EDEN
OPEN CLASSROOM 2019

Creating Conditions for Deeper Learning in Science

International Conference

29th-30th of June 2019

PROCEEDINGS

EUROPEAN DISTANCE AND E-LEARNING NETWORK

ELLINOGERMANIKI AGOGI

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Creating Conditions for Deeper Learning in Science

Conference Proceedings

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Preface

The present volume contains papers that were presented in the EDEN Open Classroom 2019 International Conference “Creating Conditions for Deeper Learning in Science” which took place in the facilities of Ellinogermaniki Agogi on 29th & 30th of June 2019. The aim of the Conference was to bring together researchers, decision makers and educators from all around the world to investigate the concepts of Deeper Learning, the conditions under which it could lead students to develop mastery in scientific subjects and the methods how these achievements can be assessed. Furthermore the conference aimed also to show that an "open" school can be an ideal environment for shaping the conditions required for students to achieve Deeper Knowledge in Science combined with Art.

Deeper Learning is usually associated with the concept that the learners have to achieve excellence at school through an equitable educational system. According to the National Research Council Committee (NRC, 2012) Deeper Learning can be defined as: “the process through which a person becomes capable of taking what was learned in one situation and applying it to new situations – in other words, learning for transfer … by developing cognitive, interpersonal and intrapersonal competencies.”

But Deeper Learning comprises more than this. In this process, learners acquire proficiency in a subject beyond just memorizing facts and concepts, techniques or procedures. Learners understand the key principles and realize when, how they can apply what they have learned in new real situations. Consequently, deeper learning refers to the combination of a deeper understanding of core academic content, the ability to apply that understanding to novel problems and situations, and the development of a range of competencies, including people skills and self-management (AIR, 2014). So, the concept of Deeper Learning has been used both to describe a set of competencies or educational objectives and to characterize a way of learning (or a process) that promotes these competencies. These competencies (following below) were first introduced by the William and Flora Hewlett Foundation and are essential to prepare students to achieve at high levels.

- Master core academic content. Students develop and draw from a baseline understanding of knowledge in an academic discipline and are able to transfer knowledge to other situations.
- Think critically and solve complex problems. Students apply tools and techniques gleaned from core subjects to formulate and solve problems. These tools include data analysis, statistical reasoning and scientific inquiry as well as creative problem solving, nonlinear thinking and persistence.

- Work collaboratively. Students cooperate to identify and create solutions to academic, social, vocational and personal challenges.
- Communicate effectively. Students clearly organize their data, findings and thoughts in both written and oral communication.
- Learn how to learn. Students monitor and direct their own learning.
- Develop academic mindset. Students develop positive attitudes and beliefs about themselves as learners that increase their academic perseverance and prompt them to engage in productive academic behaviors. Students are committed to seeing work through to completion, meeting their goals and doing quality work allowing them to search for solutions and overcome obstacles.

In this framework, more than 100 participants including academics, science educators, school teachers, and university students during the conference had the opportunity to engage in a productive and fruitful dialogue.

The EDEN Open Classroom 2019 International Conference was framed by the following five main themes:
- Deeper Learning in Science through Arts
- Enhancing Science Education through Digital Story Telling
- Inquiry based Learning
- Creativity in Science Education

During the conference, 6 distinguished keynote speakers presented their field of expertise in regard with the theme of conference, covering various aspects of achieving Deeper Knowledge and the tools that can support and validate it. 13 papers presented to the audience in which researchers presented actions designed to achieve deeper knowledge in the classroom and teachers shared their experiences, as well as their pupils', from the implementation of relevant activities in their ranks. Four workshops focused on iMuSciCA, STORIES OF TOMMOROW, eCraft2Learn and weDRAW EU projects were designed for the participants.

Last but not least, must be mentioned that on Friday 28th of June, Ellinogermaniki Agogi hosted a major pre conference event regarding the enhancement of STEAM activities in Greek schools, which was organized by GFOSS Open Technologies Alliance (https://gfoss.eu/) a non-profit organization consisted of 35 Universities and Research Centers, in collaboration with European Schoolnet. The event attended by more than 50 teachers and comprised by keynote speeches, presentations and training workshops (https://scientix.ellak.gr/conference/).

1. References

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Creating Conditions for Deeper Learning: Projects Presentations

1. Introduction to Deeper Learning
1.1 What is Deeper Learning?

Deeper Learning is usually associated with the concept that the learners have to achieve excellence at school through an equitable educational system. According to the National Research Council Committee (NRC, 2012) Deeper Learning can be defined as:

> "the process through which a person becomes capable of taking what was learned in one situation and applying it to new situations – in other words, learning for transfer … by developing cognitive, interpersonal and intrapersonal competencies."

In this process learners acquire proficiency in a subject beyond just memorising facts and concepts, techniques or procedures. Learners understand the key principles and realise when, how they can apply what they have learned in new real situations. Thus, asks for more than mastering academic knowledge and grasping relevant skills. In their recent research study, the American Institutes for Research (AIR, 2015) defines Deeper Learning as:

> "Deeper Learning refers to the combination of a deeper understanding of core academic content, the ability to apply that understanding to novel problems and situations, and the development of a range of competencies, including people skills and self-management."

The concept of Deeper Learning has been used both to describe a set of competencies or educational objectives and to characterize a way of learning (or a process) that promotes these competencies. The William and Flora Hewlett Foundation has defined Deeper Learning as (William and Flora Hewlett Foundation, 2013):

"a set of competencies learners must master in order to develop a keen understanding of academic content and apply their knowledge to problems in the classroom and on the job."

According to this definition, Deeper Learning is the outcome of the development of six interconnected competencies that are prerequisites for success not only in school, but also at university, career and civic life (William and Flora Hewlett Foundation, 2013; Chow, 2010; Trilling, 2010):

- Mastery of core academic content
- Critical thinking and complex problem-solving skills
- Collaboration skills
- Effective communication skills
- An understanding on how to learn
- Development of academic mindsets

As a process, Deeper Learning is in alignment with the Partnership 21st Century Skills Framework, namely the 4C's (P21, 2010):

- Critical thinking and problem solving;
- Creative thinking and innovation;
- Collaboration;
- Communication.

The more skilled the learners become in learning how to apply these skills the more able they become in understanding deeper the academic content. As an outcome Deeper Learning results from the self-directed transfer of the 4C's to the student's understanding of a concept's meaning (Bellanka, 2015). Despite these different views all disciplinary standards documents that have been introduced since 2010 (Achieve, 2013; NGA & CCSSO, 2010; NGA & CCSSO, 2010) have a common reference point: Deeper Learning and the development of the 21st century skills do not happen separately from the understanding of knowledge in an academic discipline (i.e. mastery of academic content).

As we prepare learners for success in school today, we are aware they will face a vastly different future. Our world changes rapidly and in a way that is different than what we have experienced in the past. Thus, the education system must be modified to serve the new generation of learners and prepare them for success in the 21st century.

Recent reports show that a very small percent of future jobs will be available to high school graduates and dropouts and those jobs will be limited to mainly three low paying job classifications (i.e. sales and office support; blue-collar jobs; food and personal services). Moreover, the need of continuing education beyond the secondary level is highlighted in a report by the U.S. Center on Education and the Workforce Report (Carnevale et al., 2010). Moreover, postsecondary education and training is not – as it used to be - the preferable path to employment but "*it is increasingly the only pathway*".

Despite the fact that Deeper Learning is referenced as an approach to help all learners tomaster academic content and have access to higher education, it is found (ACT, 2006) that it also prepares high-school graduates to perform well in workforce training programs associated with "*jobs that are likely to offer both a wage sufficient to support a small family and the potential for career advancement*".

Deeper Learning supports the delivery of rich core content to learners in innovative ways that allow them to learn and then apply what they have learned. Rigorous core content is the heart of the learning process; true Deeper Learning is developing competencies that enable graduating high school learners to be college and career ready and then make maximum use of their knowledge in life and work. Evidence also confirms that Deeper Learning environments positively influence not only student academic outcomes and but also social-emotional factors of students (AIR, 2014).

1.2 Evidence of Deeper Learning Outcomes

As it was discussed before Deeper Learning is a process where learners acquire proficiency in a subject beyond just memorising facts and concepts, techniques or procedures. Sutherland et al., 2010) state: *"It is not enough for learners only to understand big ideas; in fact, they cannot develop integrated understandings of even these core ideas unless they use their knowledge in meaningful ways, applying what they know to a variety of contexts and to novel situations"*. Furthermore, researchers in the field argue that exposure to Deeper Learning teaching prepares learners to be successful thinkers, and citizens in their adult lives (Finegold & Notabartolo, 2010). They also argue that supporting learners to acquire both academic content knowledge and skills required to critically apply this knowledge facilitates the development of *"competencies that enable graduating high school learners to be college and career ready and then make maximum use of their knowledge in life and work"* (Alliance for Excellent Education, 2010).

Emerging research suggests that exposure to Deeper Learning teaching correlates with increased academic achievement, leading to a more flexible and competent relationship with knowledge. Researchers at the Educational Policy Improvement Center (Collins et al., 2013) examined the impacts of a curriculum intended to promote Deeper Learning - the Road trip Nation Experience (RTN) - and found increases in the Grade Point Average (GPA) of RTN learners compared to their peers. However, all of these studies note limitations or lack methodological documentation.

Although early evaluation studies of schools participating in networks focused on Deeper Learning suggested positive effects, the studies had several limitations relating to their research designs, samples, data, measures and/or analyses (Yuan & Le, 2010). More recent evaluations (Collins et al., 2013; Guha et al., 2014; Nichols-Barrer & Haimson, 2013) have also suggested positive program effects on indicators such as Grade Point Average (GPA), progress to graduation and state test results, but these studies are primarily descriptive in nature or have focused on demonstrating the effectiveness of specific instructional programs or approaches aligned with the goals of Deeper Learning.

Indeed, a recent NRC panel noted the limitations of existing research in creating links between Deeper Learning competencies and long-term student educational outcomes and recommended that foundations and federal agencies should support further research in this arena (NRC, 2012). As a result of this limited empirical base, there has recently been increased interest in research that evaluates whether school approaches explicitly focused on developing Deeper Learning competencies are associated with improved educational opportunities for all learners.

The recent report Study of Deeper Learning: Opportunities and Outcomes (AIR, 2014) aimed to determine whether learners attending high schools with a mature approach to promoting Deeper Learning actually experienced greater Deeper Learning opportunities and outcomes than they would have had not having attended these schools.

For analysis and interpretation, the researchers grouped these competencies into three overlapping domains, as defined by the National Research Council (2012): the *cognitive domain*, including mastery of academic content knowledge and complex problem-solving; *the interpersonal domain*, including collaboration and communication skills; and the *intrapersonal domain*, including an understanding of how to learn and academic mindsets such as motivation to learn, academic engagement, and self-efficacy (Farrington et al., 2012; Soland, Hamilton, & Stecher, 2013; NRC, 2012).

Researchers in the field of Deeper Learning argue that approaches focused on developing such competencies can improve outcomes for all learners, including those from traditionally underserved groups and those who have not previously experienced educational success.

The abbreviated theory of action for the Deeper Learning initiative (Figure 1) delineates the key hypothesized relationships between school approaches to promoting Deeper Learning, opportunities to engage in Deeper Learning and outcomes. In the Figure, the research team provides additional detail related to the learners' outcomes. In the report the research team has focused on key questions about student outcomes: Did learners who attended participating network high schools perform better on tests of cognitive competency, report higher levels of interpersonal and intrapersonal competencies, or attain higher rates of high school graduation and college enrolment than they would have had they not attended the network schools?

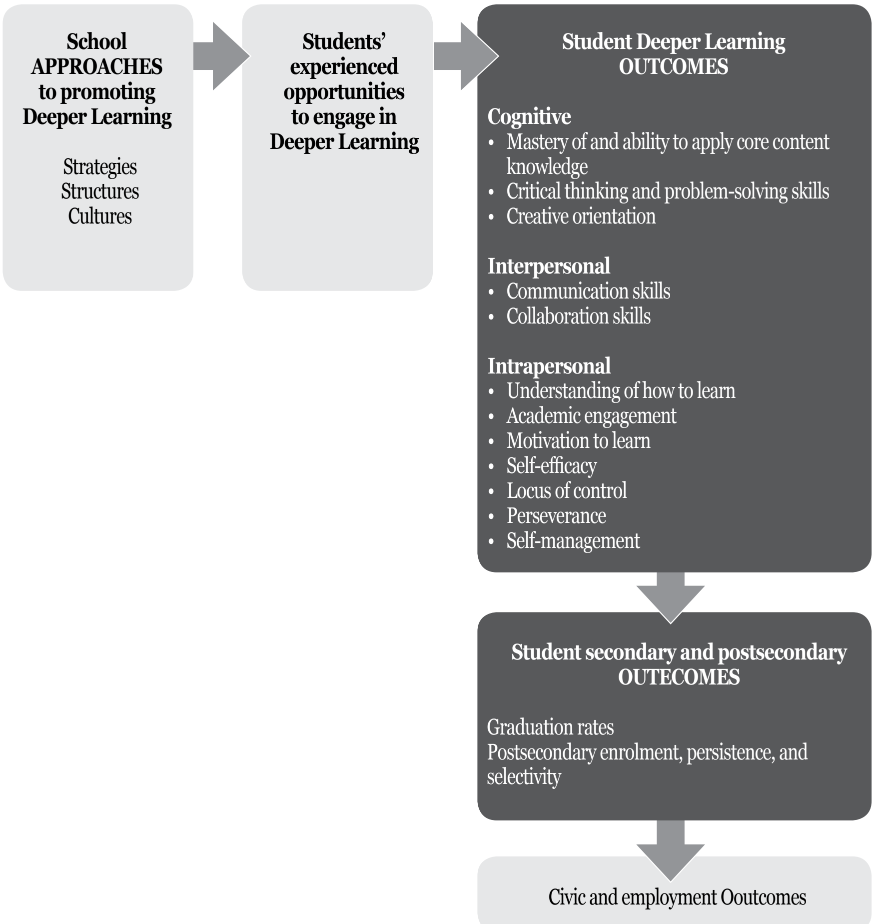

Figure 1: Process for assessing the Impact of Deeper Learning Approaches implemented in a Network of US schools. Many of the intrapersonal Outcomes shown in the Diagram align with the six Deeper Learning Competences (AIR, 2014)

The analyses focused on learners from between 10 and 13 pairs of matched Deeper Learning network and comparison schools. After statistically accounting for differences in student background characteristics, the research team found that learners who attended participating network high schools that explicitly focused on Deeper Learning experienced superior outcomes compared to learners who attended non-network comparison high schools.

Key takeaways include the following:

1. On average, students who attended the network schools in the study **achieved higher scores on the OECD PISA-Based Test for Schools** (PBTS)—a test that assesses **core content knowledge and complex problem-solving skills**—than did similar students who attended non-network high schools. Students who attended network schools scored higher on all three PBTS subjects tested (reading. mathematics. and science). They also earned higher scores on the state English Language Arts (ELA) and mathematics tests.
2. Students who attended participating network schools **reported more positive interpersonal and intrapersonal outcomes** than students who attended non-network schools. In particular, they reported **higher levels of collaboration skills, academic engagement, motivation to learn, and self-efficacy**. There were **no significant differences** between students who attended neti.vorfc and non-network schools **on reported creative thinking skills, perseverance, locus of control, or self-management**.
3. Students who attended participating network schools were **more likely to graduate from high school on time** (within four years of entering Grade 9) than were students who attended non-network high schools. The graduation rate among students who attended network schools was estimated to be about 9 percentage points higher than among similar students who attended non-network schools.
4. Students who attended participating network schools and non-network schools had **similar rates of enrollment in postsecondary institutions overall**. However, students who attended network schools were more likely to enroll in four-year institutions and in selective institutions.
5. Although there were significant positive effects of attending a network school averaging across the pairs of network and non-network schools in our sample, for many outcomes—for example, PBTS mathematics scores—the effects of attending a network school varied significantly across individual pairs of schools.
6. Attending a network school had similar benefits for students who entered high school with low achievement and those who entered with high achievement, particularly for the test score and high school graduation outcomes. However. while attending a network school increased the postsecondary enrollment rate of students who entered high school with low’ achievement, it had no effect on the postsecondary enrollment rate of students who entered with high achievement.

2. Project Paradigms of Deeper Learning
2.1 weDRAW Deeper Learning Paradigm
www.wedraw.eu

The mission of weDRAW is to create and evaluate a new methodology for teaching and a novel technology for Deeper Learning of arithmetic and geometry at elementary schools. The main novelty of such a new technology comes from the strong scientific bases it is grounded on i.e. the renewed understanding of the role of communication between sensory modalities during development, that is that specific sensory systems have specific roles for learning specific concepts. weDRAW proposes to open a new teaching/learning channel, based on multisensory interactive technology (i.e. audio, tactile, motor and visual), including a hardware and software platform to support this approach and three Serious Games. The main idea is to develop a technology that associates music with arithmetic and drawing with geometry in new ways.

Figure 2: weDRAW – Give me your Hand

Arithmetic and geometry are at the foundation of Science, Technology, Engineering, and Mathematics (STEM). They are universally included in primary school programs, commonly using a teaching approach that is primarily based on the visual modality. However, research studies showed that crucial arithmetical and geometrical concepts (e.g. counting, measuring distances etc) are heavily grounded on other modalities such as audition and touch. Furthermore, arithmetic and geometry are naturally linked to artistic expression. The relationships of crucial components of music such as pitch and melody, rhythm and fractions have been recognized since ancient times. Application of geometry in drawing and painting is widespread in all ages (since the Renaissance studies on perspective to contemporary art e.g. cubism). Arithmetic and geometry represent therefore an ideal test-bed to assess the effectiveness of a novel technology-enhanced learning paradigm for Deeper Learning of STEM grounded, both on Arts and on a body of scientific evidence that enables us to identify how each of the sensory modalities differently supports each mathematical concept.

2.1.1 Definition of Deeper Learning

Deeper Learning within the weDRAW project is considered as the acquisition of robust core geometrical and arithmetic aspects through the use of multiple sensory signals and sensory domains by using music and drawing as mediators of the process. Not only visual but also audio, tactile and motor signals are proposed as a way to differently support learning of new mathematical concepts given this spatial and temporal domain. As seen above, the approach of weDRAW innovatively starts from a renewed neuroscientific understanding of the role of communication between sensory modalities during development. Recent results from psychophysics and developmental psychology (Gori et al., 2008, Gori et al., 2010, Gori et al., 2014, Gori et al., 2012, Barrett and Newell, 2015) show that children have a preferential sensory channel to learn specific concepts (spatial and/or temporal) and that the visual signal is not always the more powerful and effective channel. In the weDRAW project, we applied this scientific evidence in teaching and learning practices, by introducing novel pedagogical methodologies grounded in it. weDRAW advocates an embodied and enactive pedagogical approach, using different sensory-motor feedback (i.e. audio, haptic and visual) to teach new concepts to primary school children.

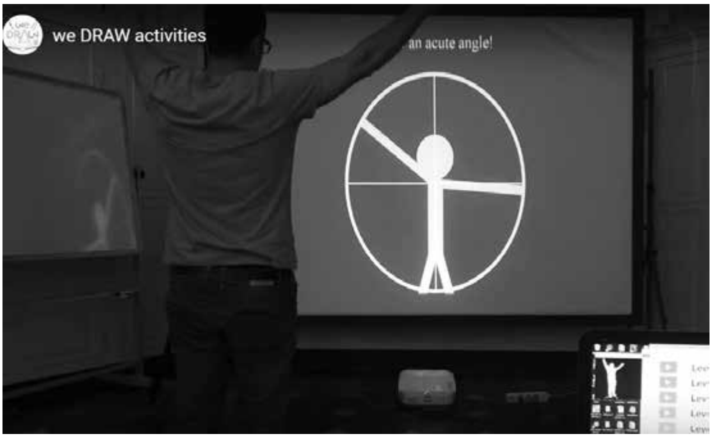

Figure 3: weDRAW – Angels ... with your Arms

For example, we used the audio pitch to support understanding of angles or force feedback to understand 2D-3D transformations. Such an approach is a direct approach i.e. natural and intuitive since it is based on sensorimotor experience: on the perceptual responses to motor acts. Moreover, the use of body movement for learning can be used to deepen and strengthen the learning, retention and engagement. For example, our results show that body movement associated with sounds enhances the conceptualization of some geometrical concepts and we are now studying if it is possible to enhance angle and Cartesian understanding through the association of body movement.

2.1.2 Conditions for the Development of Deeper Learning

In the weDRAW project, we have developed three Serious Games and a series of activities to enhance the understanding of 2D-3D transformations, 3D rotations, fractions, isometric transformations, Cartesian plane, angles, and symmetry. All these concepts were highlighted as complex by teachers using traditional pedagogical approaches, through an investigation involving over 100 teachers in Italy and the UK. With the contribution of pedagogical and neuroscientific experts, weDRAW has undertaken several studies involving interactive activities with children at elementary schools in Italy, Ireland, and the UK. During the sessions, the children explored mathematical ideas using the games and provided their feedback. More than 100 children tried Serious Games and activities within the project. From the results of these activities, we have informed the design and development of the games undertaken by expert engineers, and a multisensory embodied and enactive pedagogical framework that exploits audio, tactile and motor feedback based on music and drawing to facilitate the understanding of arithmetic and geometrical aspects.

2.1.3 Assessment of Deeper Learning

The new technology developed within the weDRAW project includes: i) a library of software modules for novel techniques for analysis of expressive and affective motoric behaviour and for analysis of social interaction; ii) a hardware and software platform; and iii) three Serious Games, developed in such a way that the teacher is involved in the learning process, through customization of the content of the games.

The validation of the new approach has been obtained by using psychophysical and pedagogical approach:

- Psychophysical experiments have been performed to gain a deeper understanding of the multisensory capabilities of typically developed and visually impaired children at different stages of their development.
- edagogical studies have been performed to define a multisensory embodied and enactive pedagogical framework for teaching and learning arithmetic and geometric concepts with primary school children, exploiting art – namely music and drawing – as a mediator of the learning experience in typical and visually impaired children.
- Psychophysical and pedagogical studies have been performed to evaluate

and quantify the effectiveness of the learning process with respect to both the embodied interactive pedagogical and psychophysical paradigm and the technology developed to implement it, and for both typically developed and visually impaired children.

- Quantification of activity and improvement has been also obtained with the use of software modules for multimodal (i.e. audio, tactile, motor, and visual) analysis of the nonverbal behavior of both individuals and small groups of children and for real-time control of sound, music, and visual content.

2.2 eCraft2Learn Deeper Learning Paradigm

https://project.ecraft2learn.eu

2.2.1 Definition of Deeper Learning

Within the eCraft2Learn framework, Deeper Learning could be seen as part of fostering the development of 21st century skills such as problem solving, collaboration and interpersonal communication. The project aims at preparing students for the future requirements of a digital society, at school and at work, help them realise their potential and strengthen their abilities to be in charge of their own learning.

2.2.2 Conditions for the Development of Deeper Learning

To achieve these aims, the eCraft2Learn learning ecosystem consists of a pedagogical core underlying a technical core. The pedagogical core is based on a craft- and project-based methodological approach in order to substantiate the integration of technology for educational purposes. This craft- and project-based approach contains 5 stages (see Figure 4), each of which is supported by specifically designed, developed and integrated into a Unified User Interface (UUI) digital platform (see Figure 5).

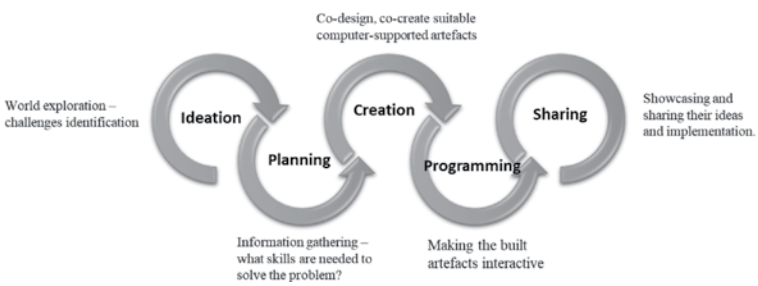

Figure 4: eCraft2Learn Pedagogical Core – 5 Stages of Craft- and Project-based Methodology

Deeper Learning within the eCraft2Learn ecosystem is tied to the idea of personalised learning. Personalised learning means that the learning process is driven by the learners' interests, needs and learning pace. In personalised learning, learners' previous knowledge, competence, life and work skills, both in formal and informal settings should be considered. Hence, learners do have the opportunity to learn in ways that are preferable for themselves and also set their learning objectives for their own learning. In this sense, in personalised learning the teacher acts as a coach orchestrating the learning experience rather than an instructor. This means that learner's self-regulation is a fundamental skill and not only the cognitive dimension, but all dimensions of the learner should be in focus (i.e. emotional, social, life experience etc). (Fullan, 2009; Patrick, 1997).

