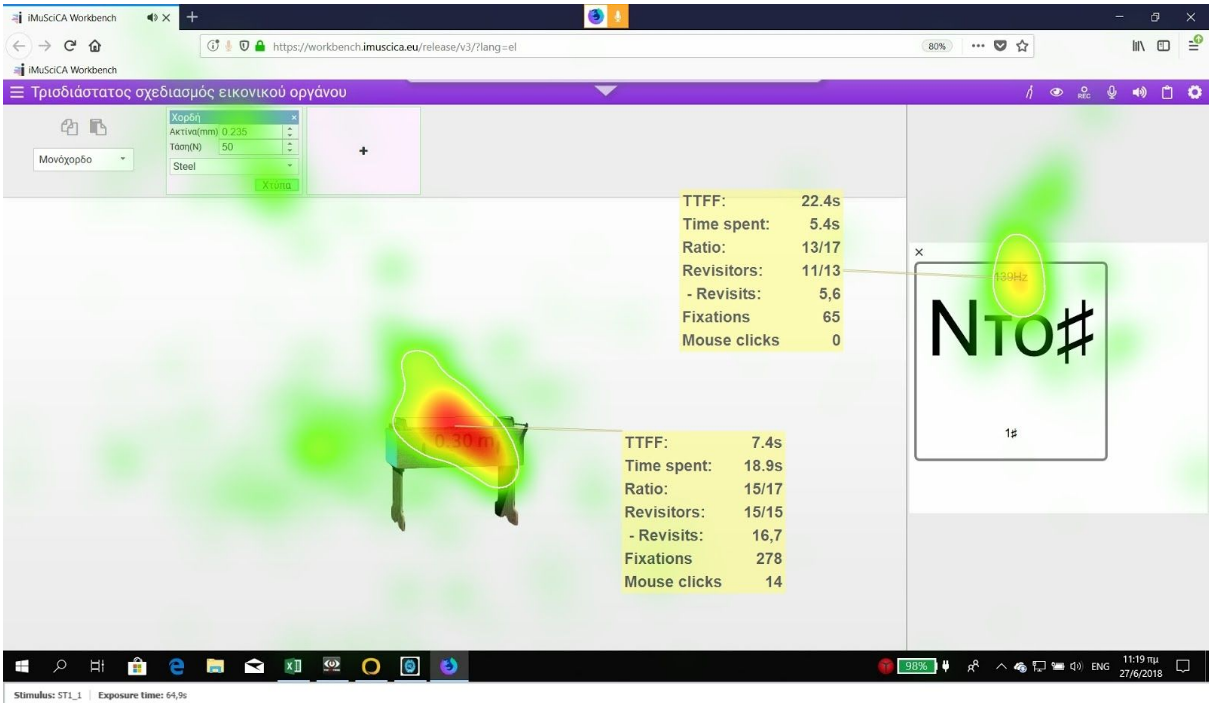
iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
Μονόχορδο
Χορδή
Ακτίνα(mm) 0.235
Τάση(N) 50
Steel
Χτύπα
workbench toolbar
TTFF: 32.3s
Time spent: 2.1s
Ratio: 14/17
Revisitors: 13/14
- Revisits: 5,6
Fixations 84
Mouse clicks 0
toolbar
TTFF: 8.4s
Time spent: 15.6s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 18,8
Fixations 441
Mouse clicks 261
3D design
TTFF: 11.9s
Time spent: 7.1s
Ratio: 17/17
Revisitors: 16/17
- Revisits: 13,4
Fixations 337
Mouse clicks 18
0.90 m
723Hz
Φα♯
41♭
music and visualiza
TTFF: 8.4s
Time spent: 13.0s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 12,3
Fixations 288
Mouse clicks 2
Stimulus: ST3_1 | Exposure time: 91,1s

Respective heat maps are presented below:

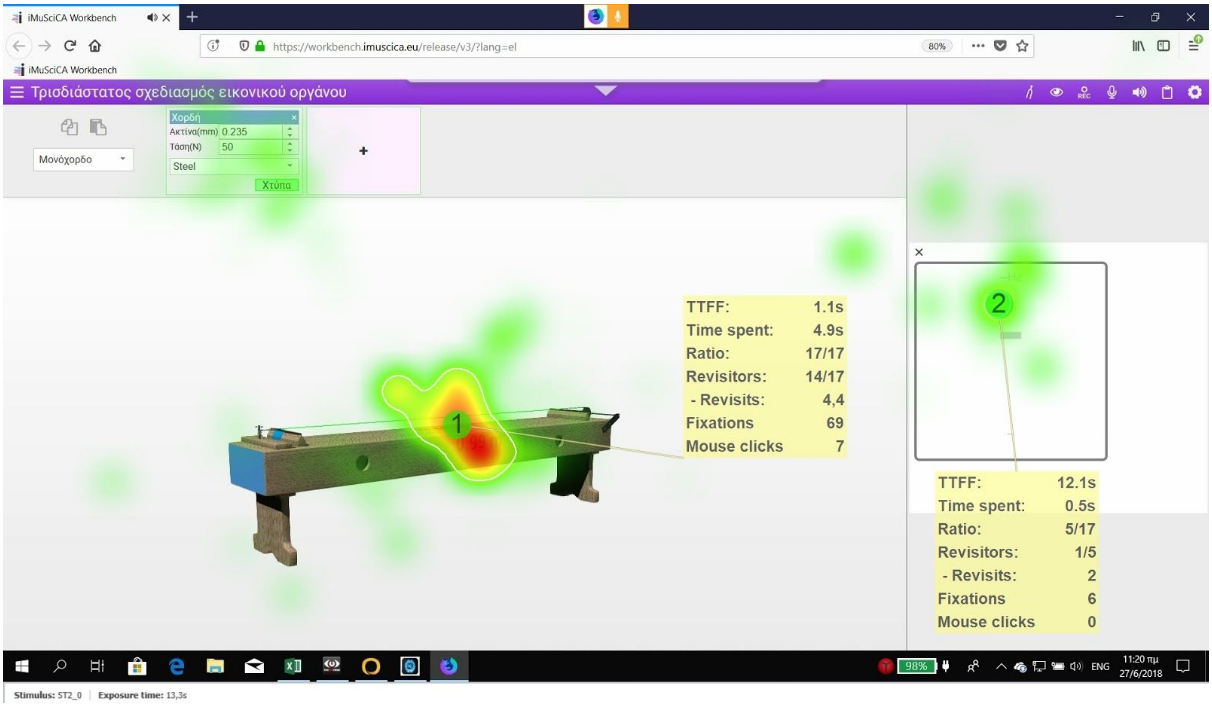
ST1_0



ST1_1

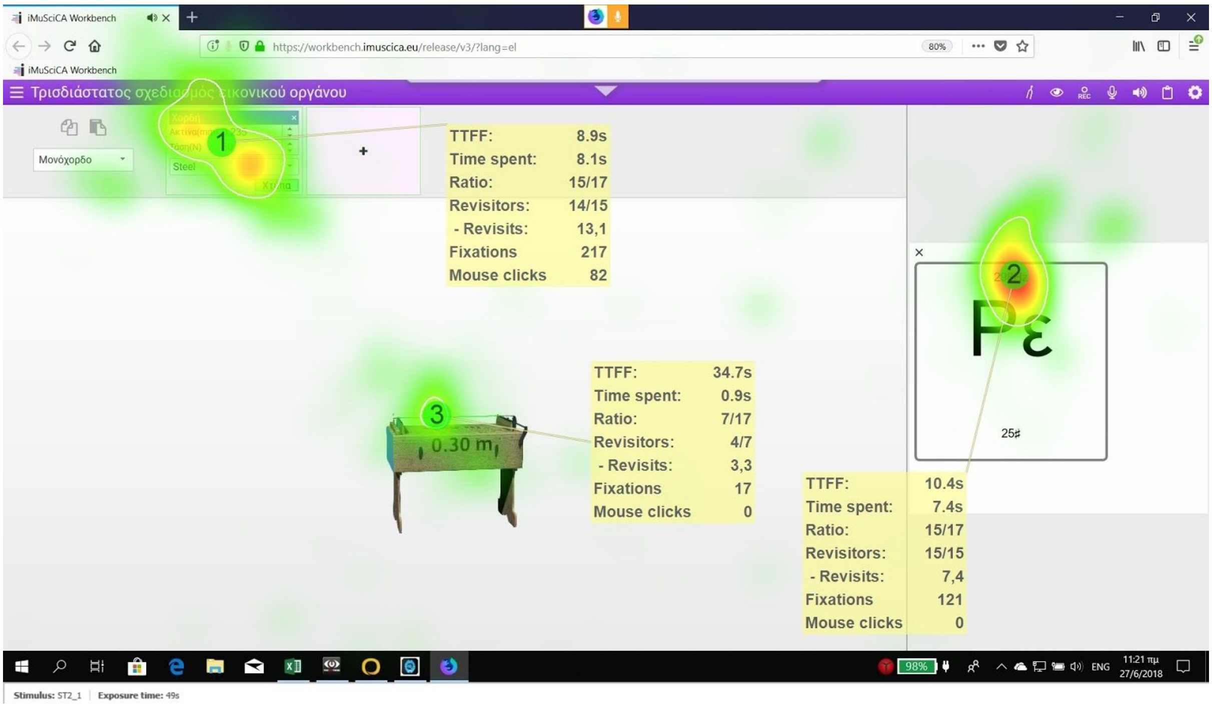


ST2_0



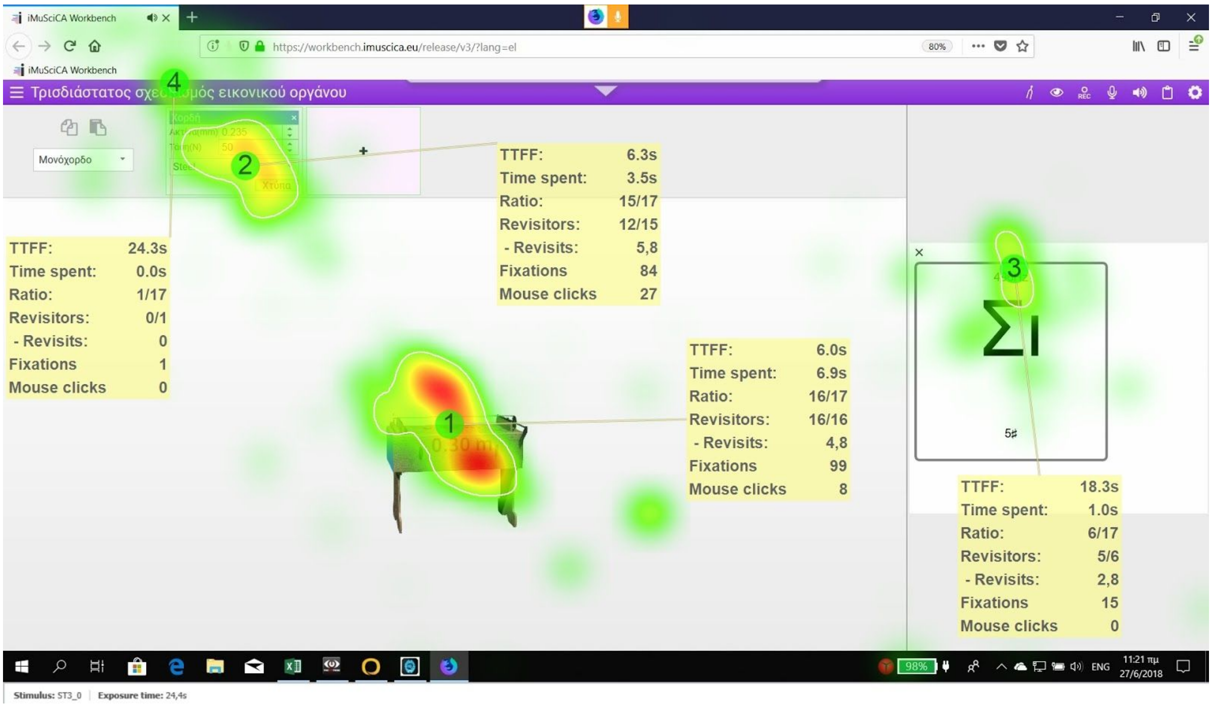
iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
Μονόχορδο
Χορδή
Ακτίνα(mm) 0.235
Τάση(N) 50
Steel
Χτύπα
TTFF: 1.1s
Time spent: 4.9s
Ratio: 17/17
Revisitors: 14/17
- Revisits: 4,4
Fixations 69
Mouse clicks 7
TTFF: 12.1s
Time spent: 0.5s
Ratio: 5/17
Revisitors: 1/5
- Revisits: 2
Fixations 6
Mouse clicks 0
Stimulus: ST2_0 | Exposure time: 13,3s