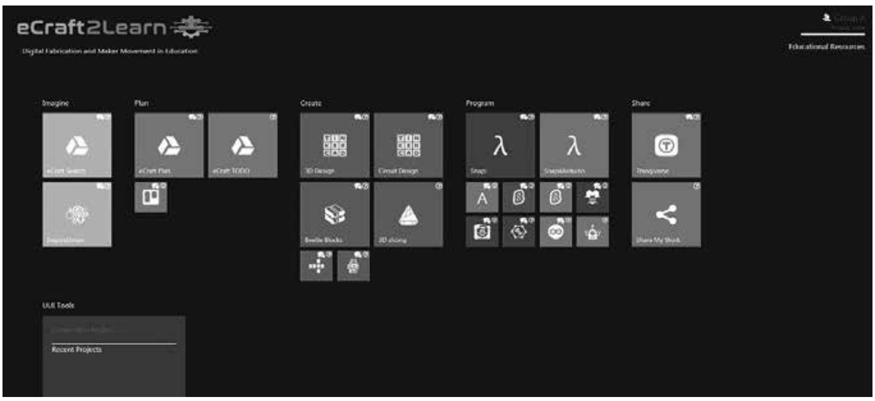

Figure 5: eCraft2Learn Digital Platform – the Unified User Interface (UUI)

Personalised learning approaches provide opportunities for students to be autonomous and develop their self-regulation skills with the optimal support from the teacher. Self Regulated Learning (SRL) includes strategies for recognition, monitoring and control of learner's behaviour, cognition and emotional reactions in learning situations (Hirvonen 2013). Learner's goals are directing individual's actions as the learner is trying to match appointed goals, actions and inner states in relation to the demands of the environment (Järvenoja & Järvelä, 2006; Pintrich, 2000).

To create a strong pedagogical core for the sustainable inclusion and use of technology for making into the education arena as well as to support personalised learning paths within the eCraft2Learn ecosystem, the three phases of Self Regulated Learning (SRL) are included into the pedagogical model of the project as shown in Table 1.

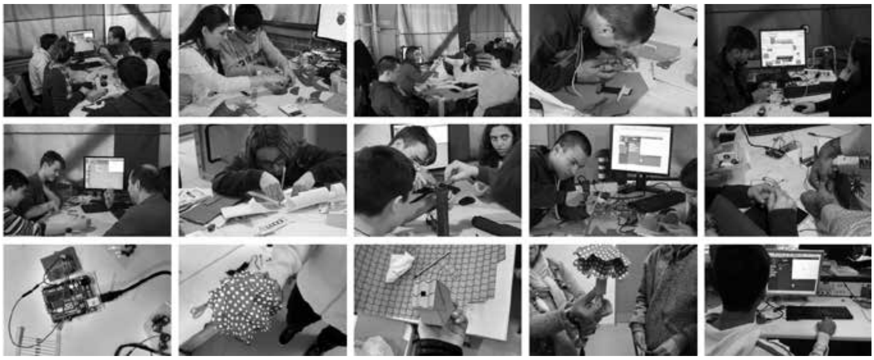

Figure 6: Scenes from eCraft2Learn Pilot in Greece

Table 1: Self Regulated Learning (SRL) within the eCraft2Learn Pedagogical Core

	PREPARATORY PHASE		PERFORMANCE PHASE	APPRAISAL PHASE
	Ideation – Planning – Creation – Programming – Sharing			
Activities	- Engaging, exploring and motivating - Creating the context	- Activating the prior-knowledge and schemas - Providing basic information	- Monitoring - Controlling - Deepening understanding	- Reflecting - Reacting - Sharing expertise
Teacher's Actions	- Create opportunities to engage into the new project topic and content	- Let students carefully plan the work ahead and the stages of the project - Balance between teacher control and student freedom	- Foster student-led and peer learning - Encourage students to find and use their own strengths - Actively monitor and guide the students - Open ended questions and cues to help students to solve problems - Motivate students in positive self-talk to model their thought processes - Balance between teacher control and student choices	- Provide time for teacher, peer- and self-assessment - Engage students to come back to the feelings/experiences during the learning process and share and compare them with others

	PREPARATORY PHASE		PERFORMANCE PHASE	APPRAISAL PHASE
Teaching Methods	- Discussions with a class or in smaller groups - Observing videos, pictures - Creating mind-maps - Organizing expert or company visits	- Discussions with a class or in smaller groups - Small tasks - Creating plans (e.g. materials, timing, roles of students)	- Hands-on work - Collaborative work	- Discussions - Presentations - Learning diaries - Blogs

2.2.3 Assessment of Deeper Learning

Moreover, formative student assessment has an important role on fostering Self Regulated Learning (SRL). Not only should the assessment come from teacher to student, but tasks should also include opportunities for peer- and self-assessment to enable students to monitor and reflect upon their progress (Kontturi 2016). In addition, teachers should create opportunities for students to reflect on their own learning. These opportunities should support students to:

a) Monitor and evaluate their progress in relation to their goals (*Am I doing the appropriate tasks to reach my goals?*)
b) Reflect on their value expectations (*Do my efforts focus on the right tasks?*)
c) Evaluate the effects of aiming towards the goal (*What are the benefits/costs for me or others?*)
d) Reflect on the importance of their own work (*Whose effort were the results?*)
e) Take their experiences into future learning situations (*What will I keep/change in the future?*) (Kontturi 2016).

The eCraft2Learn working platform is designed to provide support for student's self-regulatory and reflective processes and thus to create personalised learning paths. At appointed times by the teacher, self-reflection can be triggered by asking the students to reflect on their activities and goals. The questions help the student to reflect on the work done and provide essential information to the teacher to guide and personalise the teaching even better.

In addition, a Learning Analytics tool is included in the platform and the advantages are being investigated. The analytic tool can track learner's activity and offer immediate feedback tailored for the learner to plan, organise and direct the work.

A dashboard showing relevant information, such as the time used in each pedagogical stage, for the learner can motivate and guide the learning process. The analytics tool can also prompt learners to try working with another tool or to search help from suggested open educational resources.

Furthermore, it can identify who are performing well and predict who will be in need of extra support to improve guidance from the teacher's side.

Additionally, a badge system has been also implemented in the digital platform of the eCraft2Learn learning ecosystem to foster personalised learning within a self-assessment framework (Agatolio et al., 2018).

2.3 iMuSciCA Deeper Learning Paradigm

http://www.imuscica.eu and https://workbench.imuscica.eu/release/v4/

2.3.1 Definition of Deeper Learning

Deeper Learning is normally opposed to superficial or 'thin' learning (Jensen, E., & Nickelsen, L., 2008). According to the Hewlett Foundation, Deeper Learning *"is an umbrella term for the skills and knowledge that students must possess to succeed in 21st century jobs and civic life"* (William and Flora Hewlett Foundation, 201). iMuSciCA therefore builds upon the set of six interconnected competences grouped into three overlapping domains:

Part A: Cognitive Competencies

(1) Mastering rigorous academic content
Students develop and draw from a baseline understanding of knowledge in an academic discipline and are able to transfer this knowledge to other situations. The transfer of knowledge is one the core elements of the pedagogical approach of iMuSciCA.

(2) Thinking critically
Students apply tools and techniques gleaned from core subjects to formulate and solve problems. These tools include data analysis, statistical reasoning and scientific inquiry as well as creativity, nonlinear thinking and persistence. Critical thinking can be regarded a horizontal competence across all inquiry phases of iMuSciCA.

Part B: Interpersonal Competencies

(3) Working collaboratively
Students cooperate to identify and create solutions to academic, social, vocational, and personal challenges. Collaborative learning is one of the central pedagogical methods behind iMuSciCA and a core element of Inquiry Based Science Education (IBSE).

(4) Communicating effectively
Students clearly organize their data, findings, and thoughts. They can communicate effectively and provide constructive and appropriate feedback to their peer learners. Effective communication is addressed explicitly in one of the inquiry phases of the Educational Scenarios of iMuSciCA.

Part C: Intrapersonal Competencies

(5) Learning to learn
Students monitor and direct their own learning. iMuSciCA will focus on i) working independently (while asking for help when needed), ii) reflection and applying insights to other situations, iii) maintaining the momentum until the goal is reached and iv) the quality of work because these are parts of the applied pedagogical and interdisciplinary methods and on v) the joy of learning because of the envisaged motivation effects when learning STEM subjects through and with music.

(6) Developing academic mindsets
Students develop positive attitudes and beliefs about themselves as learners that increase their academic perseverance and prompt them to engage in productive academic behaviours. Students are committed to seeing work through to completion, meeting their goals, doing quality work and thus search for solutions to overcome obstacles.

The following Figure 7 illustrates the classification of Deeper Learning competences into the three domains of i) cognitive, ii) interpersonal and iii) intrapersonal competences.

	Cognitive (thinking and reasoning)	**Interpersonal** (expressing information to others and interpreting others)	**Intrapersonal** (self-management to reach goals)
Deeper Learning Competencies	Thinking critically	Working collaboratively	Learning to learn
	Mastering rigorous academic content	Communicating effectively	Developing academic mindsets

Figure 7: Classification of Deeper Learning Competences as used by iMuSciCA (Adapted from National Research Council, 2012)

2.3.2 Conditions for the Development of Deeper Learning

iMuSciCA is part of the educational movement of STEAM, which aims at bringing Arts at the heart of the school curriculum, to cultivate the creative skills of young people, alongside with the knowledge and skills they acquire in STEM fields (i.e. Science, Technology, Engineering and Mathematics).

iMuSciCA is addressing current requirements in education for new pedagogical methodologies and innovative educational technologies by supporting active, discovery based, personalised, and more engaging learning and providing students and teachers with opportunities for collaboration, co-creation and collective knowledge building.

iMuSciCA therefore focuses firstly on the systematic integration of innovative online Music and STEM Tools to be used for educational purposes. The Workbench of iMuSciCA is the central access point to enabling technologies for Music (i.e. DrAwME; Performance Sampler; Tone Synthesizer and 3D Instrument Interaction), Engineering and Technology (i.e. 3D Design & Printing) and for Science and Mathematics (i.e. Sonification of Mathematical Equations & Geometric Curves; Math Editor; Geometry & Algebra Tools) accompanied by supporting music and sound analysis as well as visualisation tools.

In parallel iMuSciCA teachers from different subjects co-created a set of dedicated Educational Scenarios for STEAM, which gives learners the opportunity to discover different phenomena and laws of physics, geometry, mathematics and technology by using the tools on the Workbench and through creative musical activities, to examine them from various viewpoints and increase integration among various subjects of the curriculum contributing to innovative cross-disciplinary educational approaches.

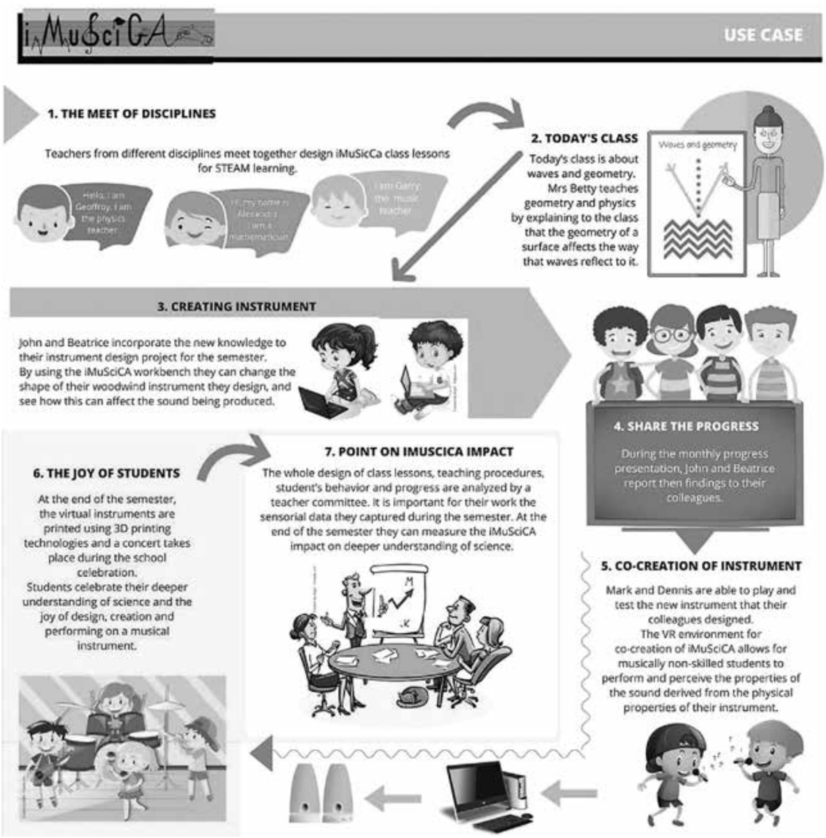

Figure 8: Overarching Educational Scenario of iMuSciCA

Another important element of iMuSciCA is to encourage students to engage in innovative interactive music activities with advanced multimodal interfaces that enable them to discover new ways to look at science with the support of creative and artistic interventions, raising their interest and motivation in STEM learning. For example, students can discover how tones and sounds are produced and analyse them. They can study the characteristics of musical instruments, create their own instrument, perform with them virtually and finally print them on a 3D-Printer. They can prepare compose a musical piece where real, virtual and printed musical instruments blend harmoniously into a unique musical experience.

Through the Activity Environments applied in specific Educational Scenarios, iMuScicA provides students with new opportunities to master core academic content on STEM subjects alongside with the development of Deeper Learning through their engagement in musical activities.

iMuSciCA finally enables teachers to design meaningful and engaging project-, problem- and inquiry-based STEAM learning activities and reinforces them in producing rewarding and self-fulfilling activities in the classroom by acquiring and integrating innovative and stimulating educational technologies in their teaching practice.

2.3.3 Assessment of Deeper Learning

The iMuSciCA evaluation framework is based on an iterative process of 'responsive' evaluation (Abma & Stake, 2001; Youker, 2005). 'Responsive' means that what is happening in classrooms is important and the focus lies on the pedagogical and learning fit and value. Therefore, the metrics employ an evaluation methodology of a mixed nature (i.e. qualitatively and quantitatively) and special care is given to make it manageable in school contexts (without disturbing too much the daily lessons). Teachers and students alike will provide responsive feedback about the iMuSciCA's STEAM pedagogy.

The findings will help to further improve the Pedagogical Framework, the Workbench (i.e. the central access to the online Activity Environments and related Tools) as well as the developed Educational Scenarios (incl. subsequent Lesson Plans and concrete Learning Activities). For this reason, the assessment is part of an iteration process, where piloting and improvement alternate.

The aim of the evaluation is to show how the iMuSciCA STEAM pedagogy supported by the iMuSciCA Workbench and Educational Scenarios can improve the practice in class and will focus on:

- The pedagogical and learning fit and value;
- Technical usability and acceptance in view of the pedagogical and learning value.

The evaluation is collecting various 'responsive' observations and feedback from teachers and students, both pedagogical ones as well some tracking data.

iMuSciCA's piloting is primarily about improvement of the practice in class. Additional feedback will be collected in classes with a 'light' implementation of iMuSciCA (i.e. 2 – 4 lesson hours). Furthermore, the evaluation of iMuSciCA and the conclusion thereafter will be based on schools with 'in-depth' implementation of iMuSciCA (i.e. 8 lesson hours or more).

The above implies that all phases of Inquiry Based Science Education (IBS) will be used and that there will be extensive use of tools, reflection, dialogue and interactions as foreseen in Pedagogical Framework of iMuSciCA. The evaluation consists out of collecting:

Real Reactions of Teachers & Students: Qualitative Input
• Focus Groups
• Interviews
• Observations
• Audio/Video Recordings & Photos as Reflective Tools and as verifying References

The developed metrics of Deeper Learning will give outermost attention to the real reactions of the teachers and students themselves, as given in authentic class observations, observations of students' activities as well as experiences reported during interviews or focus groups.

Questionnaires: Quantitative Input
• Students' Questionnaires: on i) Deeper Learning; ii) Motivation and Attitude towards Science Learning; iii) Knowledge Acquisition; iv) Software Usability etc;
• Teachers' Questionnaires: on i) Activity Environments and related Tools; ii) Educational Scenarios; iii) Summary Evaluation

The qualitative inputs are supplemented by questionnaires on acquisition of content knowledge, motivation and attitudes towards STEM.

Tracking Learner's Activity
The biometrical assessment of iMuSciCA will be implemented during the in-depth implementation in schools. Due to various boundary conditions of constancy, limited equipment and time, they can only be implemented in a 'lab environment' i.e. one student at a time in a separate room. This information will be cross-analysed in relation to the collected pedagogical feedback. The tracking information consists of:
• Events recorded by the iMuSciCA Workbench;
• Biometric data like Eye Tracking, Facial Expression Analysis, Electrodermal Activity (EDA), also referred to as Galvanic Skin Response (GSR) and Electroencephalography (EEG) collected while using the tools of the Workbench.

In order to make sense out of the tracking information, the biometric data will be analysed in combination with the input from teachers and students in order to optimize both, the technical and pedagogical usability. We give two examples of such a combined analysis:

ii) *Solving Issues around User Friendliness.*
If the interface is found to be too difficult i.e. the user has to click on many items or menus in order to find his or her way through the tool, biometrical data like eye tracking will be analysed in combination with recorded events and observational data in order to identify problematic design issues.

ii) *Solving Issues linked to Deeper Learning competences.*
If there is a problem of motivation or frustration while working with the Workbench, and this is observed in pedagogical settings, this can be further analysed by cross-checking it with biometrical data like Facial Expression Analysis, Galvanic Skin Response (GSR) that can be linked to the emotional state of the learner.

Finally, comparative research elements (e.g. control group designs) will be applied during the evaluation of iMuSciCA. The project will explore one or more of the following potential research scenarios to be applied in Belgium, France and Greece:

1. *Within one class with one subject teacher:* longitudinal approach following the curriculum; suggested sequence: 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);
2. *Teaching the same subject twice:* Phase 1: 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); Phase 2: as above;
3. *Switching between two classes:* 1st Class: 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); 2nd Class: i) STEM teaching with the support of iMuSciCA (i.e. experimental scenario) → ii) elapse time (= pause) → iiii) traditional teaching of STEM subjects (i.e. control scenario)
4. *Comparison between different Schools:* in-classr;oom 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);
5. *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);
6. *Comparison between dedicated Students' Camps:* comparison between purely scientifically/STEM oriented Students' Camps and (i.e. control groups) with Student Clubs of iMuSciCA (i.e. experimental group);
7. *Software Usability Testing:* e.g. with the System Usability Scale (SUS; https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html).

2.4 STORIES OF TOMORROW Deeper Learning Paradigm
http://www.storiesoftomorrow.eu/

2.4.1 Definition of Deeper Learning

STORIES OF TOMORROW was conceived as a project to: a) present storytelling, that enjoys a very long tradition in human history, as a catalyst for the effective interaction between Art and STEM disciplines, which share similar values, similar themes and similar characteristics towards promoting learners' Deeper Learning; b) present a new vision for teaching outlining strategies for how Educators' roles and conditions can support and enable Deeper Learning for learners and c) to support and facilitate the aforementioned approaches with meaningful digital technologies, such as advanced interfaces, learning analytics, visualisation dashboards and Augmented/Virtual Reality (AR/VR) applications.

The project's core educational method (i.e. inquiry based and project-based learning) is based on the six pedagogical principles that elaborately represent Deeper Learning abilities that are mentioned in common definitions (William and Flora Hewlett Foundation, 2016). Inquiry based learning is a method that evolves Engaging Learners; Exploring Contextual Issues; Explaining Scientific Concepts and Inquiry Abilities; Elaborating Knowledge and Abilities in New Contexts; Evaluating Learners' Knowledge and Abilities (Bybee, 2000).

This framework builds on a four-strand model developed to capture what it means to learn science in school settings by adding two additional main strands incorporated for informal science learning, reflecting a special commitment to interest, personal growth, and sustained engagement that is the hallmark of informal settings. These principles will guide the overall project and that are at the core of the Deeper Learning paradigm (see Table 2).

Table 2: Main Pedagogic Principles and Educational Objectives for the Design and Implementation of the Deeper Learning Paradigm in the Framework of STORIES

Strands – Pedagogic Principles	Educational Objectives
Sparking Interest and Excitement	*Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.*
Understanding Scientific Content and Knowledge	*Generating, understanding, remembering and using concepts, explanations, arguments, models and facts related to science.*
Engaging in Scientific Reasoning	*Manipulating, testing, exploring, predicting, questioning, observing, analysing and making sense of the natural and physical world.*
Reflecting on Science	*Reflecting on science as a way of knowing, including the processes, concepts and institutions of science. It also involves reflection on the learner's own process of understanding natural phenomena and the scientific explanations for them.*
Using the Tools and Language of Science	*Participation in scientific activities and learning practices with others, using scientific language and tools.*
Identifying with the Scientific Enterprise	*Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses and sometimes contributes to science.*

The six pedagogical principles of Deeper Learning in connection to STEM education can be translated into six crucial intellectual and motivational abilities. While (1) understanding scientific content and knowledge, (2) engaging in scientific reasoning as well as (3) reflecting on science represent intellectual abilities, (4) using the tools and language of science (collaborative problem solving), (5) sparking interest and excitement and (6) identifying with the scientific enterprise rather represent motivational abilities. However, our research will be the first to fully implement and empirically test the Deeper Learning paradigm. Regarding the interrelations among the various intellectual and motivational abilities, we will explore them in an evidence-based manner without previously analytically derived hypotheses. For that matter, we need to assess pupils' abilities before, after, and especially throughout the intervention. A successfully developed, tested and applied comparable competence model that consists of motivational and intellectual abilities in the domain of environmental education has already been developed (Kaiser et al., 2008; Roczen et al., 2014). Based on this competence model STORIES found that the intellectual components (i.e., action-related knowledge, system knowledge and effectiveness knowledge) converge for people with higher overall knowledge and higher motivational ability (Frick et al., 2004). Relying on this experience and in collaboration with the University of California, one of the leading universities of assessment in the world in Deeper Learning and in STEM, the project will developed technology-based scales and assessment instruments for each of the six motivational and intellectual abilities in STEM that relate to the six pedagogical principles. Thus, the intervention design and the assessment framework formed the basis for the development of objective and standardized student assessment instruments to meet the challenges of the STORIES project.

2.4.2 Conditions for the Development of Deeper Learning

The Deeper Learning paradigm incorporates the idea that a range of competences and their orchestrated skilful application leads to STEM mastery. To accomplish a holistic assessment of STEM mastery within the Deeper Learning paradigm in science education, STORIES developed standardised assessment tools that cover intellectual and motivational ability. Especially communicational competences (e.g., collaborative problem solving) are essential elements of the applied Deeper Learning paradigm and can relate to both, motivational and intellectual ability.

The assessment approach will assess a broad range of abilities necessary for Deeper Learning with standardised scales. Apart from its use in the evaluation of the educational interventions, most instruments will be applicable to any other Deeper Learning intervention, and thus, at the first time allow building an empirical basis to compare different Deeper Learning interventions. This possibility in turn is essential for an evidence-based promotion and development of the Deeper Learning paradigm.

To accomplish a comprehensive assessment of STEM mastery within the Deeper Learning paradigm in science education, we will develop standardised assessment instruments that cover intellectual and motivational abilities.

In the framework of STORIES, the main objective of the evaluation is to ensure a continued learning process based on the Deeper Learning paradigm that addresses not just intellectual abilities but also motivational abilities (see Figure 9).
The Deeper Learning paradigm of STORIES also incorporates the idea that a range of abilities and their orchestrated skilful application leads to STEM mastery. Considering the approach to develop STEM mastery, that is, learners' stories which include a multitude of options to broadly improve Deeper Learning abilities, STORIES emphasises its strong innovative character that leads to a challenging evaluation procedure. An evaluation that only concentrates on intellectual abilities and STEM specific knowledge that can also be acquired differently (i.e. chemistry specific knowledge about oxygen generation necessary for a trip to mars) would be far too short sighted in order to assess all the abilities involved in Deeper Learning (see e.g. National Research Counsil, 2012; Pellegrino et al., 2014).

Thus, the project will develop and apply technology-based assessment instruments that allow to universally assess all essential abilities that are central to Deeper Learning. The assessment educational data (i.e. performance indicators) generated by the proposed tools can be utilized for creating learners' Deeper Learning competence profiles. The emerging research field of Learning Analytics can provide a promising additional approach to introduce such a profiling process for learners' Deeper Learning competences, which could, in turn, feed visualisation dashboards to facilitate the educator to have an overview of the learners' competence level and development. This kind of overview can facilitate educators' evidence-based coaching, teaching planning and/or classroom delivery (Kumar et al., 2015). For this purpose, STORIES concentrated it's assessment on the educational outcome that our pedagogical method, which fosters the core abilities involved in Deeper Learning proposes to achieve.

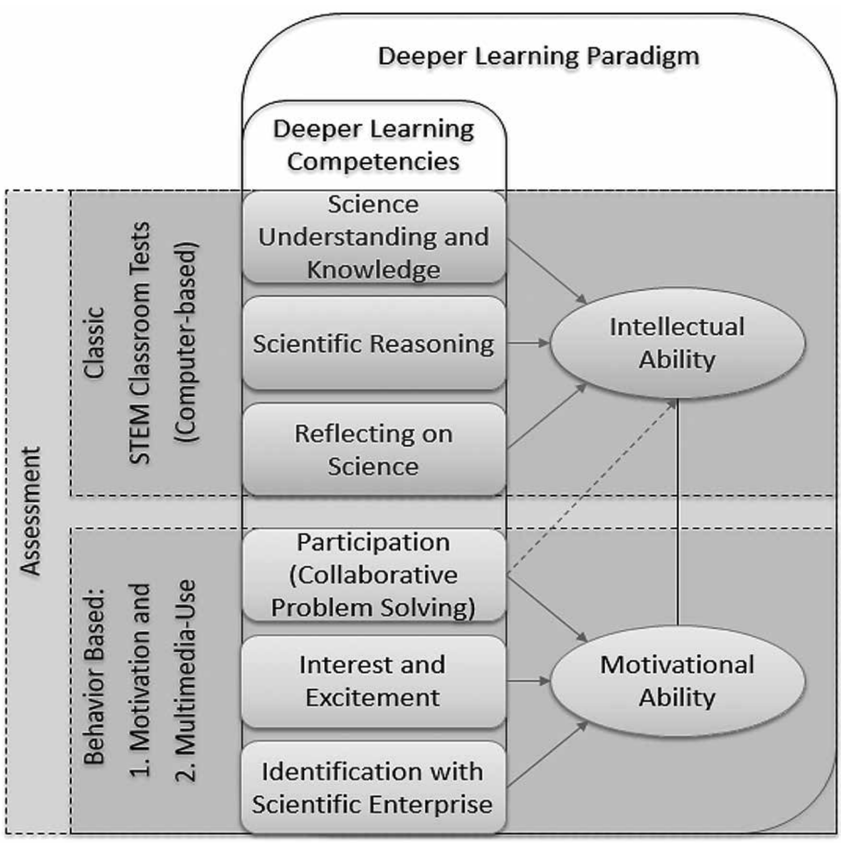

Figure 9: The Deeper Learning Paradigm in the STORIES Project

2.4.3 Assessment of Deeper Learning

The STORIES evaluation approach assesses Deeper Learning by its consequences, supposing that the consequences of the six Deeper Learning competencies are Integrated Knowledge and Fascination in Science (see Figure 10). For the assessment, we developed three instruments. While Integrated Knowledge is measured with knowledge questions that address knowledge itself, its application and reasoning, fascination with STEM is assessed with an instrument capturing emotions, cognitions and behaviors toward different science fields. Because the two Deeper Learning competencies reflecting on science and participation are highly interdependent in their consequences (integrated knowledge and fascination), STORIES assessed their amalgamation which is reflected in the ability to solve problems collaboratively.

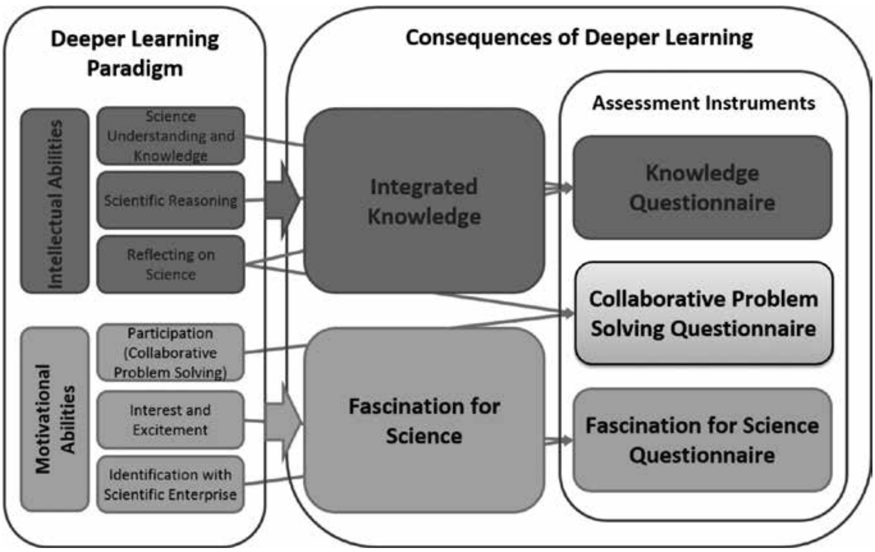

Figure 10: The Deeper Learning Paradigm and its Consequences

The STORIES evaluation approach depicted in Figure 11 follows a pre-post design. Assessing Deeper Learning prior to any intervention by applying the same instruments as afterwards is a crucial prerequisite to answer the question if students improved their Deeper Learning abilities. Additional control groups – assessing students not participating in STORIES – increase the validity and reliability of the evaluation. Because by collecting data of those non-participating students, it is possible to discriminate the changes in Deeper Learning due to the intervention from changes due to e. g., students' maturation or other educational opportunities.

During the intervention, system and classroom data like time spent on the platform, number of interactions etc are collected to check the accuracy of the intervention (fidelity check). This also allows us to analyse their relations to the Deeper Learning abilities to make out potential determinants of Deeper Learning.

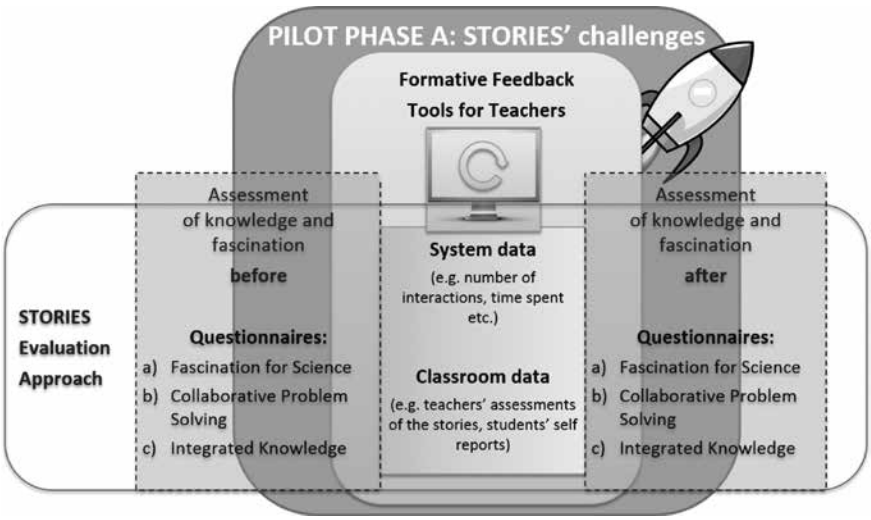

Figure 11: Evaluation Approach of STORIES

Below we give an overview of the content of the instruments and the number of questions used in this report (see Table 3).

Table 3: Overview of the Assessment Instruments used for Pre- and Post-Tests of iMuSciCA

Assessment Instruments	Pre-Test	Post-Test
Knowledge	**36 Questions** (Earth, Life, and Physical Science) based on TIMSS • Factual Knowledge • Applied Knowledge • Reasoning	**36 Questions** • 18 new questions • 18 previously presented questions
Collaborative Problem-Solving	**52 Questions** (42 positively and 10 negatively worded) • Establishing and maintaining shared understanding • Taking appropriate action to solve the problem • Establishing and maintaining team organization	**30 Questions** • only positively worded • 10 per domain
Fascination for Science	**84 Questions** • Emotions • Cognitions • Behaviors regarding Astronomy, Biology, Chemistry, Geoscience, Physics, Technics, and Science in general	**36 Questions** • six per science field • Without the questions concerning technology

Analysing Learner's behaviour using biometric sensorial data

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Abstract

During iMuSciCA project we conducted pilot studies in schools in Greece. The target was to measure students' behaviour when taking music or science-oriented tasks. We used different biometric sensors to record student's behaviour including EEG headset, GSR, facial recognition and an eye tracker. The background of the students was either music or science. We have seen that students with different background perform different on music and science-oriented tasks. Science students showed a positive attitude and a motivation approach for all tasks, whereas the group of Music students showed a relative negative attitude and less motivation.

Keywords

biosensors, deeper learning, human behaviour, iMuSciCA, music, science, STEAM.

1. Introduction

Visual attention and affective behaviour in a learning platform such as iMuSciCA [1] can have both positive and negative effect on students' learning. By investigating student behaviour from biometric data when interacting with the iMuSciCA web platform activity environments we can capture quantitative information about how discoverable or attention-grabbing visual elements such as navigation structures, screen graphics, links, text, or multimedia content are to the participants. Furthermore, confusion, frustration, boredom, as well as other affective states are elicited in response to the students' interaction with the iMuSciCA platform and they are inextricably bound to learning by affecting students' perceptions of the iMuSciCA environment and changing how well they learn from it. In order to assess student behaviour, we employed the following monitoring mechanisms:

Facial expression analysis software that analyse facial expression of positive, negative or neutral emotions and cluster them in emotional expressions. This type of tools is based on the study of Paul Ekman and Wallace Friesen back in 1987 [2], which demonstrates how interpretation of facial expressions is universal across the globe.

Galvanic skin response (GSR) measures the amount of body's sweat that gives a good indication of emotional arousal [3, 4].

Electroencephalography (EEG) measures electrical activity of the brain [5, 6, 7]. By analysing EEG data, we can take valuable information about the engagement, motivation, frustration, cognitive workload and other metrics associated with brain activity.

The rest of this paper is organized as follows. Section 2 describes the methodology of the usability tests in more detail, giving links to the actual usability scenario documents and the questionnaires given to the students. Section 3 gives an analysis of the results, while Section 4 summarizes the content of this work.

2. Material and methods

We conducted a pilot testing in Greece with 18 students in total in the age range of 13-16 years old. We used two different scenarios, one based on science tasks and one based on music tasks (see Table 1 and Table 2). In total we had 18 students (7 males/11 females) of which 6 had a music background and 12 had a science background. Two students were measured without eye tracker and another two without EEG.
In our studies, we have used the following biosensors:
facial recognition software, to analyse the facial expressions recorded by a camera
GSR, to measure how much the student sweats emotionally
EEG headset, to capture the brain activity

Table 1. Science tasks

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.

Table 2. Music tasks

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.

3. Results

We measured the time required for each task and we have observed that it is less for the music students in music tasks and for the science students in all science tasks but one, task ST3 (See Table 3 and Table 4).

Table 3. Time required for each task in secs - Science students

Task	Average	StdDev	Min	Max
MT1	28.29	16.38	8.63	61.60
MT2	30.43	24.81	12.60	89.63
MT3_0	42.92	11.02	26.73	58.67
MT3_1	50.15	37.44	17.30	135.73

ST1_0	65.13	11.17	43.30	83.00
ST1_1	59.41	28.42	32.13	124.83
ST2_0	12.73	2.84	8.07	17.10
ST2_1	43.75	13.56	22.67	67.10
ST3_0	24.92	6.77	11.60	38.30
ST3_1	104.44	50.54	39.47	216.30

Table 4. Time required for each task in sec - Music students

Task	Average	StdDev	Min	Max
MT1	23.92	7.01	14.10	35.10
MT2	17.38	11.64	7.30	37.33
MT3_0	38.78	4.54	29.67	41.70
MT3_1	38.94	31.66	8.80	97.67
ST1_0	58.13	12.48	49.23	79.40
ST1_1	77.43	34.65	27.50	111.60
ST2_0	12.23	2.75	9.23	16.27
ST2_1	58.46	40.27	21.17	125.33
ST3_0	23.07	5.66	16.77	31.47
ST3_1	65.72	21.91	38.93	99.93

Tables 5, 6 and 7 shows the analysis of the facial expression for music and science students in music and science tasks. Table 5 reports the Engagement and Attention measures. One can see that the engagement for both music and science students was relatively low for all tasks, whereas the attention was rather high. Table 6 and Table 7 reports positive, negative and neutral measures of facial expressions of the students. The facial expression analysis reports that all students show a mostly neutral attitude (no confusion or frustration was detected).

Table 5. Facial analysis - engagement and attention

	Engagement		Attention	
Task	**Music**	**Science**	**Music**	**Science**
MT1	11.75	15.80	66.30	54.51
MT2	18.72	15.91	83.33	60.02
MT3_0	16.29	11.11	92.84	87.99
MT3_1	9.97	16.63	90.13	91.91
ST1_0	8.82	13.73	87.70	89.73
ST1_1	8.82	21.14	87.62	92.55

ST2_0	5.89	12.20	92.56	91.53
ST2_1	10.61	13.93	82.33	87.40
ST3_0	15.84	22.88	82.58	92.60
ST3_1	12.68	16.40	90.17	85.70
Total	11.82	16.02	85.59	84.27

Table 6. Facial analysis – Music students

Task	Positive	Negative	Neutral
MT1	5.79	0.38	78.21
MT2	7.34	0.90	86.94
MT3_0	1.28	3.70	89.68
MT3_1	0.26	0.55	93.45
ST1_0	0.23	0.42	91.63
ST1_1	0.41	0.96	90.26
ST2_0	0.54	1.36	91.77
ST2_1	0.12	1.71	91.27
ST3_0	0.31	9.40	75.22
ST3_1	0.40	1.87	90.40
Total	1.57	2.15	87.90

Table 7. Facial analysis – Science students

Task	Positive	Negative	Neutral
MT1	0.15	0.88	88.53
MT2	5.03	3.83	88.02
MT3_0	0.01	3.20	92.25
MT3_1	1.09	5.25	92.77
ST1_0	1.81	2.82	91.32
ST1_1	1.67	4.40	89.72
ST2_0	0.00	7.18	90.03
ST2_1	0.62	4.29	86.27
ST3_0	2.05	8.88	84.64
ST3_1	1.71	4.09	83.47
Total	1.39	4.57	88.65

The GSR refers to changes in sweat gland activity that are reflective of the intensity of our emotional state, otherwise known as emotional arousal. When there are significant changes in GSR activity in response to a stimulus, it is referred to as an Event-Related Skin Conductance Response (ER-SCR). These responses, otherwise

known as GSR peaks, can provide information about emotional arousal to stimuli. The GSR peaks (see Table 8) shows that:
(i) music students sweat emotionally less than science students,
(ii) tasks MT1 and MT2 are significantly more stressful in comparison to task MT3 for both groups,
(iii) task ST1 is more stressful in comparison to the tasks ST2 and ST3 for science students.

Table 8. GSR - Average of Peaks/Min

Task	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
Total	6.04	11.54	9.55

We also measure Electroencephalography (EEG) data with a mobile head-set EEG device. From the EEG data we chose the frontal asymmetry index for our analysis [5, 6, 7]. 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 (F3), see Figure 2. An increased right frontal asymmetry shows negative feelings and withdrawal motivation, while an increased left-frontal asymmetry shows positive feelings and approach motivation, see Figure 1. We calculate the frontal asymmetry index for the students in all tasks. As it can be seen in Table 9 science students show a more positive attitude and a motivation approach than music students.

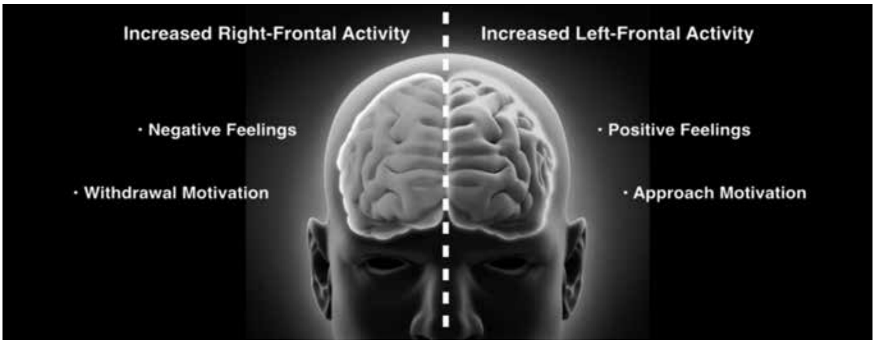

Figure 1. Frontal assymetry (picture taken from https://imotions.com/)

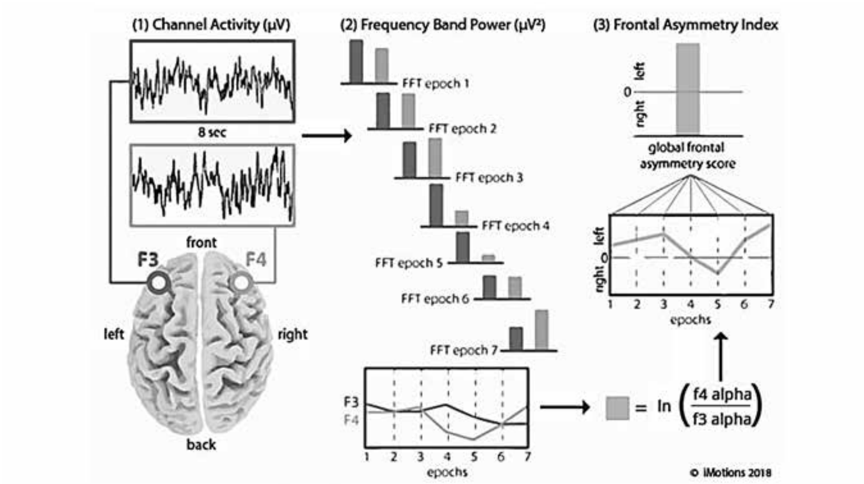

Figure 2. Measuring frontal assymetry (picture taken from https://imotions.com/)

Table 9. EEG - Frontal Asymmetry Index

Task	Science	Music
MT1	5.51	0.52
MT2	1.87	0.19
MT3_0	1.59	0.18
MT3_1	3.27	-0.17
ST1_0	1.63	-0.89
ST1_1	3.82	-0.49
ST2_0	3.80	0.57
ST2_1	1.78	-0.11
ST3_0	15.08	6.47
ST3_1	4.11	-0.66

4. Conclusions

The current study has focused on analysing students' behaviour of different background when they assigned different task. We contacted two different scenarios, one music oriented and one science oriented. To analyse the behaviour, we record data using different types of sensors. The study shows that different background students perform different on music and science-oriented tasks. Science students showed a positive attitude and a motivation approach for all tasks, whereas the group of Music students showed a rather negative attitude and less motivation in carrying out the tasks.

5. Acknowledgments

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"How Should We Go To Colonize Mars?" … MARiStotelio Has Solutions!

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Abstract

Space as intriguing subject leads students to 21st century skills. Starting from "Stories of Tomorrow–Mission to Mars" project, students researched complex problems colonizing Mars. Realizing the problems of transferring a sustainable community inquired justifiable solution by constructing a space platform. They used academic knowledge and facts they acquired by their own. Through this attempt they communicate with others by using various forms of arts (design, drawing, modelling and creating representational environments). Finally they presented their work to students, teachers and parents within a theatrical way. This attempt aimed to bring science closer to audience with interactive artistic ways.

Keywords

Space, Problem Solving, S.T.E.A.M., Critical Thinking, Creativity

1. Introduction

During 2018-2019 academic year 10 students (10-14 years old), called "MARiStotelio", worked as a team in Science Culture Educational Center "Aristotelio" – S.T.E.A.M. Academy, in order to investigate a complex and multileveled problem of the humanity in depth. The rising trends of specific environmental sizes and values will undoubtedly concern their generation. Also the parallel decrease of energy storage in more and more forms and the collateral factors of the degradation of the earth's environment will certainly lead to the need of finding an effective solution and more specifically the colonization of another planet. The reason of concern was given during the implementation of the project "Stories of tomorrow–Mission to Mars". The students had to investigate this specific multidisciplinary problem is steps, analyzing aspects and sub-problems that arose in each one. Gathering multiple the data and justifiably rejecting some possible solutions led them in developing a structured proposal, which at the same time was fully scientifically correct and proven. Thinking as responsible future citizens and using critical thinking and cooperation, they came to a general form of the solution and in specific the construction of a space-platform for the transfer of a sustainable community to planet Mars. In that step a laborious and detailed investigation of new concerns related to technological issues of designing and constructing a specific platform took place. In this way, and also with certain help from specialists in space issues, they initial solution was refined and thoroughly proved, accordingly to the processing degree of the student's age. The project was implemented on the basis of Deeper Learning approach, incorporating also traits of Creativity in Science Education as well as combining S.T.E.A.M. methodology approach (Science, Technology, Engineering, Art and Mathematics). Finally, the students used representational arts to a large extent, as they designed, drew, constructed and presented the development of their investigation using an interactive, theatrical way to a broad audience (children, teachers, parents, other adults).

2. Deeper Learning

Deeper learning refers to the competencies, knowledge, and skills that students must develop in order succeed in their lives in the 21st century, (and therefore what they should know and be able to do when they graduate from our public education system). According to the Hewlett Foundation definition [30] students should have accomplished the following six competencies:

1. Master core academic content
2. Think critically and solve complex problems
3. Work collaboratively
4. Communicate effectively
5. Learn how to learn
6. Develop an academic mindset

Deeper learning requires conscious learning behaviours broader than the traditional ones. It encourages students to take responsibility of the use of time and energy the task requires, select the proper strategy and evaluate it. Deeper learning also demands from students, when a setback or a difficulty faced, to diagnose the type of difficulty and select the proper way to overcome it towards the solution.

Emphasizing in those six competencies in order to accomplice deeper learning, "mastering core academic content," as Hewlett defines it, involves more than remembering terms, facts and formulas. It means understanding key-principles and relationships within a content area and organizing information in a specific conceptual framework. [17] Students should develop and draw basic knowledge in a more academic content and also be able to adjust this knowledge in other familiar situations. Learning activities aiming to this, should give students opportunities to apply what they learn over time and throughout challenging task. In this case, students from the MARiStotelio Project had to understand in depth laws and principles of physics, more advanced than what they are taught in school, such as Newton's laws, gravity, friction, gravity wells and electromagnetic fields. They used this fundamental knowledge in order to lead their original thoughts into a solution. Slowly and gradually they learn and master meanings, symbols and equations in order to solve a real world problem.

Putting together master core academic content with critical thinking, so as to solve complex problems, we have more active and personal intellectual process unlike the familiar scholastic exercises of copying, memorizing, and reproducing a framework developed by someone else [6]. This process calls for what Cohen refers to as "minds at work" [10].

As it's referred in Hewlett Foundation, in critical thinking and problem solving, students should apply tools and techniques they have collect to solve problems. These tools include data analysis, statistical reasoning, scientific inquiry as well as creativity, nonlinear thinking and persistence. In order to accomplice that, team had to show persistence into solving certain complex problem of Mars domestication. To do so, they have to evaluate and critically analyze sources and information they have gathered either from the web or books. In the process of finding the final solution they came along with a number of new problems they had to solve, based each time in the available data and information.

Second, Hewlett's definition of deeper learning requires that students learn "communication and collaboration," which means they cannot just work on their own. Rather, they need to "reason critically and solve problems" in the company of others doing the same activities. This also affects how we think about the work of teaching. Communication and collaboration are best learned in what some scholars call "a community of practice," into where shared norms and common ways of defining problems (and the nature of solutions) are fundamental to learning [29], [30]

In order for students to work collaboratively, they have to cooperate due to identify and create solutions in social, academic and personal challenges. As far as the efficient communication is concerned students will have to organize their thoughts, data and findings in a very clear and comprehensive way.

Each student of MARiStotelio team had to understand that they work as a team in order to solve numerous demanding problems. They had to respect, listen and encounter as equals every member of the team. To accomplish this, they had to organize personal data, information and thoughts into an easy and well organized way in order to help fellow students to be familiar with. Additionally, in order to move forward they had to evaluate and give feedback on their peers in a constructive and caring way.

Learning how to think critically, collaborate, and communicate with others, requires an entirely different approach. An approach which express that “Learning” is both the goal and the means of getting to the goal [26]. According to Hewlett, “Learning how to learn” requires “caring about the quality of one’s work, enjoying and seeking out learning on your own and with others.” This has more to do with commitment and interest rather than skills and knowledge. Through the process they actively learned how to learn as they monitored their comprehension and adapted their approach when needed. According to this, it is expected from students to work independently and ask for help from the teacher only when and if it is needed. That is the result of student’s awareness of their strengths and weaknesses. It is a point where students are actually enjoying learning by their ones and with their peers thus seek opportunities to do so.