ST2_1

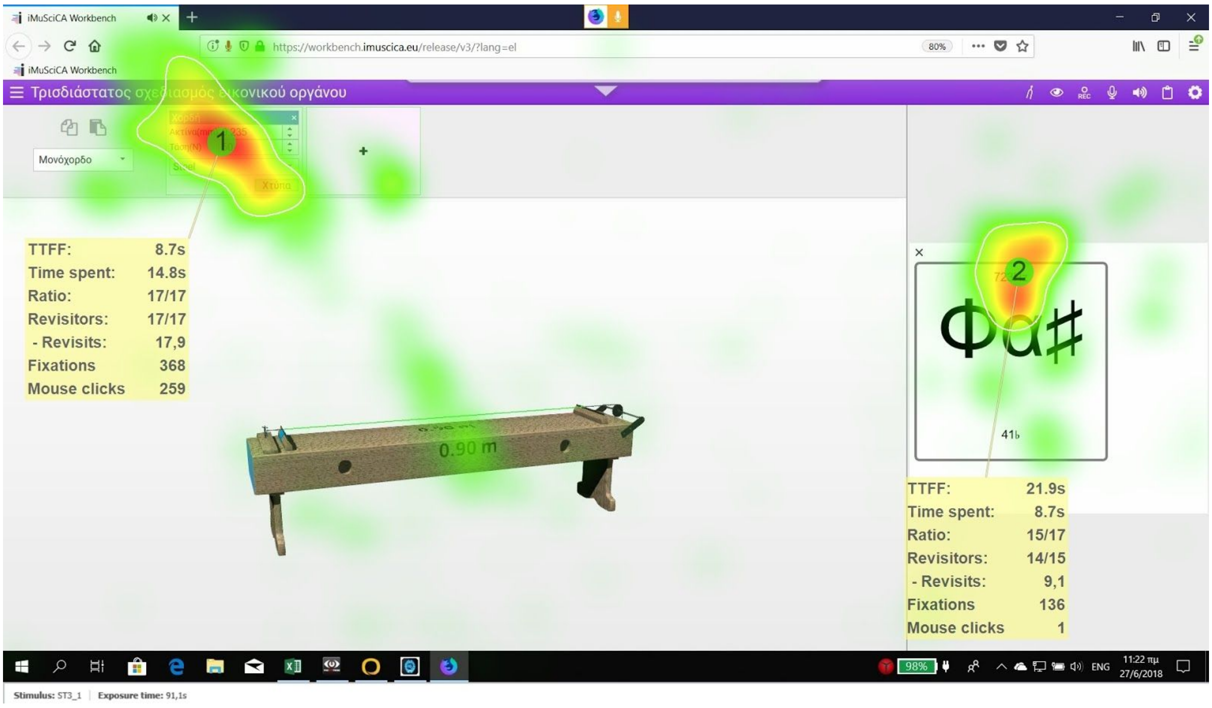


iMuSciCA Workbench
https://workbench.imuscica.eu/release/v3/?lang=el
Τρισδιάστατος σχεδιασμός εικονικού οργάνου
Μονόχορδο
TTFF: 8.9s
Time spent: 8.1s
Ratio: 15/17
Revisitors: 14/15
- Revisits: 13,1
Fixations 217
Mouse clicks 82
0.30 m
TTFF: 34.7s
Time spent: 0.9s
Ratio: 7/17
Revisitors: 4/7
- Revisits: 3,3
Fixations 17
Mouse clicks 0
25♯
TTFF: 10.4s
Time spent: 7.4s
Ratio: 15/17
Revisitors: 15/15
- Revisits: 7,4
Fixations 121
Mouse clicks 0
Stimulus: ST2_1 | Exposure time: 49s

ST3_0


Τρισδιάστατος σχεδιασμός εικονικού οργάνου
TTFF: 6.3s
Time spent: 3.5s
Ratio: 15/17
Revisitors: 12/15
- Revisits: 5,8
Fixations 84
Mouse clicks 27
TTFF: 24.3s
Time spent: 0.0s
Ratio: 1/17
Revisitors: 0/1
- Revisits: 0
Fixations 1
Mouse clicks 0
TTFF: 6.0s
Time spent: 6.9s
Ratio: 16/17
Revisitors: 16/16
- Revisits: 4,8
Fixations 99
Mouse clicks 8
TTFF: 18.3s
Time spent: 1.0s
Ratio: 6/17
Revisitors: 5/6
- Revisits: 2,8
Fixations 15
Mouse clicks 0
Stimulus: ST3_0 | Exposure time: 24,4s

ST3_1


TTFF: 8.7s
Time spent: 14.8s
Ratio: 17/17
Revisitors: 17/17
- Revisits: 17,9
Fixations 368
Mouse clicks 259
TTFF: 21.9s
Time spent: 8.7s
Ratio: 15/17
Revisitors: 14/15
- Revisits: 9,1
Fixations 136
Mouse clicks 1
Stimulus: ST3_1 | Exposure time: 91,1s

Galvanic Skin Response (GSR) summary scores

The table below presents the average number of peaks per minute detected in the GSR data for each task.

	Average of Peaks/Min		
Task Labels	**Music**	**Science**	**All**
MT1	6.72	14.88	11.82
MT2	7.26	15.44	12.37
MT3_0	5.75	10.39	8.65
MT3_1	5.78	9.87	8.33
ST1_0	6.40	17.33	13.47
ST1_1	5.16	13.12	10.31
ST2_0	5.57	7.79	7.00
ST2_1	6.94	8.96	8.25
ST3_0	3.60	8.90	7.03
ST3_1	7.25	9.12	8.46
Grand Total	**6.04**	**11.54**	**9.55**

One can observe that the group of Music students is sweating emotionally less than the group of Science students in all tasks. Tasks MT1 and MT2 are significantly more stressful to both groups in comparison to task MT3(_0 and _1). Task ST1(_0 and _1) is more stressful to the Science group in comparison to the tasks ST2(_0 and _1) and ST3(_0 and _1). On the contrary students of Music group show the same degree of stress irrespective of the science task they perform.

Electroencephalography (EEG) measures

The tables below present the measures of excitement, engagement, relaxation, interest and excitement derived from the EEG data for each task.

Music					
Task Labels	**Stress**	**Engagement**	**Relaxation**	**Interest**	**Excitement**
MT1	0.349	0.660	0.387	0.543	0.476
MT2	0.367	0.686	0.382	0.550	0.373
MT3_0	0.422	0.656	0.392	0.561	0.376

MT3_1	0.505	0.691	0.398	0.563	0.266
ST1_0	0.583	0.675	0.357	0.614	0.369
ST1_1	0.542	0.708	0.352	0.607	0.391
ST2_0	0.631	0.738	0.362	0.611	0.374
ST2_1	0.522	0.708	0.355	0.578	0.423
ST3_0	0.586	0.717	0.390	0.652	0.483
ST3_1	0.610	0.719	0.397	0.599	0.393
Grand Total	**0.527**	**0.696**	**0.374**	**0.591**	**0.388**

0

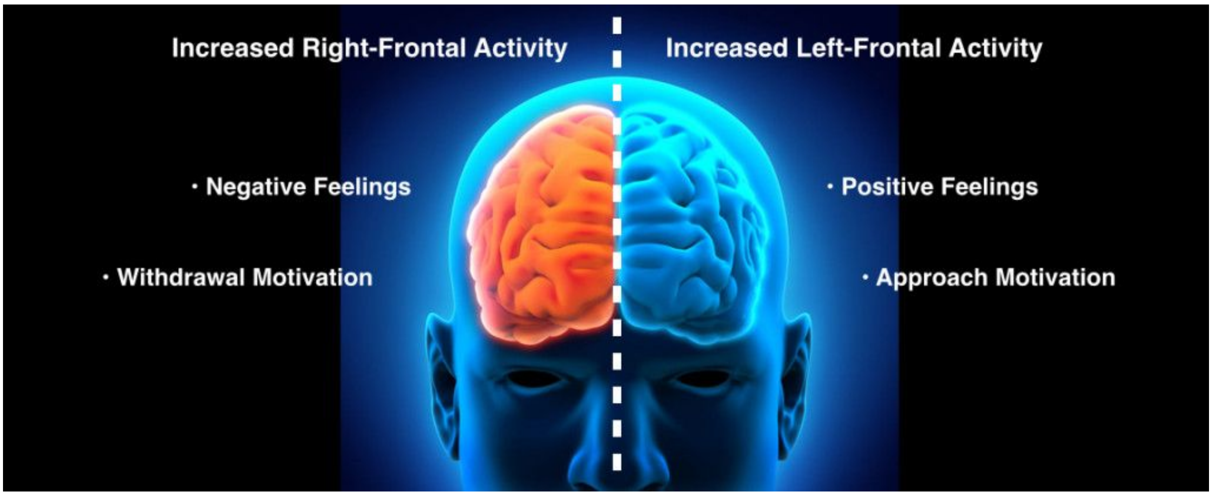
Science					
Task Labels	**Stress**	**Engagement**	**Relaxation**	**Interest**	**Excitement**
MT1	0.426	0.597	0.271	0.623	0.420
MT2	0.602	0.688	0.281	0.561	0.404
MT3_0	0.430	0.618	0.309	0.573	0.405
MT3_1	0.525	0.595	0.275	0.559	0.430
ST1_0	0.437	0.609	0.310	0.666	0.379
ST1_1	0.489	0.625	0.310	0.716	0.491
ST2_0	0.556	0.618	0.276	0.717	0.375
ST2_1	0.473	0.605	0.339	0.667	0.346
ST3_0	0.556	0.607	0.309	0.709	0.451
ST3_1	0.568	0.614	0.315	0.689	0.432
Grand Total	**0.507**	**0.615**	**0.304**	**0.647**	**0.419**

Students with music background shows more engagement during the tasks, while students with science background shows more interest.