Last but not least “develop academic mindsets” means that students could develop positive attitudes and beliefs about themselves as learners. These beliefs increase academic perseverance and prompt students to engage in productive academic behaviors as open problem solving and quality work are. [31]. Students get the feeling of belonging in an academic community and they start to value intellectual encounter. They also understand that learning is a social process that they can actively learn from one another. Moreover they gain to believe that they can succeed in their pursuit because they trust their own capacities and they feel competent. They also realize that their reward will be proportional to their effort. Thus they are motivated to invest time and effort in order to increase knowledge and achieve important goals.

Deeper learning competencies address three domains: [23]

- Cognitive: Students develop a strong academic foundation in subjects like reading, writing, math, and science. Most importantly, they understand disciplinary principles and concepts. As students master content, they are more able to transfer knowledge to other situations or tasks. Students will learn how to think critically. That means that they will have the ability to synthesize and analyze information, form questions, recognizing patterns, trends, and relationships so they can identify and solve problems, as well as assess or evaluate the effectiveness of the proposed solution(s).
- Interpersonal: Students learn how to work collaboratively to complete tasks, produce shared work, understand and solve complex problems. They also learn how to effectively communicate complex concepts to others through a variety of modes of expression in a logical, useful, meaningful, and purposeful way. For

students to do this, they must learn how to clearly organize their data, findings, and thoughts.
- Intrapersonal: Students learn how to monitor and direct their own learning, recognize what they know or do not know, recognize when and how they are confused, identify the obstacles or barriers to their success, and then determine and deploy strategies to address these challenges. In developing an academic mindset, students are able to see themselves as academically successful and therefore trust in their own competence and feel a strong sense of efficacy. As a result, students engage in positive and productive academic behaviours and persevere when they face difficulties.

Taken together, the deeper learning competencies result in students' ability to use and apply what they have learned. This ability, known as "Knowledge transfer", is widely recognized as critical to succeeding at novel tasks or new contexts [23]. Knowledge transfer ability is important for utilizing skills in non-school environments, communicating effectively, and applying content in new situations, such as future classrooms or jobs. In addition, students develop an academic mindset as well as metacognitive abilities and intrapersonal skills—they learn how to learn—and develop the ability to become lifelong learners.

Deeper learning competencies are anything will help students succeed in a dynamic and uncertain future world. Places them in a premium of people who are flexible, creative, and innovative, communicate well and work effectively in teams. The nature of work is changing, demanding less routine cognitive and manual tasks and more on analytic, interpersonal and creative abilities [2]. Organizational structures are changing as well, with more emphasis on collaborative work and transferrable skills. A recent report by workforce economists emphasized the increasing need for individuals who can work across networks of people, with greater efficiency and at an accelerated pace (Carnevale and Rose, 2015:12). Strategies that facilitate deeper learning will help preparing students to deal with the changes and fulfil the demand for higher-level skills people providing them with an ability to learn in the globally connected economy.

3. Creativity in Science Education

It is worth noting that there is a substantive number of existing studies concerning of Creativity in Education in general and in particular in Science Education, with creative thinking being an important educational objective of curriculums [15]. This is not surprising since it is a skill globally necessary for the modern challenges of the 21st century. Creativity is a complex and broad concept associated with inventiveness, but also way of thinking and acting. More specifically it is the ability to produce original and useful ideas, to explore in-depth areas, to find innovative solutions and original questions. It also makes critical thinking more productive [12], [19], [3], [27]. Creativity can be Historical (idea, theory, historical discovery) or Personal (regardless of whether it is new to others) [4]. Cardarello (2013) has made it clear, through her bibliographic review, that a discovery can be creative when it is new to a specific factor. Thus a child, due to its mental tools and experiences, expresses creativity differently than an expert scientist, yet it uses creativity as much as it already knows and understands. Also the Cardarello [7] agreed with Kind & Kind (2007) on the idea that creativity is not identical to absolute imagination but is a combination of imagination and logical reasoning.

According to Daud et al. (2012) the PBL (Project Base Learning) educational method can enhance creativity in Natural Science learning as it is a methodology that emphasizes exploratory activity as a means of acquiring knowledge. Students start working with a realistic problem, for which they need to acquire new knowledge in order to solve. So they translate the problem, collect necessary information, identify possible solutions, evaluate options and present their conclusions (https://www.openschools.eu/, D2.1 Open Schooling Model). Moreover Siew et al. (2015) found that Creative Problem Solving Learning Model helped to promote creativity of elementary school pupils in the classroom, developing their flexibility, versatility, authenticity of solutions to the scientific problem and simultaneously improving their scientific knowledge. Siew & Ambo (2018) later on developed a multidisciplinary teaching-learning approach PBL-S.T.E.M. and positively evaluated its effects on students' scientific creativity, following the 4 phases of the Directed Creative Process Model:

- Preparation (recognition - problem clarification)
- Collaborative imagination (search for solutions, alternatives, optimal solution)
- Evolution (collection of materials, creation and improvement of a project)
- Action (presentation, course feedback, student-teacher evaluation).

Also the evolution of S.T.E.M. to S.T.E.A.M. methodology (with the incorporation of Arts) has brought positive results to the development of creativity, critical thinking on existing problems, mobilizing students and facilitating the learning of Natural Sciences. Boy [5] also recognized Creativity and innovation in S.T.E.M. - and even more in S.T.E.A.M. In a research conducted by the "International Space University Space Studies Program" at Florida Space Station (summer 2012) on "How Space Can Contribute to World S.T.E.M. Education" it was found that space-related Science is inextricably linked to cognitive functions, innovation and risk-taking. A typical example is the Apollo program as an attempt to combine analytical thinking and creativity

Rhodes [25] analyzed creativity and categorized it as: person, product, process and press, with each category being equally important. As far as it has to do with the product, this is related to the end result of the creative process (the embodiment of ideas), which is not limited to tangible objects (e.g. constructions) but also refers to the ideas themselves. A teaching style that promotes creativity must prompt students to produce several ideas (flexibility) and different ideas (flexibility) in order to create something new (originality) [1]. Auxiliary techniques in these directions are, for example, brainstorming [13] and mental maps [20]. Then, beyond the individual characteristics of creative persons (e.g. cleverness, character, behavior), [25] made it clear that everyone can be trained in the creative process. Creativity is a key feature of the Nature of Science [24], since scientific thinking and ideas are creative thinking products [21]. Natural Sciences have a wide range of activities and practices to promote creativity, since scientific research (which has been highlighted as a creative process in the new K-12 Framework for Science Education) includes creative skills (e.g. production-testing of ideas). In order to foster creativity in Science classes students should be encouraged to create questions and hypotheses, as well as to use cognitive tools of creative scientific thinking (e.g. analogies, transports, visualizations) [3], [7]. In addition, teachers need to ask open questions, provide more time for answers and accept students' innovative questions and answers [20], [3]. They can assign them autonomous research activities and push them into divergent thinking through scientific procedures (observation, categorization, research questions, hypothesis formation, design of measurement methods and deduction of empirical data). It is legitimate to encourage the search for alternative examples, descriptions, explanations of scientific ideas, as well as the opposition to existing ideas. Furthermore, creativity also involves the presentation of scientific knowledge (e.g. role playing, theatrical performance, music, images) [9]. Hadzigeorgiou et al. [15] having summarized previous findings on Creativity Growth in Natural Sciences suggests that students must have sufficient scientific knowledge so as to think creatively, while at the same time embedding activities that drive thought into future events and chances is very helpful. They also propose appropriate activities such as creative scientific exploration (e.g. power generators in case of emergency) and teaching-learning approaches to Science through Arts (e.g. painting for phenomenon representation) [15]. Finally, with regard to the press as a creative sector, this is related to environmental factors that affect students' creativity (e.g. climate, teaching method, peer relations, collaboration) [25]. A useful environment for developing creativity is a learning environment that is safe and non-critical, with social interaction of students about Science [15].

4. Open School Culture

PBL and S.T.E.M. educational approach, Creativity, Critical Thinking and Deeper Learning are features of Open School Culture that has been and continues to be discussed at international level. A school like that is an innovative ecosystem that shares learning and science with factors within and outside of it. Such a school is in communication and interaction with other schools as well as with society outside of it, by importing and exporting information and features that prompt exploration and promote knowledge. Students in an Open School are practically working with problems related to realistic needs of the society outside the school, using society's experience and knowledge and presenting their works publicly. Thus they cultivate 21st century skills, strengthen their independence and act with the motto "act locally but think globally" in a school that becomes a factor of social well-being. In such a context equality between genders is propelled by promoting participation not only of the boys but also of the girls in Science.

Rhes (2007, as mentioned in Manas at the Manara,[32] also recognized this important relationship of an educational organization and society, with mutual support and development. Among others, the aim of this collaboration is to provide the best learning outcomes by taking initiatives and applying innovations such as: developing activities useful to students (according to their inclinations and interests), linking the educational organization with the production units of the region, utilization and exploitation of building facilities and infrastructure of the educational organization and the region. In Greece the cooperation between school and society has been accepted as a need for action, but no moves similar of both sides are being promoted, mainly due to its centralized education system (Eurydice, 2002, as mentioned in Manara, 2007) which gives only limited autonomy. Indeed in Manara's research [32], who investigated aspects of Greek educational reality on the issue, the results showed that no particular effort was made and that the Greek school was not intergraded into society.

The Project of "MARiStotelio" was related to a realistic problem of mankind, for which a multidisciplinary PBL-S.T.E.M. approach was applied, in line with the model of Directed Creative Process Model (see above). At each stage the form of exploratory process and more specifically creative scientific inquiry was followed. Taking into account the age and the experiences of the students, a guided rather than an autonomous investigation was considered more appropriate. The exploratory activity of the 10 children of the team (including 4 girls in order to increase their participation in Science) has led to the development of their creative and critical thinking skills. The gradual exploration of different problems (e.g. the need to colonize and to find the most appropriate place) led them to seek out and analyze a number of factors and to develop critical thinking so as to find the best solutions. Engaging them with real future problems played an important role, encouraging them to think more creatively since they had to deal with problems that concern them as future responsible citizens. As independent sub-teams, they recovered preexisting individual knowledge to identify data and problem solving factors through persistent brainstorming (Figure 1) and data analysis.

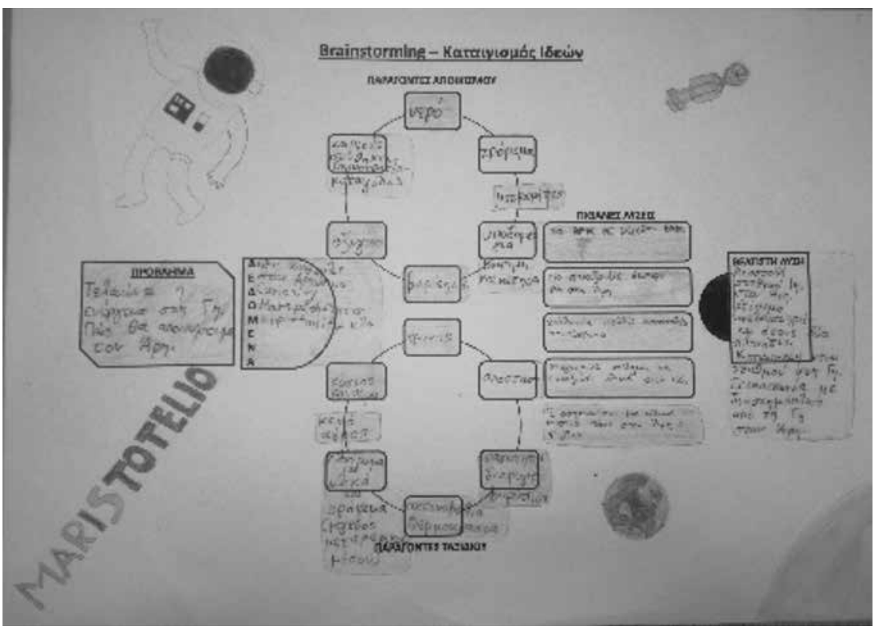

Figure 1. Brainstorming of the students for the project.

The students had a remarkable backdrop of scientific knowledge about the issues they were concerned with, but not from the beginning in all aspects of the investigation. They therefore searched for information in printed and electronic sources, contacted experts, exchanged ideas and views with another students' team in Xanthi that was working on another project and talked to each other to categorize the factors that affect the journey to Mars and its colonization. By creating mental maps (Figure 2) they also captured both the gathered data and the process by which they found solutions. The networks of these maps constantly created new concerns that directed searching for optimal solutions and applications.

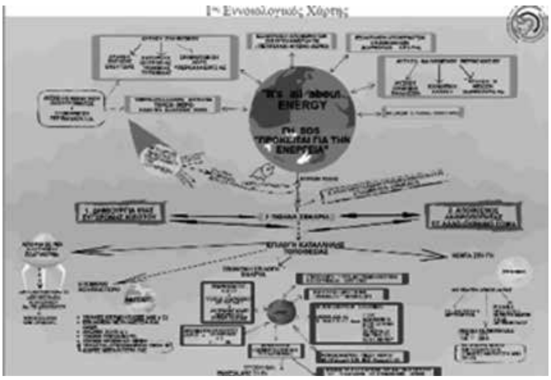

Figure 2. A mindmap which was created from the students for the 1st phase of the project.

Throughout the research process, they asked questions of scientific research, while having enough time to ask, to collect data, to make assumptions (e.g. possible solutions and their appropriateness) and to examine by critically rejecting or maintaining them. So the students interacted socially with their peers within a group, but also with educators and experts to draw scientific conclusions, which turned into empirical and technological data to find a solution to a large-scale enterprise (space platform). They also attempted to analyze and explain their ideas, with analogies and modeling (e.g. an example of a fountain-concept pond, an aerodrome platform layout for the space platform, the representation of planetary motions with their own bodies, experimentation in a digital environment for movement geostationary satellite). In this modeling, their interaction in virtual space contexts using appropriate equipment was also very helpful. In addition, they cognitively set up and described processes and schedules of implementation in realistic times (e.g. sending a platform to Mars and simultaneously building a second platform on Earth in order to continue the mission). They attempted to understand and model explanatory demanding scientific concepts (e.g. gravity, gravity wells, escape velocity, forms of energy). While seeking alternatives, they even countered the existing ideas-solutions of the scientific community (e.g. sending missiles directly to Mars for colonization). Beyond the creative nature of the process, the product of the possible and of the optimal solution was innovative for the pupils, since it was something new for them based on their pre-existing knowledge and experience (e.g. a student suggested creating an elevator to connect Earth and the platform without knowing that it already exists as a thought). Throughout the process, scientific opinions emerged through constructive discussion of different ideas, reinforced by spontaneous and flexible expression of thoughts and opinions. The usefulness of the ideas (both individually and socially) has been deemed essential, as they have not only built new knowledge into various subjects but also their final proposal concerns the future of mankind.

The creativity of the students has been extended to the field of Arts. They not only depicted space issues but also painted, designed, constructed mental maps, maquette of the mooring field and the space platform. In addition, they used the performing arts of theater, music and dance and created a theatrical play that presents the concern, the process of investigation and the process of finding their solution. The presentation was more specifically based on an interactive theatrical performance that prompts the general public to approach scientific concepts, processes, finding of solutions, do experiments within a polymorphic environment inextricably linked to modern reality. Having an Open School Culture, it was first presented to a wide audience at the "4th Children's and Adolescent Book Festival" in Volos (2019) and then at the "FFL Junior" organized by EduAct in Thessaloniki (June 2019).

We assume that the approach and development of this Project enabled students to show their creative features that can of course be cultivated further. The process of the implementation took place in a safe educational environment, where they could express themselves without the fear of error and interact socially so as to build scientific concepts and ideas.

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We are the Coding Maestros! What's your Super Power?: A K12 Case Study where Art Meets Science

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Abstract

What is the result when music and dance meet coding in an informal, cross-grade, student-led context? This was the focus of a case study that was based on the Coding Maestros project. Under the guidance of the Elementary School Music teacher and the Director of Educational Technology, 17 ACS Athens students representing grades 1 through 9, created, and led four well-attended and enthusiastically received sessions. The project goal was to demonstrate a continuum of learner-centered, authentic educational activities, from basic to more advanced that were founded on an innovative blend of student-performed music and coding with the support of an augmented reality software, as well as live instrumental and dance performances. The underlying research goal was for the teachers to understand each other's perspective and build a shared framework, and for the students to develop a deeper understanding of this holistic, inquiry-based approach to education through creativity, collaboration, and communication outside the boundaries and expectations of formal learning. The culminating performances demonstrated how through holistic, inspirational and innovative educational STEAM activities, students can enjoy an unforgettable and unique learning experience that engages their attention and sparks their curiosity to pursue deeper learning in any of the STEAM related fields.

Keywords

STEAM; creativity; communication; collaboration; inquiry-based learning.

1. Introduction

What is the result when music and dance meet coding in an informal, cross-grade, student-led context? Having started about a year ago, *The Coding Maestros* project was presented in May 2018 as part of the annual ACS Athens (K12 International School) Literacy Festival, and in the Athens Re-Science Festival 2019. Under the guidance of the Elementary School Music teacher and the Director of Educational Technology, 17 ACS Athens students representing grades 1 through 9, created, and led four well-attended and enthusiastically received sessions. The project goal was to demonstrate a continuum of learner-centered, authentic educational activities, from basic to more advanced that were founded on an innovative blend of student-performed music and coding with the support of an augmented reality software, as well as live instrumental and dance performances. The underlying research goal was twofold: for the teachers leading this inter-disciplinary, STEAM initiative to understand each other's perspective and build a shared framework; for the students to develop a deeper understanding of this holistic, inquiry-based approach to education through creativity, collaboration, and communication outside the boundaries and expectations of formal learning. The culminating presentations/performances demonstrated how through holistic, inspirational and innovative educational STEAM activities, students can enjoy an unforgettable and unique learning experience that engages their attention and sparks their curiosity to pursue deeper learning in any of the STEAM related fields.

2. First things first: From literacy to literacies

Owing to the fact that the learner (future employee and citizen) of the 21st century is required to possess a carefully redefined array of character qualities, competencies and skills, the pathways that may lead the development of such learner, and most importantly the very concept of literacy itself has necessitated a complete reform (Figure 1).

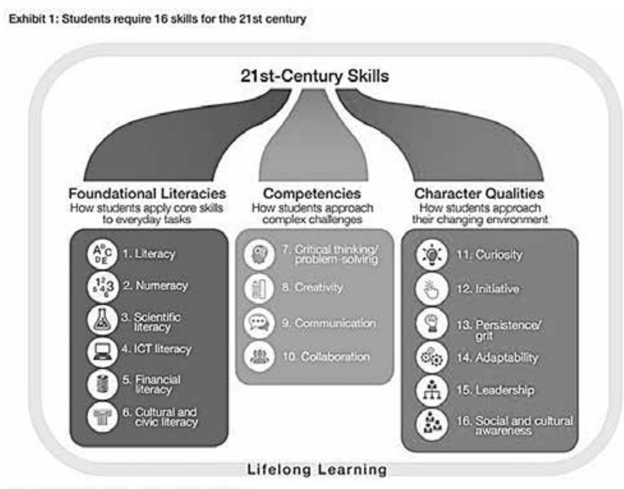

Figure 1. New Vision for Education (World Forum, 2016)

As a result, in this century Literacy has been transformed into multi-literacy, an umbrella term that includes different types of literacies from foundational and scientific, to civic and ICT/coding. All of these literacies, despite being familiar or new, are not only interrelated but also perfectly aligned with the fabric of the learner profile that contemporary education systems across the globe, aim to create. Yet, education philosophers, researchers and practitioners have not reached a consensus as to which among the aforementioned literacies are more important; they have even advanced literacy sets that may differ in their focus and associated domains.

For the theoretical framework of the Coding Maestros project, we specifically selected an educational Blogger's (Pietila, 2017) view of the top 10 literacies in education today. These were put forward as follows:

1. ***Digital Literacy***
2. ***Media Literacy***
3. ***Visual Literacy***
4. ***Data Literacy***
5. ***Game Literacy***
6. ***Health & Financial Literacy***
7. ***Civic & Ethical Literacy***
8. ***News Literacy***
9. ***Foundational Literacy***
10. ***Coding & Computational Literacy (***Few literacies are more hotly debated than coding literacy. No, not every kid will grow up to become a computer programmer, but each can benefit from learning to think about how a computer could help solve a problem – like how to unearth fire hydrants more efficiently after a snowfall (hint: write an app!). The ability to dream up a solution is just as valuable as the ability to code it).

3. Music and coding

As the name suggests, *The Coding Maestros* project emerged from, and reflected an integration of the musical and computational/coding literacy. After all, the notion of multi-literacy is not new to musicians since the number of literacies practiced and involved for the performance/creation of a piece of music are multiple, and require a fine equilibrium and handling of all actions involved.

But, how did the project start, and, most importantly why?

From the Educational Technology perspective, the EdTech Director had noticed that all popular technology-based games (including programming/coding) were heavily focused on Science, Technology, Engineering, and Math (STEM). Yet, her own philosophy and resolution coupled with the school's vision, was to bring the Art component (STE**A**M) into these games and associated activities, thus helping students and parents familiarize themselves with ways in which technology could be applied in the arts and humanities, open windows of possibility, and instigate informed exploration into interdisciplinary territories.

Upon evaluating existing educational technology software and apps, award winning Osmo's *Coding Jam* became the tool to help us blend coding education with music through iPads (Wiggers, 2017). This augmented reality software is based on the intersection between the physical and the digital world, as recommended -among others- by MIT's media research group (2018). MIT's researchers have strongly emphasized how important physical, tangible elements are in children's learning- especially when introduced to a challenging and complex process such as programming. And so, even if a pedagogically appropriate tool had been identified for the coding with music endeavor, still careful instructional design and planning had to occur. After all:

Certainly, the use of computers to expand our abilities and realize our dreams--or even to create brand new abilities and dreams--is the more forward-thinking, productive, and desirable direction for technology in music. Creative endeavor, just like scientific endeavor, requires careful consideration of what goals are to be pursued (Dobrian, 1988).

From the Music end, the ES Music teacher's teaching philosophy has always translated into endeavors toward finding ways to make transferring of knowledge fun, relevant, and meaningful. She has embraced Barate et al.'s (2015) statement that:
In the digital era, new technologies and computer-based approaches can influence music learning and teaching processes. (...) Many researchers, experts and music teachers feel a pressing need to provide new ways of thinking about the application of music and technology in schools. It is necessary to explore teaching strategies and approaches able to stimulate different forms of musical experience, meaningful engagement, creativity, teacher -learner interactions, and so on.

When the teacher was introduced to music with coding, and in particular to the relevant software for children, she was concerned that using those programs without possessing at least foundational understanding of music, learners would most certainly be lead to falsely believe that they have become successful and knowledgeable composers. This is particularly problematic for young children, who are often impressed by the visual anime and fast delivery results that game technologies of the 21st century offer. She fully believes that understanding of the basic ingredients of music, and experience of performance are necessary in order to achieve satisfactory musical results. In effect, performance skills and knowledge of musical norms, not only can enable coders to deliver what they intend to express in terms of sounds and their combinations, but can also help them attempt to input fine functions for the necessary delivery of various musical styles.

After much research into coding and analysis of teaching norms, the Music teacher concluded with a teaching model of integration, and introduced coding as a medium for transferring knowledge and for deeper understanding of music within the 21st century education framework. Like in Barate et al.'s project involving primary school students, she found great educational merit into applying current pedagogical thinking and research coding and music into her music teaching "through a playful approach to music composition, ... designed to encourage the computational way of thinking" (Barate et al., 2015, 4).

4. Our journey

In our efforts to identify a shared vocabulary and a common ground to launch the project successfully, it became apparent to both of us that we use codes in our every day life. In language, the littlest code is represented through letters and words. In every day music and in music making, it is all the elements, devices, notes, performance-related specifics, etc. As a visual metaphor, to a musician, a code is like the ingredients of a food to a chef. The more one understands the ingredients –e.g. how each ingredient tastes or sounds- the more one can apply them with more success and awareness of their fine combination with other ingredients.

Existing research on the cusp of coding and music has offered a few interesting leads, as well as a solid rationale in support of blending these areas. Interestingly enough, "musicality seems to be a powerful predictor of coding success" (Hughes, 2017). Furthermore, current research spans from identifying the best music for coders to concentrate while coding, to lending support to the fact that many professional musicians nowadays easily follow a coding career precisely because they already possess the following essential skills:
• Attention to detail
• Sequencing
• Matching the right things together
• Collaboration but also ability to work independently without much supervision
• Good timing
• Synchronization
• Self-Discipline and Patience
• Focus
• Creativity
• Visual abilities (both Spatial and Temporal)

Yet, let us side with Hughes (2017) when he observes that:
These are just some of the parallels between musicians and coding. In fact, there are myriad of ways in which being proficient on an instrument is a great pathway to learning how to program. And, the ability to code in today's information economy is a ticket to some great career opportunities.

On the other hand, becoming a computer programmer or computer scientist should not be the only reason why we teach coding. As Resnick (Merrill, 2017) beautifully puts it:
Very few people grow up to be professional writers, but we teach everyone to write because it's a way of communicating with others—of organizing your thoughts and expressing your ideas. I think the reasons for learning to code are the same as the reasons for learning to write. When we learn to write, we are learning how to organize, express, and share ideas. And when we learn to code, we are learning how to organize, express, and share ideas in new ways, in a new medium.

On a similar vein and while looking at coding and music composition, Brantingham (2016) suggested that one can learn a new language (composition or programming), "by understanding the basic elements of the language, and then applying that understanding to the process of modeling great compositions. This process is:

1. Experiencing the music (listening and playing)
2. Reflecting on the music (copying by hand and analyzing)
3. Creating abstract conceptualizations (pulling ideas from them, and giving them names)
4. Experimenting with those concepts (composing new music based on what you learned)

And to conclude, through both our individual research paths, and our professional synergy and shared explorations, we came to agree that coding should be viewed as an effective teaching tool for literacy. We subsequently went on to concur that coding should not be available exclusively to STEM curricula (toward the development of requisite skills), but also to Arts and Humanities curricula in support of a truly integrated way of learning. Let us not forget that our students no matter what they study, they are somehow connected to technology, both as consumers and as creators. Therefore, positive online presence (Buchanan, 2018) and digital citizenship, that is knowing how to behave responsibly as a "pro-sumer" (Toffler, 1980) of technology is a skill of paramount importance that needs to be developed through a variety of learning experiences, including interdisciplinary projects such as The Coding Maestros.

5. The Coding Maestros in action!

Wiggers (2017) reminds us that "Music is a strong motivator — and a powerful learning tool. One study found that students who listened to their favorite songs wrote twice as much while doing so as those who didn't".

On a similar vein, our students initially showed a strong interest in the project for different reasons. Some were into coding (#4 students: all 3^{rd} Grade), and into learning a new software. Some were dancers (#5 students: *2 3^{rd} Graders & *3 9^{th} Graders) who became rather intrigued by the notion of reproducing the smallest music element via their body movements. Some were music instrument performers (#6 students: *1 2^{nd} Grade; *1 3^{rd} Grade, *2 5^{th} Grade, *1 6^{th} Grade, & *1 9^{th} Grade) who had never reproduced a digitally created sound, or improvised on the basis of that sound. It took a few, short yet full of "a-ha moments" meetings to let the students explore, unpack, and get inspired by the blend of coding with music (and dance).

During the presentations, some of our students were responsible for live coding (basic, and progressively more advanced) utilizing Osmo. Another group was in charge of a range of movements that represented simple codes all the way to more complex moves reflecting equally complex sounds, accompanied by live instrumental performances. And a third group participated with more advanced live music coding demonstrated through the 12-bar blues (ACS Athens Literacy Festival), and then via a student-composed musical piece (Athens Science

Festival), playing guitars, violins and piano. For this last part, we had been inspired by Sorensen's concept of "creative computing" (2014) whereby the presenter engages in live-coding the generative algorithms that will be producing the music that the audience will be listening too. For the 2019 presentations, we introduced a narrator (Brain character) who appeared to orchestrate all groups while explaining to the audience what their actions were about and why. Another character (the Jester) would engage the audience's attention throughout the performance with signs that either emphasized the Brain's shared concepts at different times, or invited the audience's input via applauds, or agree/disagree positions.

6. Results
6.1 Presentation

Student input was collected via surveys and personal interviews. We also have our own reflections, and observations of student input in and on action. For the purposes of this work, we mainly present student data. Questions addressed to students regarded both their perception of learning through the rehearsals and performances; and, their satisfaction with the overall engagement with the project. Results emerged through data analysis (content analysis) indicate that this was an overall positive (91%) and fun (82%) learning experience for them. In addition, they enjoyed and valued collaboration (65%), and the opportunity to be creatively engaged with inquiry-based learning (76.5%) with minimal guidance from the teachers. All this taking into consideration that the project run outside the boundaries and expectations (e.g. assessment) of formal education. Despite it all being above and beyond their expectations, their regular school day, there was no assessment involved or any other incentive. There was no direct or indirect reference made to negative feelings, and all students would recommend this project to their peers. Words such as *happy*, *fun*, *inspired* emerged as major themes of the data analysis.

It was clear from the data, that the element of mystery/unknown had captured and sustained student attention. The fact that this was a project based on cross-grade, cross-curricular collaboration and co-investigation was a major positive factor for the students.

The students demonstrated that they had internalized and could use new, STEAM-related vocabulary (terminology), which implies new and expanded thinking (e.g. *STEAM*, *synchronized*, *coding*, *instruments*, etc.).

Students' perception of the project's goals was to have fun; to experiment with their selected roles; to pursue their individual interests; to exchange ideas with students from different grades; to put together a performance and formally present it in front of an audience (inside, and outside their school premises). The overwhelming majority (16 out of the 17 students) reported high satisfaction (88.2%) with their perceived understanding of how coding, dance, and music work. However the project's main thrust was not didactic: we were not interested in teaching them coding, or music learning per se. Rather, we used this approach as a springboard to begin discussion and/or further exploration of STEAM related experiences, and to create the conditions for deeper learning in STEAM. That was certainly achieved.

6.2 Discussion

Discovery learning as an educational approach that was designed as a series of informal, thematically connected instructional events with volunteer student participation, worked successfully for this project. Project roles were assigned by us but with the students' prior consent, and with little teacher guidance and intervention. Essentially our role was limited to helping the students synchronize, and put information on a script.

Further, the project inspired students to experiment with different project roles at a later stage, beyond the life of the project. For example, students who were involved in the coding part, after the project ended, started lessons on a (new) instrument, and vice versa. Their goal was to join the project under a different capacity in the new academic year.

Essential to the nature of our project, was the fact that exposure was expected through performance in front of an audience. And while performing arts people are accustomed to exposure in front of audiences, coders and IT practitioners by working in isolation, are typically not used to such exposure. The amalgamation of the three disciplines in the Coding Maestros, offered a platform to the latter to develop performing skills in a safe and creative context. Music and Dance transformed Coding into an almost performing art subject.

In education, we must capitalize on both of the aforementioned elements, that is, discovery learning and a holistic approach to learning, in order to increase our students' chances to engage with STEAM education at a deeper level, but in a more holistic, inquisitive, and out-of the-box way.

In closure, here are a few of our students' comments that underline exactly that:
Student A: "I really liked this project because no one had ever before composed music for me to dance!"
Student B: "I liked figuring out how to code music in collaboration with others".
Student C: "This was so much fun! I loved playing all this music with my friends".
Student D: "I never thought I could code with music!".
Student E: "I love music and I thought coding would be hard. It turns out that coding is fun and makes me better understand how music works!"
Student F: "when I came to the room, when I first sat on the chair and saw everybody playing, my eyes moved back and forth and it was fun everything that was going on".
Student G: "So STEAM is basically what the acronym is and is basically what you want to communicate with people using the languages and make more friends and be open minded".

7. Conclusion

In conclusion, let us reiterate the importance of STEAM experiences for the development of 21st century skills, as they combine hands-on, innovative problem solving, with interdisciplinary and inquiry-based learning, while also allowing for intuitive training on design thinking, as well as direct transferability of skills. From that angle, our perspective is in total alignment with Segarra et al. (2018) who state: (…) STEAM strategies are a good complement to conventional pedagogy and training approaches in the sciences—allowing trainees to exercise creativity and innovative thinking. As we look to innovate in the sciences, we should strive to use STEAM approaches to foster the creativity of scientists and scientists-in-training.

8. Acknowledgements

We are deeply indebted to the students that participated in our study for we could not have done it without them: thank you, Coding Maestros!! Here's to your generosity, kindness, courage, determination, open-mindedness, curiosity, and imagination!

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"A proposal for an experimental seminar on the concept of "Ξένος" (Alien) through the use of the virtual three-dimensional platform @postasis"

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Abstract

This paper presents a case of deeper learning based on a 3D multiuser virtual space and an educational methodology towards deepening in Digital Arts and Digital Culture. This virtual artistic laboratory (@postasis platform) enables people from all over the world to collaborate in joint projects. It creates a contemporary space of deeper learning, where various issues are addressed, such as human computer collaboration, development of large-scale artworks, use of the "intelligence" of the computer, and enlargement of hidden human abilities. The presentation unfolds through a course-seminar, developed in @postasis platform, which is based on the concept of Alien.

Keywords

Art as deep learning, Alien project, virtual entities, @postasis platform

1. Introduction

This paper presents an educational methodology, close to the concept of deep learning, developed through an Art process. It is the "Ξένος" (Xenos = Alien) seminar that takes place through a multiuser platform, the @postasis platform, developed in the scope of Erasmus+ @postasis: Virtual Artistic Laboratory project (apostasis.eu).
@postasis is a virtual multiuser three-dimensional space. It aims to provide a distributed real-time learning capability to different collaborating teams of students and professors.

Our time is particularly sensitized as to the concept of Alien. On the one hand, large segments of populations immigrate because of violent situations. On the other hand, technology creates new, different kinds of life structures that will play an important role even in our everyday life (robots, smart machines, AI).

Students are invited to experiment with the Alien concept by creating, in an empty 3D space, virtual entities that are programmed to have "autonomous lives". They learn to formulate complex ideas, convert them into a composition of real-time images and programming language commands/scripts. They also learn to create from distance, collaborate with people from different nationalities, via digital art approaches. Each team creates three-dimensional models and simulates life, through the use of mechanisms from computer games (scripted behaviours).

All groups participating in the seminar observe the procedural life, within the virtual space, via avatars that they create themselves and that evolve their world. Which of these entities could be aliens?

2. Thoughts on deeper learning

A reference to the concept of "deeper learning" is necessary, in relation to the conditions of today's era.

In the post-digital age, there is a great accessibility to any information or knowledge, its interpretation and its visibility.

Through this process, old experiences are discovered, re-examined and institutionalized.

Thus, a great emphasis is put on some human processes that exist since many centuries ago, in the adventure of man for a better life. The novelty in this case is not the discovery of these processes, but the incorporation of their structure in basic education.

Therefore, data of the past return with another composition and hierarchy.

This, also, concerns the case of "deeper learning". In our days, this concept is defined in the US, where it first appeared as a "set of student educational outcomes including acquisition of robust core academic content, higher-order thinking skills, and learning dispositions... Items that are definitely needed as supplies since ... the nature of work, civic, and everyday life are changing and therefore increasingly requires that formal education provide young people with mastery of skills like analytic reasoning, complex problem solving, and teamwork".[1]

In other words, deeper learning reflects the everyday life of scholars of all levels that has been gradually modeled through experience. The greatest change that has been made since the beginning of industrial civilization (18th century), apart from the development of the tools, was the development of the concept of the "project" (17th century in research, 20th in education) and thereby of the teamwork.

Certainly, people who actually had the gift of deep thinking and an enhanced ability of combinations had described a method towards this direction, in a very targeted way. Gottfried Wilhelm Leibniz, around 1680, describes the ideal library as a multi-center structure, which, in addition to books and pictures, contains also descriptions of the machines and the machines themselves. [2] It is a space for scientific experiments of groups of artists, technicians and scientists, even a printing laboratory to publish various theoretical studies.

3. Art: a characteristic method of deep learning that consists of a combination of insight, science, imagination, inspiration and interpretation

One of the most important fields for deeper learning is Art. Art comes from man's attempt to interpret the unknown force of nature. This effort is gradually separated into Religion, Science and Art, three fields each of which, in its own way, attempts to interpret the mystery of life.

The creation of an important work of art requires a deep theoretical and scientific knowledge of the historical period that is taking place, the ability of interpretation of the events, excellent technique of the tools or devices and the efficiency of continuous evaluation of the result during its completion. Artists introduce the entire knowledge and structure of the historical period of reproduction to the surface of the artistic work.

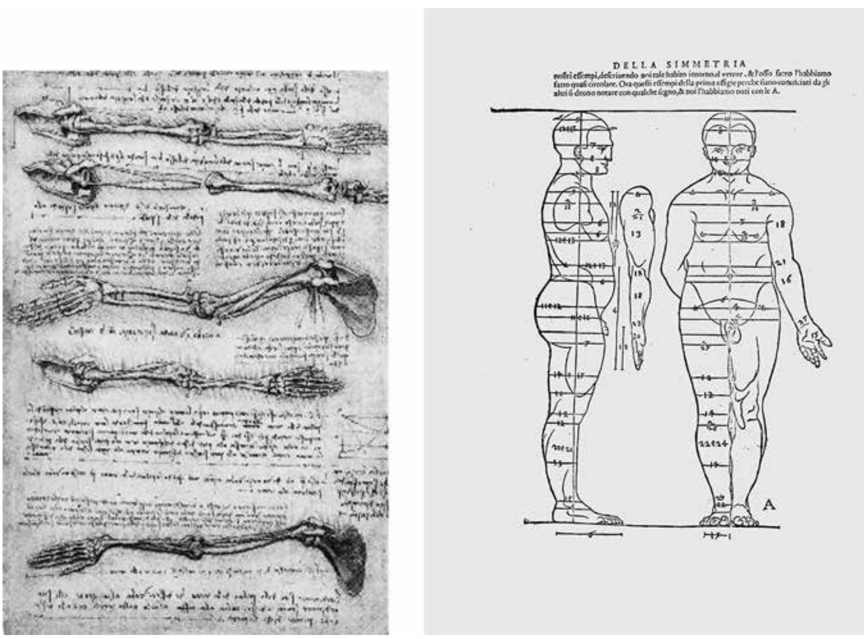

Figure 1. (left) Anatomy, Studies of the Arm, drawing by Leonardo da Vinci (1510) (right) From the Four Books on Human Proportion of Albrecht Dürer

The above is reflected in many historical examples, such as the scientific work of Leonardo da Vinci, through his notebooks, his anatomy and scientific drawings, as well as the work on anthropometry and geometry published by Albrecht Dürer [3], the methodology for art and technology of Bauhaus, and the contemporary close relationship of computer science with artistic creation.

Therefore, it is important that the concept of Art be included in deep learning as an autonomous equivalent process of intelligibility and scientific enlargement. [4] Art can contribute dynamically since it contains a number of particularly important educational properties, such as a) in relation to the theories of Piaget and Papert (about learning objects) [5] it provides both intermediate tools, and an entire space within which creation forms may arise, and b) it is one of the few lessons that does not have one correct answer and everything else is wrong (like in math, physics, etc.), but there is the possibility of developing many different interesting solutions.

Art is a complex system of intelligent organization of thought, creating new concept structures and links. It lies on the border between science, mathematics and philosophy. It is the result of a highly concentrated thought.

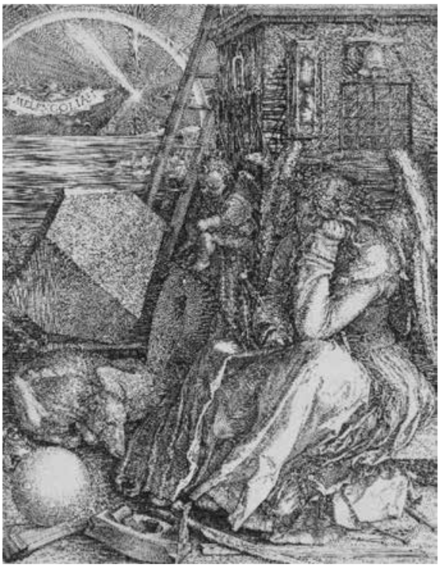

Figure 2. Melencolia I, gravure by Albrecht Dürer (1514)

4. The proposal “Ξένος – The Alien”: A seminar of digital artistic creation for artists, or for younger people, that considers artistic creation a means of cultural education and growth

4.1 The concept

The “Ξένος – Alien” incorporates different conceptual dimensions, depending on the point of its observation. Our time is characterized by the violent migration from the south to the north, and, on the other hand, by space colonization, biotechnology, robotics and artificial intelligence that influence human existence. For all these reasons, the concept of alien will be a dominant research issue, at many different levels.

The processing of these different ideas and combinations is an interesting tool that can provide an important intellectual material for the theoretical part of the seminar. It inevitably faces questions, such as: in an empty space who is the alien and who is the intimate? What are the morals that apply inside this space? What is an artificial identity? Can there be any evolution of this artificial life? Which rules will be incorporated?

The participants are invited to create entities in a neutral space and to study in this space the concept of the alien and the acquainted.

They create programmed beings (NPCs) (three-dimensional models with programing actions) that develop an autonomous life, as well as avatars through which participants and visitors are introduced to the game. Participating teachers and students visit, watch and discuss the creations and life they create in order to capture and interpret it as well as its evolution.

4.2 Practical aspects

The practical objectives of the “Ο Ξένος –Alien” seminar are:

a. the creation of entities and artificial life in the multiuser space of @postasis platform
b. the development of life evolution through proposed conditions
c. the development of actions inside this space
d. the study and interpretation of the actions and the operation of the space
e. the evolution of space and entities based on the conclusions of the studies.

4.3 The technical objects: entities, avatars and neutrals objects

There are different types of technical objects that the participants are asked to construct:

Neutral objects: It is any object which may have attributes (e.g. color, hardness, gravity) but has no life.
Dynamic objects:

Avatar: It is the entity that the creator or the visitor “wears” in order to navigate and interact with the space.

NPC: It is the entity that will inhabit the @postasis space and gradually will create its life. An NPC (Non-Player Character) in a digital game environment is any character that is not controlled by the player but by the computer, through predetermined behaviors, simple or complex.

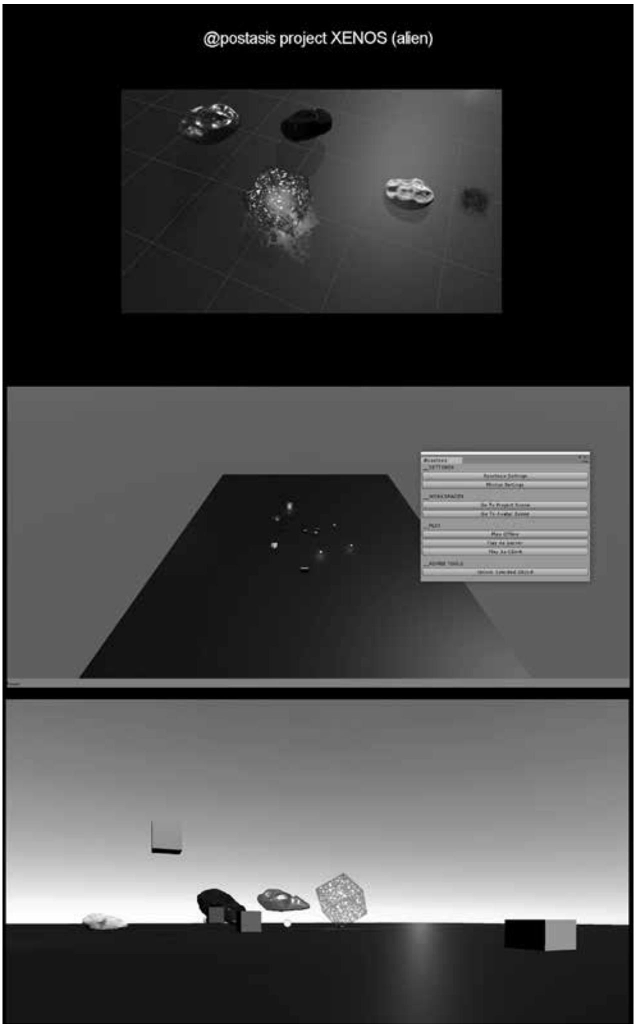

Figure 3. a. entities for the project “Ξένος –Alien”, b. the virtual place (bird view), c the virtual place (from avatar view)

4.4 The seminar's virtual multiuser space

The space, as proposed by the seminar, is initially empty. Its base is composed of a flat ground while its properties are close to the properties of the earth (gravity, hardness in materials, etc.). Of course, these may be overturned by the participants.

A specific range of the space is defined and transparent boundaries are inserted.

The final form of the space will be defined by the movement and life of the entities inside it. The proposals of the participants determine the space. Therefore, the life of the space is created by the way the entities are programmed, as well as the space itself.

Gradually, the space evolves through the autonomous life and the results it generates. Through new regulations. Through the theoretical conclusions and new proposals.

Figure 4. Workshop at Eindhoven, 2019 (in collaboration with University of Ioannina, Prof. Amalia Foka

4.5 The @postasis network

The three-dimensional virtual space of the seminar is open to groups from all over the world. In order for a group to participate a preparatory work is necessary with the seminar coordinator in order to clarify the methodology of collaboration, and distribute relevant materials as well as the project template software within which the group may develop their work.

Finally, all groups speak the same "technological language" but have different ways of behaviour and possibly aesthetics. This is one of the great advantages of the platform.

Each group prepares the basic artistic works in their laboratory, which will then be integrated into the @postasis common platform, in order to create the collaborative experience.

5. The @postasis platform

@postasis platform constitutes a multiuser virtual environment which combines technologically advanced features, emerging educational techniques, experimen6ts with theoretical research potentials, and a space for the presentation of completed composite artworks.

The implementation of this hybrid space, which combines the virtual and the physical space, is realized based on Unity game engine.

In the context of the @postasis program, certain interfaces that expand the virtual space of Unity are implemented, in order to enable links of communication between entities of the virtual and the physical space (e.g. sound installations, IoT, constructions), through a compatible data protocol (e.g. Open Sound Control - OSC).

Also, collaborative project synthesis mechanisms, from many geographically remote collaborators, as well as real-time multiuser actions are incorporated.

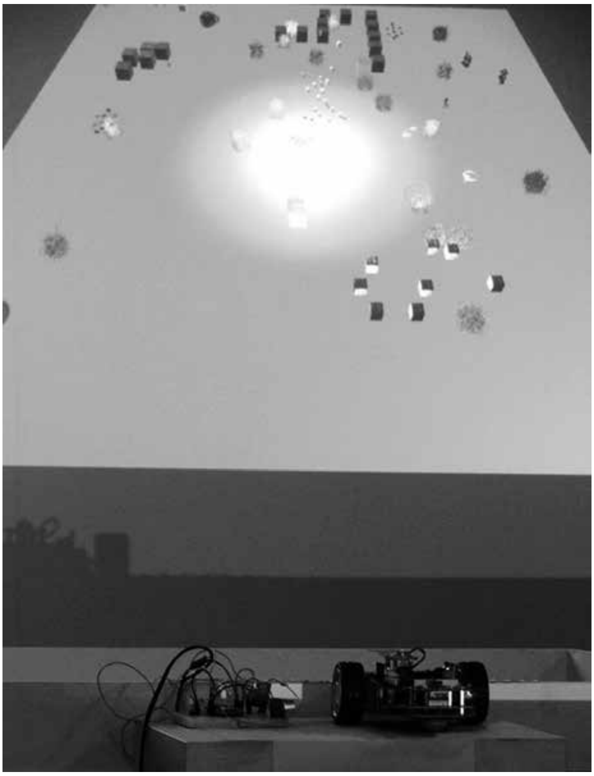

Figure 5. @postasis platform Virtual and real space via Internet of Things

6. The objectives of the seminar

The "Ο Ξένος – The Alien" seminar aims at understanding the new concepts introduced with digital culture, and specifically:
Develop complex concepts and in a friendly way transfer them into programming language.
Understand the concept and mechanism of the multiuser - real time system.
Become familiar with the creation of self-evolving systems
Become acquainted with distance cooperation with people of different nationalities
Become familiar with the creation of digital artworks
Become familiar with the concept and aesthetics of digital art 4th generation.

7. To whom it is addressed

The "Ξένος - The Alien" seminar is addressed to Art and New Media students of all levels (undergraduate, masters, doctoral) as well as to students of Digital Humanities

A more simplified form is also available in primary and secondary schools in conjunction with the lessons of visual art or STEAM.

8. The program: The participants and the next level

The "Ξένος – The Alien" seminar and the @postasis platform are part of the Erasmus + program @postasis: Virtual Artistic Laboratory, which is in progress (Coordinator: Athens School of Fine Arts, partners: Paris-8 University, Omega Technology, MAD, and Argenia).

Most of the platform's technological functionalities have been successfully created. The seminar "Ξένος – The Alien" has been developed and has been tested with undergraduate, master and doctoral students as well as students of primary school. Based on the experience, corrections are in progress and systematic courses and seminars will begin in the next academic year.

In this paper, a proposal for a course-seminar was presented. The flexible form of this platform enables to accommodate many and completely different course ideas. The platform is not in the form of a user-friendly application, but of a difficult puzzle that can be solved only through deeper learning and close cooperation between students and teachers from all over the world.