All					
Task Labels	**Stress**	**Engagement**	**Relaxation**	**Interest**	**Excitement**
MT1	0.398	0.620	0.313	0.594	0.440
MT2	0.534	0.687	0.310	0.558	0.395
MT3_0	0.427	0.632	0.339	0.569	0.395
MT3_1	0.519	0.625	0.313	0.560	0.380

ST1_0	0.496	0.636	0.329	0.645	0.375
ST1_1	0.516	0.668	0.332	0.659	0.439
ST2_0	0.582	0.659	0.305	0.681	0.375
ST2_1	0.499	0.659	0.347	0.620	0.387
ST3_0	0.570	0.658	0.346	0.683	0.466
ST3_1	0.580	0.644	0.338	0.663	0.421
Grand Total	**0.515**	**0.646**	**0.331**	**0.625**	**0.407**

The special effect of the asymmetry in frontal alpha power was initially detected in studies investigating biomarkers of personality (Hagemann, Naumann, Thayer, & Bartussek, 2002). People with increased left-frontal alpha were found to process information in a rather positive way, whereas right-lateralization indicated a more negative processing mode. While this "emotional" effect was found to be indicative of a personality trait (supposed to be very stable across the life span), recent evidence suggests that it also varies dependent on emotional stimulation, reflecting whether or not someone is drawn towards or away from something or someone. In short, this "approach-avoidance effect" reflects someone's motivation (Harmon-Jones et al., 2010). Relatively increased left-frontal activity may serve as an index of approach motivation or related emotion (e.g., anger and joy). In contrast, relatively increased right-frontal activity may serve as an index of withdrawal motivation or related emotion (e.g., disgust, fear, and sadness).



The frontal asymmetry index is calculated as the natural logarithm of the ratio of the alpha power on the right (F4) over the alpha power on the left. The table below presents the frontal asymmetry index calculated for each task.

Frontal Asymmetry Index			
Task Labels	**Science**	**Music**	**All**

MT1	5.51	0.52	5.07
MT2	1.87	0.19	1.62
MT3_0	1.59	0.18	1.11
MT3_1	3.27	-0.17	2.77
ST1_0	1.63	-0.89	1.61
ST1_1	3.82	-0.49	3.75
ST2_0	3.80	0.57	3.45
ST2_1	1.78	-0.11	1.61
ST3_0	15.08	6.47	14.74
ST3_1	4.11	-0.66	3.96

One can observe that the group of Science students have a positive attitude and motivation for all tasks, whereas for the group of Music students the respective index is much lower for all tasks with the tasks MT3, ST1, ST2 and ST3 demonstrating a rather negative attitude and withdrawal in motivation.

Frontal Asymmetry Index						
Task Labels	**Female MS**	**Male MS**	**Female M**	**Male M**	**Female S**	**Male S**
MT1	1.07	**8.18**	**1.35**	0.63	1.01	**10.60**
MT2	1.62	**4.26**	**1.31**	0.18	1.68	**6.51**
MT3_0	1.03	**2.58**	**1.22**	0.19	1.02	**8.73**
MT3_1	0.01	**5.75**	**0.71**	0.62	-0.06	**8.16**
ST1_0	0.43	**6.67**	-0.64	1.29	0.49	**6.78**
ST1_1	0.62	**4.84**	-0.79	0.96	1.16	**4.87**
ST2_0	0.75	**6.91**	-0.94	2.09	0.87	**8.40**
ST2_1	0.55	**5.49**	-0.75	1.17	0.62	**7.32**
ST3_0	8.44	**16.42**	5.12	6.91	8.46	**17.22**
ST3_1	0.39	**8.44**	-0.05	1.29	0.39	**9.01**

One can observe that the Female Music students have a positive attitude and motivation for the music-oriented tasks while they show a rather negative attitude and withdrawal in motivation for the science oriented tasks.