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Fostering Deeper Learning through iMuSciCA's STEAM-pedagogy

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Abstract

In this contribution we show how a STEAM-pedagogy scaffolding deeper learning can look like in practice. We present the case of the European project iMuSciCA that developed a STEAM pedagogy connecting Science and Mathematics with Art and Engineering and which is concretized and brought into the classroom through an ICT-workbench and dedicated lesson suggestions.

1. Introduction

Most students nowadays in school see hardly any relation between concepts or skills that are being taught to them in different fields or subject matters (Honey et al., 2014; Bevan et al., 2015). Following the recommendations of the American report on STEM Education (Honey et al., 2014) iMuSciCA not only uses concepts and skills *through different subject matter fields*, but more important, this cross-subject journey is made *explicit* both to learners and to teachers. Learning becomes more relevant when learners can experience how insights from different fields concerning the same subject are complementary and reinforce each other.

Examples:
Students often learn about waves and their superposition in physics or mathematics, but they don't connect these insights to what they experience when listening to music: to melody, to timbre or to harmony.
On the other end when students get an engineering task like 'design and build a music instrument', they discover that concepts of mathematics and physics are needed in order to complete the task.

Note that connecting disciplines does not mean abolishing them. On the contrary the aim is to show the relevance of the different disciplines to learners. This is precisely the power of an interdisciplinary STEAM pedagogy. By doing so such an interdisciplinary STEAM pedagogy addresses the well-known aspects of deeper learning: i.e. enlarging cognitive, interpersonal and intrapersonal competencies. The iMuSciCA STEAM pedagogy builds upon the definition of Deeper Learning as given by the Hewlett Foundation. In what follows we describe how.

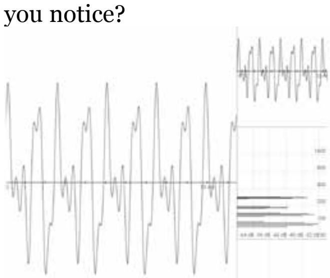
2. Deeper learning in iMuSciCA
Cognitive Competencies

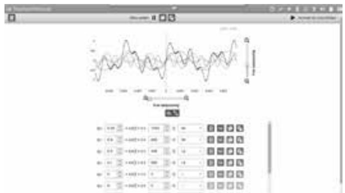
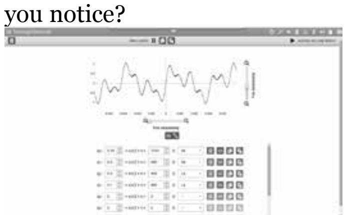
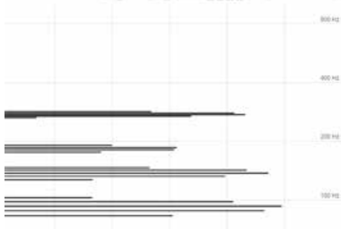
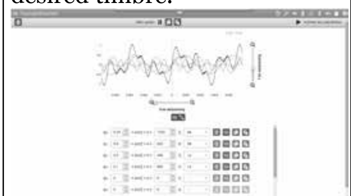
The aim of the iMuSciCA STEAM pedagogy is precisely to help learners applying the acquired knowledge of one STEAM discipline to the context of another and hence to make the links between disciplines more explicit (see also Honey et al., 2014). Indeed, as Sutherlands states: “It is not enough for learners only to understand big ideas; in fact, they cannot develop integrated understandings of even these core ideas unless they use their knowledge in meaningful ways, applying what they know to a variety of contexts and to novel situations” (Sutherland et al., 2010).

The iMuSciCA STEAM pedagogy enables students to work on a horizontal dimension connecting the various STEAM disciplines and on a vertical dimension deepening the knowledge of each individual discipline. iMuSciCA let learners choose their learning path across different subject matter fields making this broad and deep learning possible (Andreotti and Frans, 2019). iMuSciCA’s tasks are designed to actively make connections between scientific insights, musical experiences, and engineering designing tasks.This ‘*diving into different aspects of the same’*, is a powerful tool to strengthen cognitive competencies and especially mastering rigorous academic content.

Below we give an example taken from one of iMuSciCA’s scenarios: *Synthesize the timbre of your preferred instrument*. It shows how a learning path through different subjects looks like. Insights and experiences of different subjects interact and reinforce each other.

Table 1: Learning path from the iMuSciCA's scenario: *Synthesize the timbre of your preferred instrument.* It shows how a learning path through different subjects can look like and how this contributes in performing the task.

Music	Science/Maths	Engineering/ Technology
		We start with an engineering task: the aim is to *reproduce or synthesize* the sound of a musical instrument.
Listen to the same tone on your prefered instrument and compare to the same tone produced on another instrument. Do the tones of two different instruments sound the same?		
	Why does the same tone sound differently on different instruments? Register the *waveform* of the tones of the different instruments with the iMuSciCA workbench. What do you notice? 	

	How does the complex waveform arise? 	
	Measure the *spectrum* of a tone of your prefered instrument: the frequencies and relative strengths of the partials. Compare the spectra of the different instruments. What similarities and differences do you notice?  	Use the superposition of partials as a mathematical model to *synthesize* the desired timbre. 
Listen to the designed timbre and compare it to the desired one.		

Interpersonal Competencies

iMuSciCA's pedagogy makes students confront their thinking with practice and evidence from different fields. Teachers are stimulated to give their students a '*learning studio*' in which small groups of students collaborate on a given issue and reflect upon this with their peers and teachers.

This interaction with different ideas from different people and from different fields helps them to challenge their preconceptions. Indeed, as shown by research, students will stick to their misconceptions until they can discover more coherent explanations based on new experiences or more coherent models (Perkins & Grotzer, 2005). This is precisely what iMuSciCA is working on: iMuSciCA's inquiry let learners seek out for more coherent explanations. iMuSciCA's scenarios support students' metacognition by addressing reflection in different inquiry phases: talking through their own thinking, reflecting on their model or presenting it to peers. This reflection and discussion among learners makes working with iMuSciCA so interesting in the classroom. During the piloting in schools it turned out that the iMuSciCA's workbench can be used as a rich learning environment. Moreover the musical part of it engages learners in a collaborative play and discovery. In this way iMuSciCA also supports the development of positive mindsets by students.

Figures 1: Students working collaboratively in a 'iMuSciCA learning studio'.

Figures 2: Students working collaboratively in a 'iMuSciCA learning studio'.

Intrapersonal Competencies

It is reported that connecting disciplines makes lessons relevant to learners and works positively on student's motivation and creativity (Csikszentmihalyi, 2008; Sternberg, 2006). Indeed iMuSciCA activities can start from different fields and so you can engage students from different perspectives. The context of music 'resonates' clearly with students and this has the potential to motivate students for science and engineering. iMuSciCA let learners play *the whole game*: it is not *talking* about science in music, it is about *experiencing* it (Perkins, 2010).

Furthermore concepts and skills from a certain discipline are applied in a meaningful context. This has the potential to increase students' motivation and creativity. Creativity is indeed an incremental characteristic that needs to grow: creative development requires structure and intentionality and learning 'through the disciplines' is reported to impact creativity (Robinson, 2001; Kim & Park, 2012a; Kim & Park, 2012b).

> For example in scenario *Synthesize the timbre of your preferred instrument,* reported above, students start the task from one specific discipline, namely Engineering, and connect to other disciplines, namely science and music. In this way within iMuSciCA students play the 'whole game' of interaction between the disciplines (Perkins, 2010). Indeed the learning subject is often a small scale copy of something bigger in the real world, but this is seldom made explicit to students. Often in class teachers talk about other contexts

in connection with the studied subject, but this is not sufficient for a deep understanding of the relations between fields and concepts. For instance sometimes periodic functions are presented by teachers as being the basics of music. Or students have to apply the learned concepts further in different exercises. What makes iMuSciCA different is that students not only hear about such connections or apply them in activities designed for them. On the contrary in iMuSciCA students connect by themselves scientific concepts to music and engineering ones (and the other way around). Scenario *Synthesize the timbre of your preferred instrument* for example let the students design, like a real engineer, the timbre of a chosen instrument. So in iMuSciCA students can really play the whole game. iMuSciCA avoids getting stuck in a 'learning about', but stimulates student's learning by letting them play the whole game.

Deeper and intrinsic motivation comes from within (Ryan & Deci, 2000): the question is to trigger the desire to understand main concepts or to perform an integrated task like the one in the example reported above (*Synthesize the timbre of your preferred instrument*). iMuSciCA challenges students to get the whole picture from different fields and synthesize it in a solution. Hence, the interdisciplinary nature of iMuSciCA makes the learning more relevant to learners which in turn increases the possibility to trigger intrinsic motivation (21st century skills). This all makes iMuSciCA quite a biotope for intrapersonal competencies as well as *Learning to Learn* and *Developing Academic Mindset*.

3. Didactical tools to foster deeper learning in iMuSciCA

An important didactical tool in the envisaged interdisciplinary inquiry learning are *concept maps*. Most scenarios are built around some core concepts and skills from different fields: music, science, maths and engineering. Indeed skills and concepts are, though related, not the same in all these fields. iMuSciCA wants learners to discover the 'whole picture' (or at least a more complete one).

Below we give an example taken from the scenario '*Synthesize the timbre of your prefered musical instrument*': it shows how different concepts from different fields contribute to a more complete understanding of a certain phenomenon (in this case: timbre).

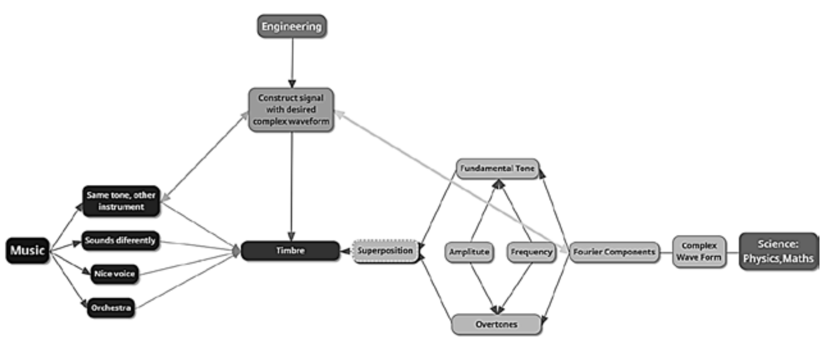


Figure 3: Concept map of the scenario 'Synthesize the timbre of your prefered instrument'.

In the centre of the concept map we find the phenomenon timbre, which is the subject of this scenario. All around we find the connections to the fields of Music, Science and Engineering. For each discipline learners have to inquire and understand the concepts and/or processes of that discipline connected to timbre. The iMuSciCa workbench gives students the tools to discover these core concepts and processes:

> **Music:** in music timbre has to do with orchestration, recognizing a voice or the tone colour of an instrument. Example questions for students are: Can you give examples of these? Can you demonstrate this in an musical piece?
>
> In **Science** (Maths and Physics) one tries to understand sound by functions that are periodic in time. Periodic waves of which the frequencies are entire multiples seem to play an important role in music. Timbre is then understood as a superposition of harmonic periodic waves each with a certain amplitude in order to get a resulting wave. Example activities for students can be: Can you demonstrate on the iMuSciCA workbench how the colour of a tone can be understood as a superposition of simple sine waves? How are the frequencies of these partial sine waves related to each other?
>
> In **Engineering** one wants *to construct* a signal with the desired periodic waveform starting from the harmonics thus using a scientific model to create the desired timbre. An example of task for the students can be: Can you now synthesize the desired timbre for your instrument?

Through this iMuSciCA scenario and with the support of the related concept map students discover how science tries to understand and to explain phenomena (if possible with a predictive mathematical model), how an engineer wants to construct something using scientific or mathematical models and how music is about creating, playing and listening (in this case about different timbres of sounds). In this way students in iMuSciCA learn to see a more complete picture from different viewpoints and from different fields. Concretely the iMuSciCA concept maps can be used by teachers to guide reflection moments throughout an iMuSciCA scenario: for example teachers could 'rebuild' such a concept map together with the students by asking them questions on the results of the activities performed.

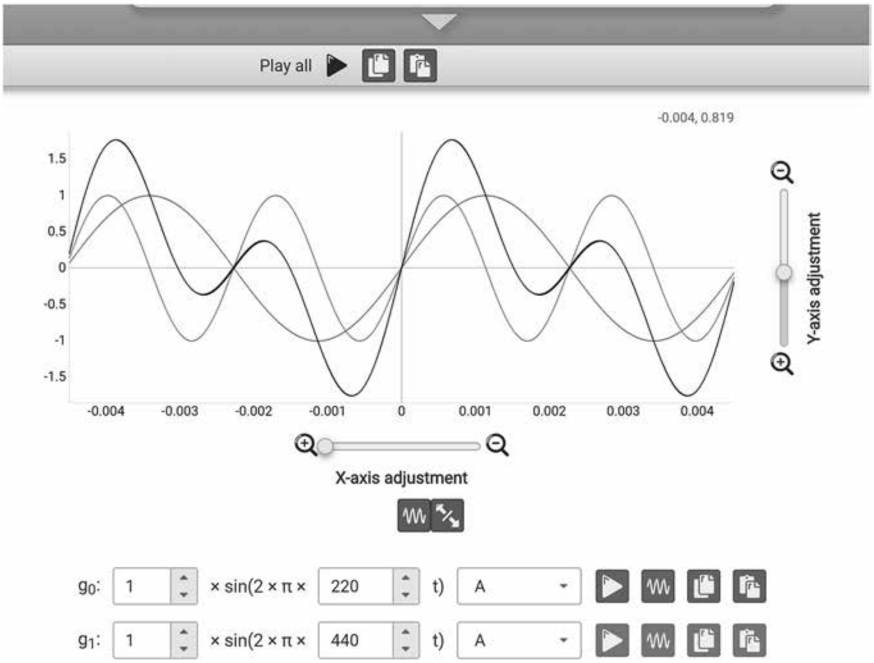


Figure 4: The Tone Synthesizer on the iMuSciCA workbench. It let learners discover the different aspects of the colour of a tone: the musical experience, the mathematical superposition, the design task of an engineer.

4. Conclusions

We presented how the iMuSciCA STEAM pedagogy fosters deeper learning by proposing some examples of activities and didactical tools. It is the interdisciplinary nature of this STEAM pedagogy that addresses all aspects of deeper learning. Students are cognitively challenged by offering them different viewpoints, from music, from science and mathematics, from engineering, to a same problem, and by connecting explicitly these different disciplines. The learners are stimulated to collaborate on a given issue and exchange ideas and reflections with their peers and teachers. This interpersonal approach helps them to question and adjust their preconceptions. Furthermore literature reports that connecting disciplines positively influences student's motivation and creativity and hence addresses the intrapersonal skills. Shortly resumed iMuSciCA has the potential of making learning whole.

5. Acknowledgements

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A School Experiment Inside Blue Origin's New Shepard Space Vehicle Under Microgravity Conditions

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Abstract

American Community Schools (ACS) Athens high school students, with the guidance of ACS Faculty, have brainstormed, designed, prototyped, and built an experiment that was conducted under microgravity conditions inside a space capsule, carried at 100 km altitude by the Blue Origin New Shepard reusable rocket. Launch, flight, and touchdown were successfully completed on May 2nd, 2019. Having to prepare a device to investigate the viscosity of honey under microgravity conditions autonomously, students designed their own learning paths by collaborating in inquiries and decision-making. The payload size and mass limitations inherent to space flights of the kind, as well as the need to meet strict safety criteria, required critical thinking and problem-solving skills on behalf of the students. Placing Physics concepts into a real-life context fostered a deeper scientific understanding and exposed students to necessities of professional research and development programs like multivariate *open ended explorations, project management, and risk management. As a result, students engaged in experiential learning activities on the topic of fluidity which they have not encountered before, realized the many real applications of the theoretical knowledge obtained, and linked between scientific goals and engineering constraints in a S.T.E.A.M. context. Students will be modelling honey's kinematics and will be processing and analysing the data logged during the flight.*

Keywords

Microgravity, Physics, S.T.E.A.M.

1. Introduction

The rapid adoption of information and communication technologies in societies around the world is already shifting job opportunities from the routine cognitive and manual type to those that place an emphasis on critical thinking and higher-order cognitive skills [1]. Fulfillment of such changes in the learning environments that precede exposure to employment seeking is still not adequately represented as shown by the divergent perceptions that college students have about their future labor opportunities as compared to those of their potential employers [2]. An educational framework that promotes building such skills for both teachers and students has been described with the umbrella term "21st century skills", largely based on the synonymous concept of "Deeper learning". Deeper learning is based on building in students the skills of analytical reasoning and application of knowledge in complex real-world problems, usually in a teamwork setting. In particular, deeper learning has been recently articulated in a more focused manner as a set of specific educational outcomes [3]. These concepts are by no means new; for instance, as early as the late 19th century, John Dewey had described education as "not only as a place to gain content knowledge, but also as a place to learn how to live" [4]. As arguable as this might have been more than a hundred years ago, our current fast-paced and ever-changing world renders now this realization as imperative as ever, and its application to education a *sine qua non*.

Traditional teaching encompasses passive learning and absorption of concepts by the students following demonstration of knowledge by the instructor and simple reading of a textbook. Modern teaching nowadays is enriched with inquiry-based learning, where youth actively researches, designs, investigates and reflects on outcomes. What is even more meaningful and completes the circle of inquiry is that students also find a constructive way to communicate their investigations to a wide audience [5]. The National Science Education Standards underlines the importance of inquiry-based learning in K-12 and in all domains of Science and re-defines the use of the scientific method not only as a structured step-by-step process but as a combination of knowledge, experience and skills [6] [7]. Studies have shown that students at all levels of performance who become inquirers develop higher order-thinking skills, better analytical skills and improved communication and social skills. In parallel, educators who promote this kind of learning in Science subjects become more reflective of their practices, more innovative and more effective in engaging students in Science learning

[8] [9]. What can be better than emerging new inquirers who may/will become professional scientists to acquire early on logical thinking, independence, objectivity, skepticism and open-mindedness to finally become ethical civilians of this world?

Gardner [10] underlines the crucial role of creativity and characterizes it one the five most important cognitive abilities a leader should have, while progress in science and creative thinking are inseparable. It is indisputable that imagination and creative thinking are crucial in order to produce new theories in science. However, in science education creativity has a slightly different meaning. It is not the unique ability of a person but the process in order to instill in each and every student traits such as creativity, imagination and critical thinking. Numerous articles have been written about the importance of creativity in science education. Creativity in science education refers to all the exciting and innovative ways to deliver the curriculum through a variety of activities that promote teaching and learning. The types of activities that enhance creative learning include discovery, understanding, presentation, application and transformation of scientific knowledge [11]. Other activities, such as creative writing, science inquiry, creating analogies to understand phenomena and ideas, as well as appropriate connections to art, were proposed by Hadzigeorgiou et al. [12] that stimulate students' curiosity and increase the possibilities for their creativity to emerge. According to Toh [13] a student-centered teaching approach not only will increase participation in classroom activities, but will also stimulate enjoyment and self-concept.

The school experiment presented in this paper was conducted autonomously on May 2nd, 2019, inside Blue Origin's New Shepard vehicle, launched from Blue Origin's West Texas Facility for its 11^{th} mission, carrying a total of 38 experimental payloads from NASA, schools, and research organizations around the world. The main objective of the experiment was to investigate how the viscosity of honey, expressing its internal friction, changes under different degrees of microgravity. Numerous scientific experiments have been conducted in space under microgravity conditions, essentially free falling, since 1970, including the ones aboard the International Space Station (ISS) and other Space Shuttles while orbiting the Earth. Short duration microgravity experiments that utilized free-fall experiment facilities have been ongoing since the 1950s [14].

Blue Origin [15] is a cutting-edge aerospace company that has achieved rocket reusability, thus lowering the cost of access to space, paving the way toward space tourism and, eventually, space colonization. The New Shepard vehicle [16] is a vertical-takeoff, vertical-landing suborbital rocket, capable of carrying payloads inside its capsule beyond the 100 kilometers altitude Karman Line, the boundary between the Earth's atmosphere and space. Once the rocket reaches a specific altitude, the capsule containing the various payloads separates from the booster, free falling for a few minutes. Finally, the rocket lands vertically on a landing pad using its engines, followed by the touchdown of the capsule using its parachute system. The whole flight takes about 10 minutes to complete.

The scientific experiment is described in Section 2. The structure of the team of students and educators is outlined in Section 3. The implementation of the Design Thinking methodology is explained in Section 4. Section 5 presents the extensions of students' work, both in scientific and outreach terms. Discussion and Conclusions are provided in Sections 6 and 7, respectively.

2. The Experiment

Choosing an experiment idea for microgravity conditions was not trivial. The experiment needed to be as unique as possible, be feasible, be simple for reduced risk of failure, and be able to fit inside a small 10cm x 10cm x 20cm box ("Nanolab") [17] with its total mass being less than 500 grams. Additionally, it had to comply to strict safety criteria set by Blue Origin and evaluated by the Nanoracks company [18]. Moreover, 9th to 12th grade students did not have experience in suggesting novel scientific investigations or in evaluating the effects of microgravity. The most challenging part though was that the experiment needed to run autonomously when in space.

Students finally brainstormed, researched on, and suggested more than twenty experiments, indicatively regarding "controlled ignition", "thermal transfer during combustion", "yeast alcohol fermentation", "E. coli antibiotics resistance", "food coloring diffusion in water", and "viscosity of a fluid". The latter idea was the one selected, with honey being the fluid to investigate.

Then, the team had to conduct literature research, set up experiments, analyze the data collected, and work on building the apparatus, to eventually arrive to the experimental design and sequence: a small motor would operate on the surface of 5 ml of honey inside a plastic cylindrical container; the honey would rotate and its motion would be monitored by a small camera; the experiment would repeat a couple more times at different microgravity conditions. To have the above sequence run autonomously at specific degrees of microgravity, a microcomputer was used, programmed to receive data from the space capsule (effective gravitational strength, altitude, velocity, etc.) and use it to control the motor and the camera. LED lights were used to provide the interior of the Nanolab with sufficient light conditions for the camera to record a good quality video, a temperature and humidity sensor was included to monitor the respective values inside the Nanolab, and the microcomputer was powered by the space capsule through a USB connection. The Nanolab and its interior are shown in Fig. 1.

Figure 1. Left: The Nanolab containing the scientific apparatus.
Right: The interior of the Nanolab (scientific apparatus).
Part of the electronics used is visible.

3. Team Structure and Mechanics

The students involved with the experiment were grouped into three separate teams [19], each one with its own leader(s): i) the Research Team, working on the literature research, the design of the experimental apparatus, the conduction of experiments, and the data collection, analysis and evaluation, ii) the Development Team, with CAD (Computer Aided Design), 3D printing, code development, and mechanical and electrical engineering tasks, and iii) the Administration Team, responsible, among others, for outreach initiatives, fundraising, and dissemination in related journals. Additionally, the American Community Schools (ACS) Athens faculty, staff, and administration, together with a few experts, facilitated the students accomplishing their tasks trying to interfere the least possible.

Regarding the team's learning modes and working habits, students have been working both independently and collaboratively, either during or after school at the ACS Athens Incubator of Students' Creative ideas (ISCI) premises [20], or at home, following the i^2flex inquiry-based, independent, flexible learning methodology [21]. The team has been meeting weekly to discuss the progress that had been done and plan the next steps toward meeting the team's goals.

4. Design thinking implementation

On top of having students working in the aforementioned framework of dedicated groups and variety of learning modes, the Design Thinking process was implemented to enhance the team's decision making effectiveness. Design Thinking [22] is a creative, solution-focused and action-oriented methodology used to solve problems and innovate. It is implemented in five different stages, a) Empathy (connecting with needs), b) Definition (understanding what it is to be solved under certain constraints), c) Ideation (brainstorming solutions), d) Prototyping (building solutions), and e) Testing (fine-tuning solutions upon feedback).

Accordingly, the team initially empathized and defined the challenge as having to build an experiment and its necessary containment (Nanolab) to investigate the viscosity of honey under microgravity conditions, attempting to optimally compromise the overall design and expected results to meet size, mass, safety, and time punctuation limitations. Then, solutions were brainstormed (e.g. indirect investigation of honey's viscosity through the motion of surface air bubbles caused by a motor, appropriate video analysis software, requirements for the apparatus' containment) and built (e.g. experiments' conduction, data collection and analysis, Nanolab design and 3D printing). Finally, the evaluation of the findings of the Prototyping stage led to improved solutions (e.g. use of glitter to better track honey's motion, modification of the Nanolab to firmly mount the electronics).

Beyond providing a solution-focused structure for the students to follow, implementing the Design Thinking methodology was particularly useful for the team's educators to more effectively manage the program and keep students focused and productive.

5. Extensions

In parallel with the construction of the experiment, a group of students, guided by their educators, engaged in mathematical modelling of the experiment's underlying physical mechanisms. More specifically, they explored the data having already been collected during regular-gravity experimentation and fit fluid dynamics mathematical equations to it. Students will be working on the mathematical modelling including modifications referring to microgravity conditions and apply their models to the actual data obtained during the conduction of the experiment in space.

Beyond academics, students demonstrated their experiment at the Athens Science Festival 2019 [23] and had their work been showcased in various media [24] [25] [26].

6. Discussion

Students went beyond what they have been introduced with, which was the basics of fluid dynamics and kinematics relevant to the experiment. They had to research on Physics topics and concepts that they are not taught sufficiently in secondary education, if at all, identify all the important - independent and dependent - variables they had to measure or control to draw valid conclusions, and compromise to meet the strict size, mass, and safety criteria. Transferring theoretical knowledge to a real-life, high-risk context had them immerse into experiential learning and work beyond static, well defined, predictable laboratory investigations.

Additionally, they were introduced into real research situations, having to meet deadlines, manage risk, and manage the project in general in terms of human resources, financial needs, and dissemination of their work, use scientific software, and pursuit collaborations with experts to explore more data analysis possibilities. Furthermore, having to design the Nanolab itself in 3D, assembly the necessary electronics considering mechanical and electrical engineering constraints, and develop code, had students to complete an integrated S.T.E.A.M. (Science, Technology, Engineering, Art, Mathematics) endeavor. The above remarks are valid for any complex S.T.E.A.M. investigation, not limited to ones referring to microgravity or space experiments in general.

The success of investigations of the kind is not guaranteed though, especially when students are just guided toward instead of being specifically instructed to effective decision making. Risks include, but are not limited to, missing deadlines, incomplete knowledge of the electronics' functionality which data acquisition depends upon, students' engagement in the long term, the steep learning curve, and in general taking students and educators out of their comfort zone.

7. Conclusions

American Community School (ACS) Athens high school students engaged in a challenging but rewarding S.T.E.A.M. journey, by designing and building a Physics experiment that was carried by the groundbreaking Blue Origin New Shepard rocket at 100 km altitude and was conducted autonomously under microgravity conditions. The students transferred theoretical scientific knowledge to a real-life research and development exploration, deepening on the Physics topic of fluidity. The students will be analyzing the data obtained and will be comparing between regular gravity and microgravity experimental findings. Both students and educators immersed into a steep but exciting and meaningful learning process in the context of the technological breakthroughs aerospace companies like Blue Origin are delivering. A second experiment of the kind will be designed and built in the near future.

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Art objects as research tools for cognitive approaches in geometrical thinking

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Abstract

Geometry is an integral part of the curriculum on a global scale as it is a learning object where students can engage in inquiry learning process and develop skills and competences. The teaching of geometry in secondary education is an active field of reflection between teachers, editors of curricula, as well as among researchers and there is a strong interest in enriching learning and teaching strategies where they will improve understanding of the basic concepts of geometry that will help cultivate and develop the geometric reasoning of students,

But, what is the way that students learn geometrical concepts and in which way they construct and transform geometrical concepts? What are the basic frameworks of teaching and learning geometry that could be used of educational and research community as base for assessment the level of students' geometrical thinking? In what ways can we explain the difficulties faced by students in reasoning geometrical problems? What is the cognitive learning progression in learning geometry? This paper replies to above research questions and presents the art objects (paintings) as research tools under the theoretical frameworks of learning process of geometry. In other words, this research work attempts qualitative analysis of cognitive processes for the construction a theoretical model of cognitive progression in geometrical thinking based on art objects. This approach focus on understand and interpret the potential of students and the processes that follow in learning geometry. In this case, theory is not the basis for research planning but is used as a tool to explain the situations and results that provided by students worksheets under the terms of art objects.

Keywords

Geometrical thinking, art objects, teaching geometry

1. Introduction

The skills of this 21st century, such as innovation, creativity and creative problem solving, can also be considered as demands for deeper learning by helping students develop transferable knowledge that can be used to solve new problems or effectively address new situations. On the one hand, the relationship between deeper learning and the skills of the 21st century from the perspective of modern research and the theory explained of the nature of cognitive structures and cognitive processes related to learning [1]. On the other hand, the difficulties faced by students in learning geometry through to synthetic structure [2], [3] requires a cognitive approach to the learning processes of geometry [4].

The research of this paper, related with the cognitive perspective on types of knowledge and structure in learning process of geometry based on art objects (paintings) of exhibition 'Everything is Number'[1] The quantitate approach focus on assessment students' geometrical thinking that is strongly connected with 21st skills and so on with deeper learning in geometry. In this case, theory is not the basis for research planning but is used as a tool to explain the situations and results that provided by students worksheets under the terms of art objects. The main objective is to draw conclusions that will be put to the knowledge of the educational community to improve the deeper learning in geometry based on teaching methodologies of geometric concepts through innovative approaches embodying

2. Theoretical framework

2.1 Deeper learning in geometry in terms of cognitive approach

Deeper learning involves the development of an interconnected network of five types of knowledge [5]

- Facts, statements about the characteristics or relationships of the objects in our real world.
- Concepts, which are categories, shapes, models or managers.
- Procedures in particular procedures step by step.
- Strategies, general methods
- Beliefs about learning

Moreover, the way that student organizes these five types of knowledge affects whether knowledge leads to deeper learning and transfer (matrix 1, [6]).

1 *http://creations2018.ea.gr/exhibition/.*

Matrix 1 level of knowledge and ways of transfer

Knowledge	Beginners	Experts
Fact	fragmented	intergraded
Concepts	surface	structural
Procedures	effortful	automated
Strategies	general	specific
Beliefs	unproductive	productive

2.2 Van Hiele model in cognitive approach of geometrical thinking

Van Hiele's (1986) [2]model includes explanations of geometrical learning process based on the levels of development of geometrical thinking. At the level of total perception (Level 1), students perceive geometric forms as single entities, at the level of analysis (Level 2), students distinguish the characteristics of the shapes and classify them according to their qualities and at the level of informal production thinking (Level 3) students can understand the relationships that exist between the shape itself and the relationships that exist between the shapes. In this research the modification of A. Hoffer [7] (published in his "Geometry is more than proof», 1981) used, because it is connected with the skills needed in each level, [8].

2.3 Duval cognitive approach of geometrical thinking

Geometry involves three kinds of cognitive processes that highlight the importance of teaching and learning [10]. These procedures are:

- Visualization or imaging process for representing objects in the space, explaining a proposal, systematically investigating a complex state or verifying different geometric situations, or checking some cases using representations (eg numbers, images, diagrams, symbols).
- Manufacturing process is related to specific actions for forming a situation with specific tools and under specific conditions.
- The reasoning process includes the procedures for proof based on theorem and axioms through argumentation.

2 *Van Hiele, P. M. Structure and Insight: a theory of mathematics education. Orlando, Fla: Academic Press, 1986.*

Visualization essentially means the ability to shape and negotiate a mental image that is necessary to solve problems in mathematics. Visual images refer to the representation of the visual appearance of an object, e.g. shape, color and size [11]. They also play a key role in promoting critical thinking learning and communication in the mathematics class [12]. This is so that visualization encourages the use of this concept to conceptualize abstract ideas and ideas [13], [14]. While mathematics includes many abstract concepts, visualization, and visual use of tools, these abstract concepts become more accessible to the students.

2.4 Comparison deeper learning framework with frameworks of geometrical thinking

Summarize the five types of knowledge for deeper learning and cognitive learning process in geometrical thinking (except of beliefs) we could mention common characteristics:

Beginners tend to store properties of geometrical shapes as isolated units, whereas experts store them in an interconnected network as properties as visualise all related information into an art image or he/she uses the properties of a shape to design new shapes. Beginners tend to create categories based on surface features of geometrical shapes, whereas experts create categories based in structural features. Beginners need to expend conscious effort in applying procedures, whereas experts have automated basic procedures, thereby freeing them of the need to expend conscious effort in applying them. Beginners tend to use general problem-solving strategies such as means-ends analysis, which require a backward strategy starting from the goal, whereas experts tend to use specific problem-solving strategies tailored to specific kinds of problems in a domain, which involve a forward strategy starting from what is given.

3. Methodology

3.1 Research framework

Each painting of maths exhibition includes and presents geometrical concepts through shapes[3]. Representations of painting used to research the geometrical cognitive learning process that explain the five types of knowledge of deeper learning.
Students asked to write and solve a problem based on painting (see picture 1 to appendix). As a guide to the realization of the students' activity we gave them a worksheet with structured questions (see appendix 1)

3 Access to paintings of exhibition http://creations2018.ea.gr/exhibition/

3.2 Participants

Students aged 16 years old of 4 departments from 4 different schools (total number 95 students) that are worked in teams of 4-5 and this means that analysed about 20 worksheets of geometrical problems to paintings

3.3. Methods

The methodology used for the analysis of scientific data is a merger of qualitative and quantitative analysis [15]. The data were analyzed and categorized. This conceptual classification takes into account the theoretical framework of this research along with empirical evidence gathered from problems. It is worth noting that this combination of methodological tools is required for the validity and reliability of the research. In addition, a "combination of design methods" can lead us to more specific results and allows a mutual validation of qualitative and quantitative results by providing a clear logic for the choice of each method.

4. Results

The categories provided by students worksheet at first phase are:

- Students' Prior Knowledge/ Assimilation
- Mathematical Knowledge/ Scientific Notions Students' missing Conceptions
- Phenomenological Factor
- Psychological Factor
- Anthropological/ Cultural Factor
- Holistic focus on the Painting
- Literature/ Expressive Verbalization
- Factors of History of Science
- Art Factors
- Combining Factors of Education to Workplaces
- Combining Algebra and Geometry
- Using arithimitcal data for desrcibe and slove the problem
- Methodological analysis of problem solving
- Geometrical Shape

Students followed a methodological analysis of problem solving guided by questions on worksheet. They used notions in the shapes of painting and they insert arithmetic data for problem solving

Art objects could be used not only as teaching tools and include them in curricula of geometry, as students recall prior knowledge, but also as research tools in order to provide results for levels of geometrical thinking[4] and cognitive approach of deeper learning.

Most team of students implemented the Pythagorean theorem with basic concepts of calculation square and perimeter. They have different approaches in writing problems based on art based on prior knowledge.

4.2 Levels of geometrical thinking
4.2.1 Optical skills

According to optical skills, high-level percent of students recognize the different shapes included in painting and they analyse the properties of them, but their answers had scientific misconceptions. They have difficulties to conclude new data related to shapes of painting (38,9%) and they are not able to Induction: He/she uses information related to a shape to conclude new data and they are not able to recognize false assumptions about a problem that were used in shapes (33,3%).

4.2.2 Verbal skills

According to verbal skills (88,6%) and (86,7%) of students associate the shape with correct name in angles in order to describe properties, but they couldn't extent them in inductive systems (33,3%).

4.2.3 Design skills

The notions and names into shape of painting follows the designing of it for problem solving and the description of properties (recognition, analysis, layout, induction, rigidity percentages up of 70%) Examples for designing skills (picture 5.1, picture 5.2)

4.2.4 Logical skills

The results for logical skills highlight the difficulties in reasoning the data (31, 3% of students use uses logic rules to make evidence and 31,3% could expand the properties of shape in other systems)

4 Access to graphs of results http://bit.ly/31cOmqi

4.2.5 Implementing skills

Although they identify geometric shapes in objects of real life (66,7%) they could not develop more mathematical models or geometrical problems related to real life (only 5 teams of 20). In general, there are difficulties to transfer their knowledge on physical and real phenomena.

4.2.6 Learning process and type of knowledge

For learning phases characteristic examples that give the level of beginners or experts in five types of knowledge: Team A: "The little Orpheus plays with his toys and observes and observes that when joining them creates specific patterns in which each square contains a smaller lozenge and vice versa. The little Orpheus now looks for similarities in shapes and dimensions" Team B: "Find the perimeter and the area of the two small squares. Then prove the sum of their perimeters is equal to the perimeter of the big one"

- Visualization or imaging process:
  Team A: There is a strong element of identifying geometric shapes, but they do not give or explain why they observe them. Team B : Identify the correct shapes.
- Manufacturing process:
  Team A: They divide the problem into sub-questions that have strategic resolution elements. When they solve the problem, they draw the geometric shape of the table, name the sides and give numerical values. Team B: Record geometric meanings and geometric relationships in the painting
- The reasoning process:
  Team A: The solution to the problem has clear scientific evidence, but not complete because the solution in many places is worded verbatim. Team B: Side Symbols and Numeric Data for Perimeter and Area Calculation. The solution contains correct analytical algebraic calculations that are properly linked to the geometric theories needed to lead to the metric calculations.

4.3 Beliefs in learning

Art objects had positive impact to beliefs of students in learning geometry as they tried to create their own paintings based on mathematical concepts (picture 1, Appendix 2).
Summarize the results of skills : Most teams of students at the level of total perception (Level 1), students identify the properties in shapes, but less percentage could product evidences for them(Level 2) and more less percentages (Level 3) can understand the relationships that exist between the shape itself and the relationships that exist between the shapes.

5. Conclusions

It is essential to educational community the assessment of geometrical thinking process, as it is related (by cognitive perspective) with the development of 21st skills for transmission from school to work. In this research art objects of painting of mathematical exhibition “Everything is number” are the basic tools for assess the geometrical learning process through to geometrical problems that are required by students and based on properties of shapes in painting. The results highlight that the teaching methodologies have to improve including connections with real world, as students had difficulties to expand their knowledge. Mostly, art objects in learning and teaching methodologies increased students’ creativity and create positive feelings in learning.

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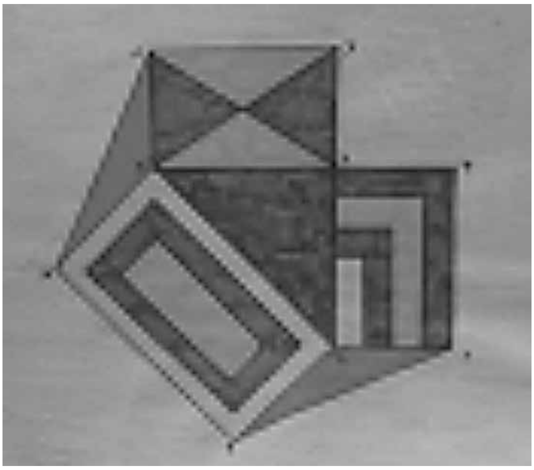
Appendix 1

The questions as guide for required problem based on art painting, that students asked to reply:
Make a problem or situation related to the selected painting of art exhibition
What is the target / s of the problem or situation?
Report the mathematical concepts or relationships or the axioms or the theories that can be hidden behind this table. Write the names and details.
Can you find patter / repeating motifs?
Can you solve the problem you raised?
Can you break the problem or situation into sub-problems or simpler situations?
What concepts or relationships did you use when proving?
What axioms or theorems did you use when proving?
Write the shapes that will help you in the process
Write algebra or geometric relationships that are associated with the shapes you have considered

Appendix 2



Picture 1 Students' paintings

An approach for teaching concepts of programming to students of Digital Arts

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Abstract

This paper presents a methodology and an experimentation framework for teaching programming concepts to students of digital arts, targeting both individual deepening, and group collaboration. A multi-participatory platform built on top of Unity engine, the @postasis platform, is utilized. The concept of an Entity Class is put at the centre of the proposed approach, as an abstract structure which when instantiated to a certain context, unfolds specific behaviours (e.g. movement, interaction with other entities, goal fulfilment). The Entity Class is collaboratively defined by students, supported by the instructor, through an analytical process. Sample experimentations in multiuser virtual space are presented.

Keywords

programming concepts, visual arts, behavioural entities, @postasis platform

1. Introduction

The teaching of programming concepts to digital art students (especially oriented towards visual arts) is a complex and dynamic process for the instructor, as it is based on three basic conditions:

Condition 1: *A balance should be kept between the teaching of a programming language philosophy, and rules (which is an abstract, and rather analytical* *process), and the connection with human perceivable concepts (e.g. space, time, body and presence, decision and action)*. Especially the link between programming and the direct correspondence with a visual structure is very important to students of visual arts; otherwise they may lose orientation and become discouraged.

Condition 2: *The individual characteristics of each student, but also the dynamics of the group of students as a whole play an equally important role to the educational process*. To a great extend, a digital arts class is composed of students with different personal goals and backgrounds (e.g. arts, architecture, engineering, humanities), and thus different levels of knowledge, ways of thinking (e.g. analytical, synthetic, interpretative) and skills in programming and digital construction. This complementarity facilitates teamwork (tasks distribution in collaborative projects, asset sharing), but may make it difficult for a student to deepen in programming concepts and acquire a comprehensive personal perspective, in order to proceed autonomously, as a creator. Therefore, each student should be equally engaged to teamwork and sharing, but also to individual work and deepening. This is an important condition, also, for life-long learning curricula.

Condition 3: *Students should be taught to create programming structures that are transferable to different contexts* (e.g. a prototype in the virtual space may be transferred to different target devices or to an installation in physical space), and not necessarily targeted to a specific problem, as in other cases.

This paper presents an experimentation framework and a methodology for teaching programming concepts to students of digital arts, targeting individual deepening, while taking into account class dynamics. Towards this end, a multi-participatory platform built on top of Unity game engine, the @postasis platform, is utilized [1]. It provides tools for individually creating assets, which may then be shared into a common space. The common space can be visited in real-time by multiple participants, enabling real-time joint experimentations, in different contexts, including human entities (avatars), virtual objects and Internet of Things (IoT) constructions (mainly based on Arduino and Raspberry Pi).

@postasis platform, and the overall educational methodology behind it, targets joint working at different levels, theoretically and practically, towards complex artistic ideas, which require – at the same time - different ways of thinking: analytical, synthetic, and interpretative. This paper puts a special focus on the analytical aspects stemming from the need to transfer concepts to a programming substrate; the other two aspects, which are developed in parallel, are described in [2].

The concept of an *Entity Class* is put at the centre of the proposed approach, based also on the overall educational methodology of @postasis. It is described as an abstract, parametric definition of a digital "existence" (a "class" in terms of object oriented programming) which when instantiated (becomes "object") to a certain environment (e.g. virtual space) and context (e.g. other entities, avatars, certain space zones) may unfold specific behaviours (e.g. movement in space, interaction with other entities, goal fulfillment). The abstraction of this concept helps to reflect on basic object oriented programming terminology (e.g. Class, Instance, Inheritance, Encapsulation), in combination with familiar concepts and bibliography, mostly from the world of games (players, Non Player Characters (NPCs)), during the educational process. At the same time, it provides a framework for further deepening to individual issues that lie between artistic creation, theory, but also contemporary issues of advanced technology (e.g. Artificial Intelligence, Human Computer Interaction), depending on particular background of students and personal interests.

The parametric *Entity Class* is collaboratively defined by students, with the support of the instructor, through an analytical process. This process takes place at different levels, starting from basic functionalities and proceeding gradually to higher degrees of complexity. All levels include – after collaborative definitions – individual work of each student, who creates a prototype in the @postasis space and presents it to others, under different contexts.

In the rest of the paper, we elaborate more on the proposed approach. In Section 2, the @postasis platform is presented and its particular use for creating contexts of experimentation, both individually off-line, and in multiuser, real-time sessions, focusing on programming concepts and an analytical way of thinking. In Section 3, the educational workflow towards the collaborative definition of an *Entity Class* is described. In Section 4 experimental setups and samples of results are presented and related aspects are analyzed. Finally, in Section 5 conclusions and directions for further research are exposed.

2. @postasis platform and tools

@postasis platform is developed under Erasmus+ *@postasis: Virtual Artistic Laboratory* project [1]. It enables the setup of educational multi-participatory sessions, linking virtual entities, IoT constructions, and humans (e.g. avatars, observers, performers), in the globally interconnected physical and virtual space. The main infrastructure of @postasis platform is technologically implemented by Omega Technology partner, while Athens School of Fine Arts (ASFA) is providing the artistic and educational specifications, regarding the basic actions and interactions of dynamic objects (avatars, NPCs, IoT), required for setting up a range of educational multiuser sessions.

@postasis multiuser framework, built on top of the Unity game engine, provides a complete API (the *Apostasis Unity Framework - AUF*), for easily setting up multiuser sessions, in Unity, using the Photon Cloud Framework.

AUF provides an *Apostasis Behaviour Class* (inheriting from Unity's MonoBehaviour class) and virtual methods which can be overridden by the creator, with which it is possible to develop dynamic objects (e.g. NPCs) with server-side behaviours, without advanced knowledge of multiuser programming.

Any virtual object, through the Apostasis Behaviour Class, may communicate with physical space (e.g. a sound source, an IoT construction) through the OSC protocol.

Moreover, the *Project Interconnection Framework* (a key-value database on the backend of @postasis) enables any dynamic object (e.g. NPC or registered IoT) to send/receive values, thus affecting behaviours of other objects.

Through the *Avatar Lab*, any virtual object may be setup to play the role of an avatar for @postasis multiuser navigation.

An @postasis *collaborative workflow* is provided for sharing and mixing student's assets created from distance, in a common space without overlapping effects resulting to errors.

Finally, an easy *Client-Server Multiuser Build* interface is provided.

@postasis platform, unlike existing professional collaboration tools and services (e.g. Unity Collaborate) is not targeting on perfecting skills by assigning different roles to students (e.g. 3D designer, programmer, sound engineer) when working all together. This is why it is not equipped with advanced automations for asset management (e.g. asset syncing, versioning, dynamic timelines). On the contrary, it aims to enhance individual creativity through joint experimentation and communication, while trying to solve problems related also with technology (thus acquiring insights to programming aspects). Therefore, the contribution of the instructor and the adopted methodology play an important role to its use. As a part of the collaboration procedure through @postasis is developed outside the platform, it could be complemented with existing tools, such as GitHub - a social network for coders [3].

3. Educational workflow

The educational workflow, for collaboratively defining versions of the Entity Class and setting up the experimentation framework is developed in two phases, the *Preparatory phase*, and the *Definition and analysis phase*.

A. Preparatory phase: this phase is necessary for helping students to acquire an overall picture of the field of reference, both theoretically (existing literature) and practically through targeted seminars. The field of reference is divided to the following categories:

- **Object oriented programming:** basic concept, e.g. classes and objects, inheritance, overriding, etc. Emphasis is put on the Unity C# based framework, which is a mixture of hierarchical object oriented and synthetic component-based thinking, combining scripting with visual interfaces. There is a huge amount of on-line tutorials for beginners (e.g. Unity web site), as well as relevant books for more advanced levels [4] [5], or even more specialized techniques (e.g. design patterns) for even more deepening [6].
It should be mentioned here, that in the last years, a variety of tools are being developed towards linking object oriented programming with visual arts. The most indicative is the Processing language [7] [8], which, based on the metaphor of "sketch", encourages artists to learn programming, while producing visual prototypes. Others include the vvvv, openFrameworks, TouchDesigner etc. Pre-existing knowledge of

such a framework helps a student go faster, as they include common concepts.

- Game programming. This is a particularly demanding field, requiring high specialization, at professional level. On the other hand, games engines, such as Unity, and Unreal, provided for free, constitute complete experimentation laboratories for creators, in which programming is directly linked with construction of 3D virtual spaces. There are, also, a lot of implementations, such as basic steering behaviours for autonomous agents, (e.g. patrol, attack, hide), but also collective ones (e.g. Boids invented by Craig Reynolds in 1986), provided under free licenses (e.g. MIT License), and can be accessed through code repositories like GitHub.
The study of games programming and freely accessible components helps explore very important concepts and metaphors (e.g. avatar vs NPC, casting rays and Line-of-Sight, god's view, first person view) which when being transformed artistically may provide interesting frameworks of experimentation. [5]
Unity provides a class hierarchy with most of the functionalities required to implement a complete game.

- Vector programming. A virtual object may be controlled inside a 3D space, mostly through its position, direction, and movement. Moreover, in order to enable different interaction and navigation devices it is necessary to calculate transformations from the Cartesian 3D coordinates system of the virtual space to that of the physical space or target device. Therefore, vector3 (and even vector4 in the case of quaternion rotations) calculations are required. In the case of Unity game engine, a basic API is provided for directly handling most of the situations. However, a student with more specialized background (e.g. mathematics) may go deeper through developing own custom implementations. [9]

- **Introduction to @postasis API (AUF).** Students are introduced to basic concepts of multiuser architecture (young generations are usually familiar due to MMORPGs). Then, they are shown how existing single-user logic may be transferred to @postasis server-side multiuser logic, through the AUF framework and the Apostasis Behaviour Class.
The basis of experimentation is the adjustment of existing implementations of basic behaviours (e.g. wandering, waypoint moving) to AUF (Figure 1).

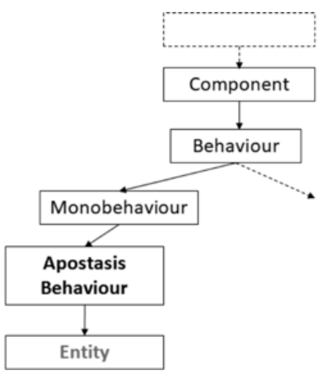

Figure 1. Apostasis Behaviour Class

As @postasis supports interfacing with physical entities, special seminars take place regarding the Open Sound Control (OSC) data protocol, as well as the backend web service-based *Projects Interconnection Framework*.

Notes on the preparatory phase: It is obvious from the above, that the preparatory phase includes a huge material and there is a double risk that students may either get discouraged, or may resort to imitations or to copying existing approaches, that they easily find for free. Therefore, it is a critical phase for the rest of the procedure.

To overcome this risk, we adopt a collaborative approach during the next phase (Definition and analysis phase); working all together towards a common goal helps to identify the intersection which is more suitable and activates complementary skills. Moreover, this process is assisted by the synthetic and interpretative processes mentioned above, that take place in parallel, in the scope of the @ postasis overall methodology.

B. Definition and analysis phase: during this phase, initially the Entity Class is defined as a whole structure, through a collaborative, analytical process, including the following steps:

STEP 1: Discussion about the main characteristics of an entity object, created from the Entity Class, and how these can be implemented as scripts. There is a considerable amount of bibliography, mainly coming from games (autonomous agents) and artificial intelligence (e.g. [5], [8]). Indicatively, the main points of interest are the following:
Body and its mechanics: This refers to whether the entity body plays a role to the movement. If it is a rigid body with physics (e.g. collider, gravity), or whether it is a single object or divided to parts linked with joints.
Sensory system: There are important concepts involved in how a virtual entity senses its environment. We may emulate human, animal or imaginary senses, such as vision (Line-of-Sight, Cone vision, 360°, seeing in the dark), touching (e.g. through collision), hearing (e.g. through distance from an audio source and volume), 6th sense (e.g. perceiving invisible objects or any other external stimulus / signal), through data-based mechanisms and metaphors, dependent on the current context, but the virtual entity can't really physically experience them.
Decision system: While in real life an entity (e.g. human, animal) makes rational decisions based on limited knowledge possibly perceived, in virtual worlds an entity (e.g. autonomous agent) can be omniscient; that means it may "know" beforehand the results of any action it may take. Emulating the two approaches or mixtures of them may result in completely different behaviors of entity objects. At a first level of familiarity with scripting, an if-then-else rule mechanism may be adopted for the decision system, enclosed in short but condensed scripts. However, more advanced students may experiment with other specialized mechanisms (e.g. state machine behaviors, behavior trees).
Another important aspect is whether the Entity has memory, providing a feedback when it has to make a decision.

Context: This includes concepts that affect the decisions system of an entity, such as the relations between similar entities (e.g. a flock as a whole structure), the role of space; whether it is neutral, it contains a navigation mesh, or a context map (e.g. zones of danger) [10].
For all the above, example implementations are analyzed in the classroom.

STEP 2: Collaborative definition of the Entity Class, as a whole structure. Towards this end, the above points should be taken into account, as well as parameterization that would allow for different varieties. An indicative overall structure to be implemented is reflected in Figure 2.
This is a difficult point, as putting all the above to single Class requires a high synthetic capability, in terms of algorithmic thinking and coding. Moreover, during discussions, several contradictory points arise. Therefore, different simpler prototypes are produced and tested in single-user mode, by each student.

Body
    RigidBody
Collider
Other property [tag]
None

Senses
    Vision [LoS, CoS, 360°, Invisible, Other]
    Hearing [Distance, Volume, On/Off, Other]
    Touch [Collision, Distance, Other]
    6th sense [Perception of IoT or other worlds]

Decision
    Input data [Position, State, ...]
    Target entity [NPC, Avatar, IoT, ...]
    Space [Object, Trigger Area, Context Zone, ...]
    Memory [Entity's Data, Collective Data]
    Rules of actions [Wander, PathMovement, MathMovement, GoTo, Avoid, Hide, ...]

Context
    Space
        Uniform [Flat, Sloppy]
        Zones [Context Map]
        Navigation Mesh

Figure 2. Entity Class structure

STEP 3: Adjustment to the AUF and creation of an @postasis template project for multiuser space experimentation. The prototypes of the Entity Class are transferred to the multiuser space of @postasis and the template project is distributed to all students.

STEP 4: Individual work of each student: Each student works individually inside the @postasis template project. The distributed versions of the Entity Class are instantiated and investigated as to the behavior unfolded inside a certain context. The student defines additional elements (e.g. an obstacle, a target entity, a goal) in order to illustrate the specific characteristics of the entity object. They observe entities' characteristics and behaviors and keep notes.

STEP 5: Students present their individual work to others, in the multiuser space. Other students enter as avatars and they communicate through chat. Varieties are discussed and refinements are defined. More advanced students may incorporate specialized mechanisms. Working in @postasis multiuser space helps define more complex and dynamic contexts (e.g. through including avatars, external IoT), and the process of communication between students enhances engagement.
The above steps (1-5) may be repeated several times (differently by each student), until they reach the desired level of comprehension and goal achievement.

STEP 6: *A common library of reusable assets is created,* with a short documentation that all students will then have in common.

4. Experiment setup

In this section, a first level of experimentations is described, based on the described approach, in the scope of the Greek-French Master "Art, virtual reality and multiuser systems of artistic expression", ASFA-University Paris-8, 2018-2019.
The experimental setup of the template project is based on a horizontal level space, with no navigation mesh, no context map, and no slopes (as this would possibly require a custom gravity implementation), thus of low complexity (Figure 3).

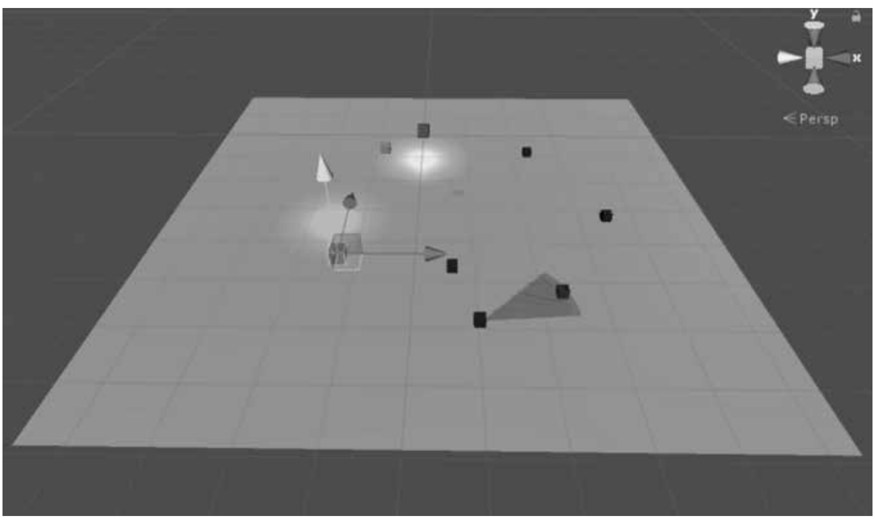

Figure 3. Basic level experimental setup

No scenographic elements are allowed (e.g. nice terrains, visual effects), unless they are absolutely necessary to illustrate aspects of the behavior (e.g. light sources, in case an entity goes towards a light). This limitation is important to help focus on the programming aspects.
Tools of visualization in the virtual space are defined, such as drawing the cone of vision or line of sight, leaving traces, (Figure 4). In this way, moving and other behavioral patterns may be visualized for observation, from different views provided by the @postasis platform: perspective view, god's view. Moreover, aspects, such as network latency that distorts a trajectory are discussed.

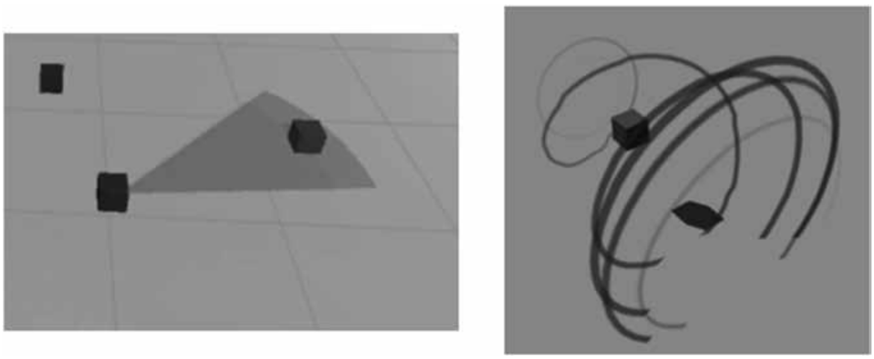

Figure 4. Visualization in the virtual space. Left: Cone vision of entity. Right: spiral trajectory illustration.

Indicatively, some of the primitive behavioral entities defined at this first level of experimentation are the following:

Entity is periodically wandering, in x, z axes (in some cases in y also) with no space sensing, but leaving a trace.
Entity is wandering in x, z axes with Line-of-Sight. When target is identified, the entity goes towards it and follows it. When the target exits LoS the entity is wandering again, until next target.
Entity is wandering in x, z with Cone-of-Sight. If a target avatar is identified, it attaches to it as a shell. The trapped avatar, has to jump to escape.
Omniscient entity, having full knowledge of target entities' state (e.g. light sources on/off, IoTs "presence") chooses (either randomly or based on criterion) to go towards one of them to get energy.

The above procedure may continue endlessly and as courses progress, the produced outcomes acquire more and more complexity. Moreover, the above simple patterns of entities' behaviors are reusable and shareable among students.

5. Conclusions

This paper presented an approach for teaching aspects of programming to students of digital arts, through the development of simple behavioural patterns for entities.

The @postasis multiuser platform is used in this approach, as it enables both personal deepening though individual work, and collaboration and multiuser experimentation in real-time. This educational setup provides a framework for further reflection and endless experimentation in a contemporary topic, that of studying behavioral aspects of machines, in their coexistence with humans [11].

6. Acknowledgements

A part of this work is developed in the scope of Erasmus+ @postasis: Virtual Artistic Laboratory [1] (Coordinator: Athens School of Fine Arts, Scientific Coordinator: Prof. Manthos Santorineos, partners: Paris-8 University, Omega Technology, MAD, and Argenia).

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People on the move

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Abstract

In this paper we develop an idea on how to study themes of forced migration, mainly of people fleeing war or natural disasters, but with an emphasis on both cultural/historical and geospatial thinking skills of students aged 9-12.It is designed with the aim to use interdisciplinary activities from The Enquiring Classroom project and the field of STEM. It also aims at addressing local issues of migration and how it affects the community, whether a hosting or sending one. We believe that the approach addresses areas of deeper learning such as thinking critically in solving complex problems through collaborative work and developing an academic mindset. The idea is also developed with the use of the Open Schools for Open Societies student project authoring tool.

Keywords

migration, war, refugees, disasters, history, culture, geospatial thinking, language

1. Introduction

In structuring such an approach, students are introduced to various facts and issues on the theme of forced migration. There are plenty of both historical and contemporary examples. Focusing on forced displacement due to war and conflict, students may consider an example concerning the local community, an event involving members of the community fleeing in the past. An effort should be made to consider particular sensitivities to highly contested political issues that may affect public and school life (civil wars for example). Obviously, the Syria conflict, with the biggest movement of people in the history of the world is a strong example1.

"Since the Syrian civil war officially began March 15, 2011, families have suffered under a brutal conflict that has killed hundreds of thousands of people, torn the nation apart, and set back the standard of living by decades… About 13.1 million people in the country need humanitarian assistance. Millions scattered, creating the largest refugee and displacement crisis of our time… More than 5.6 million Syrians have fled the country as refugees, and another 6.2 million people are displaced within Syria. Half of the people affected are children." (2019)

Focusing on forced migration due to climate change and issues such as natural disasters, desertification, etc. is also an option here. This is a very good opportunity to discuss current themes and facts concerning this hugely important issue2

2. Addressing migration in the classroom: on fleeing war

The mass influx of refugees into Europe from war-torn Syria reached unprecedented levels in 2015. Over 870.000 refugees from Syria arrived in Greece by sea, crossing the Aegean Sea. For a few months in the second half of 2015 until early 2016, refugees and migrants enjoyed almost unimpeded passage from Turkey to countries in northern Europe such as, Germany, Sweden, etc.

The events sparked tensions in all countries along the route leading to the closing of boarders along the Balkan route and to the controversial EU-Turkey refugee agreement that saw Turkey agreeing to take back all refugees and migrants, including asylum seekers, who reach Greek islands. In turn, the EU committed to resettle Syrian refugees from Turkey and to provide 6 billion euro in assistance to improve the conditions for refugees in Turkey.

Despite the overall positive attitude of the Greek people in assisting refugees who arrived by sea, tensions run high within Greece, a country already hit by a massive economic crisis since 2010

Despite such tensions, a similar story emerged involving Greek refugees in Syria in WWII. This is the story of Greek residents in many islands in the Eastern Aegean Sea during WWII, who, following the famine that resulted from the German occupation, crossed the Aegean Sea into Turkey and then arrived in Aleppo and

1 *Syrian refugee crisis: Facts, FAQs, and how to help. (2019, June 07). Retrieved May 12, 2019, from https://www.worldvision.org/refugees-news-stories/syrian-refugee-crisis-facts*

2 *Climate refugees in Bangladesh | DW Documentary. (2019, March 20). Retrieved May 12, 2019, from https://www.youtube.com/watch?v=co5uywe-1Z8*

Homs in Syria, where they found safe refuge. Over 30.000 islanders attempted the cross with small boats during the night in order to avoid being spotted by the German Navy.

In this exercise students are asked to stand in the shoes of persons fleeing war. They may use historical figures as examples. There are many examples in the press and in various curricula. Students are asked to produce short memoirs narrating the fleeing of a warzone and reaching a safe heaven in a third country. Students may work in groups. The aim of the exercise is to facilitate the building of a “stand in their shoes” scenario and to support students in becoming creative thinkers by embarking on the task of writing a literary piece (a short memoir) accounting for particular events, feelings and ideas in a situation when one has to flee war. By completing this exercise students should be in a position to fully grasp basic issues of migration and the refugee crisis. They also develop skills of emotional involvement and understanding of the suffering of fellow human beings in a rather structured way and not as a plain empathy activity. They also cultivate their writing and narration skills (the latter is considered an emerging 21st Century skill).

This exercise is a type of strategic writing that focuses both on skills and causes. It is also an excellent opportunity for collaborative work and for the introduction of brainstorming techniques to a young audience, such as Brain Writing (the teacher/ facilitator introduces the theme and asks students to write their own ideas before a discussion commences in order to avoid bias and influencing). Another technique is to focus on the generation of as many questions as possible by the students. Here are some initial ideas:

- Select a particular question/theme/idea that will guide students in their task to create a memoir. Examples: navigation, terrain, relationship with others on the move, emotional strain, etc.
- Revisit the story/text that you discussed in the preparation phase (WWII and the fleeing of Greek islanders).
- The writing of the memoir commences.

3. Addressing migration in the classroom: words that wound

This is a group activity in which young learners are explicitly asked to spot and discuss certain (very basic) devices used in hate speech. The activity should be undertaken in a group responding together to a text, video, speech etc. or a combination of both.

Here is a bit of theory behind this approach. J. L. Austin investigated language use as a type of *performance*. Following the latter Wittgenstein, he rejected the importance of utterances as descriptive statements in a pictorial sense. Austin talked of speech as action: For example, when the groom says “I do”, he is not describing (declaring) a state of affairs in which so and so is true (or false), but he is rather doing something: he is performing an action. The same is the case with other examples, such as when one utters "I bet you 20 euros that England will go out in penalties", "I promise to return this loan in 2 months", "Je suis…", "ich bin…", etc. In all these instances, promises, bets, acts of solidarity, etc. are actually manufactured by our utterances. Austin calls these bits of language *performatives,* juxtaposing them with *constatives* that are descriptive in nature (declarative statements). In addition, he talks of constatives as *locutionary acts* and performatives as *illocutionary acts*. The aim of a locutionary act is to truthfully describe a state of affairs ("there is a blue car in front of the house"), while the aim of an illocutionary act is the effective execution of an action through speech ("I do"). There is a third type of a linguistic/speech act: The perlocutionary act. It describes the effect that our utterances might have on a hearer. The activity proposed here is focusing on the effect that a bit of language might have on a person or a community that has fled home due to war or a natural disaster and is already under enormous stress. This is a particular type of perlocutionary acts of speech that deserves our attention (especially its many appearances and disguises in the classroom setting) and it is the one intending to cause harm to a hearer, an outsider, a foreigner, a group in a vulnerable position, etc. by deploying the weapons of hate speech. Whether in the form of racial abuse, propaganda, fake news, exercises of authority, etc., hate speech is considered a major issue and it affects all aspects of public life, including, naturally, schools and classrooms. It is a truism that hate speech causes harm to those targeted. Recent research in the field of neurobiology has been looking into mapping the type of harm involved. According to a whole new body of evidence in various studies (Barret 2017), "words can have a powerful effect on your nervous system. Certain types of adversity, even those involving no physical contact, can make you sick, alter your brain — even kill neurons — and shorten your life." In this context and age-group (9-12), we focus on the uses of cultural stereotypes specifically framed to dehumanise a targeted group, presenting it as collectively possessing negative, different or dangerous traits. Contemporary typical examples include depictions of members of newly arrived migrants and refugees as being prone to commit violence because of certain so-called intrinsic cultural attributes or due to a natural tendency supposedly "verified" by past historical world events involving previous generations in the country or region of origin.

This exercise builds on students' practice in communities of enquiry, asking them to work more carefully with key concepts in order to analyse basic aspects in a multi-modal text. The aim of this activity is to support students in understanding how hate speech operates in human communication by learning to understand how hate speech affects those that are targeted and with what types of devices.

- A text of is selected with a view to looking at some aspect of (possible) hate speech.
- Students first take notes individually and then are asked to work in pairs on a second encounter with the material.
- Students conduct a basic analysis of the text, seeking to identify illegitimate

claims and arguments, and to locate how speech act is working. The teachers may ask initially for a focus on 'normalising generics' and on 'humpty-dumptying'.
- Each pair should offer their own analysis of the text to the wider group.
- The various elements used in hate speech should be "put on the table".

4. Geospatial thinking

In this section students become researchers themselves and are implementing a number of activities.

- Session1: students set out to explore the history of the local community by investigating family migration stories. This can be done by conducting interview and videos of members of their families, exploring aspects of their fleeing. Here, the students should be guided to focus also on issues of the fleeing trip itself, by trying to collect information on means, objects, dangers and return.
- Session 2: Students are asked to reconstruct the fleeing trip that they have investigated. (For practical issues the students may focus on a family member's trip that is the result of economic migration).
- Session 3: Students, under the guidance of their teachers, should turn their attention to STEM issues involving people movement across the globe. This is the session that concerns the cultivation of navigation and geospatial skills. See here[3] for a list of resources. "Spatial thinking allows students to comprehend and analyse phenomena related to the places and spaces around them—and at scales from what they can touch and see in a room or their neighbourhood to a world map or globe. Spatial thinking is one of the most important skills that students can develop as they learn geography, Earth, and environmental sciences. It also deepens and gives a more complete understanding of history and is linked to success in math and science. Young students also enhance their language skills as they collaborate and communicate about spatial relationships. Students who develop robust spatial thinking skills will be at an advantage in our increasingly global and technological society" (2019).

5. Acknowledgements

These activities and overall approach have been developed in the framework of The Enquiring Classroom (http://www.enquiring-project.eu/) and Open Schools for Open Societies (https://www.openschools.eu/) EU funded projects.

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Erasmus KA2+ Project "Oxford Debates for Youths in Science Education": The Contribution of Oxford Debates in Deeper Learning of Science

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Abstract

The goal of the current paper is to present an innovative Erasmus+ KA2 project in STEM and, especially, in science education which is inextricably interwoven with the concept of deeper learning due to the use of argumentation and debate. The "Oxford Debates for Youths in Science Education" consists of a strategic partnership between scientific institutions of four European countries: Poland, Greece, Serbia and Esthonia. It is addressed to students and teachers of STEM education in Junior and High Schools (13-19 years old) and aims at promoting and deepening students' knowledge through their participation to argumentative debates relative to modern controversial scientific topics.

Keywords

debates, STEM education, teaching Science, Oxford Debates, secondary education

1. Introduction

Controversy is essential within the Science context. Scientists' disagreements are related to the application of experimental methods, to theories that explain certain phenomena or to various research hypothesis. For example, the transition from the geocentric system to the heliocentric theory for explaining the planets' motion is a characteristic scientific controversy. Its duration was quite long. The debate lasted more than two centuries after the death of Nicolaus Copernicus (1543). It was hard to convince both the scientific community and the masses of people about the scientific truth of the new model [1]; [2]. New scientific evidence, as the elliptic orbits of Kepler (1609) and the theories of Galileo (1610) contributed to the progressive conversion of the era's scientific beliefs and to the transition and final acceptance of the new model.

Such scientific controversies are essential for the promotion of Science, as Thomas Kuhn [3] notices. In the *Structure of Scientific Revolutions*, the author invites all the members of the scientific community to get acquainted with the techniques of persuasive argumentation, signaling "a rhetorical turn" [4] within the Science field.

In other words, scientists as modern orators, are invited to express their personal opinion about a scientific issue and to search for evidence in order to efficiently support their position. Within this framework, both controversy and argumentation are related to the promotion of research and to the further examination of significant socio-scientific issues with moral dimensions that influence daily life, such as cloning [5].

As we understand, controversy and argumentation used for the rejection of old scientific models or beliefs and the acceptance of new ones become closely related to the teaching of STEM education (Science-Technology-Engineering-Mathematics) and, consequently, to the formation of scientifically literate students. Following this line, the European Research Program Erasmus+ KA2 O*xford Debates for Youths in Science Education* attempts to involve teachers and students of Secondary STEM Education (Junior and High School students) in debating, since controversy and argumentation are interwoven with the debating process. So, the aim of our paper is at presenting the main educational goals of the program which might deepen students' learning. Before the afore-mentioned presentation, we will attempt to, shortly, review some of the main theoretical positions regarding controversy and argumentation within STEM educational context.

2. Theoretical framework: Argumentation and controversy in educational praxis

The demand for enhancing students' scientific literacy because of the continuously increased needs of the 21st century becomes imperative, since a scientifically literate person is able of following the appropriate processes and principles, needed for decision making. Such an individual can be intellectually and actively involved to public dialogues and debates concerning the management and resolution of problems that influence his/her personal and social life [6].

Undoubtedly, the formation of scientifically literate students is related to teaching practices which are opposite to teachers' traditional didactic monologues, to limited dialogic interaction among students [7] and to the passive acquisition of knowledge. The transformation of students from "empty vessels" to "deeper learners" presupposes their exposure to a new form of teaching related to:

a) inquiry processes and
b) to theories that situate problem's resolution to the center of the learning process [8]. Within this framework, controversial scientific issues get the form of ill-structured problems that demand a solution which is not universally or commonly accepted [9]. Subsequently, both learning and the construction of scientific knowledge are conceived as a complex socio-cultural and constructivist process, since they are influenced by cognitive operations, the context and the subsequent interpersonal interactions [10]; [11]; [12].

So, within this framework, the cultivation of students' discursive practices for the solution of ill structured problems becomes imperative. Among them, the development of argumentative skills is prominent for the construction of meanings and the acquisition of scientific knowledge.

For Sampson, Grooms & Walker[13], scientific argumentation consists of an explanation, a conclusion, a generalization, a response to a research question which is supported by evidence based upon facts, measurements, observations or findings of other researches. In more, the development of argumentation skills requires the enhancement of reasoning processes for ensuring the validity of the evidence used through principles, models, hypothesis and various concepts.

The pre-mentioned model of scientific argumentation is a simplified version of Stephen Toulmin's procedural model of argumentation. For Toulmin [14], argumentation aims at the sufficient and acceptable justification of a thesis. Its validity depends on the structure of the argument within a specific context or field. The argument is described as a motion from acceptable information (data), to a claim through a warrant, that is a reasoning line which justifies the validity of the motion.

Within the framework of teaching Science, teachers' and students' familiarisation with argumentation might contribute to the development of a new learning form, since argumentation:
a) permits students' involvement to the public dialogue related to scientific issues and
b) allows the implementation of the acquired knowledge for individual decision making relative to these issues. In particular, Driver, Newton & Osborne [15] support the idea that students' acquaintance with argumentation facilitates:
   a) the evaluation of the provided evidence,
   b) the invention of alternative ideas,
   c) the establishment of the validity of the proposed scientific positions,
   d) the presentation of opposite scientific proposals and
   e) the presentation and support of the opposite evidence.

In other words, the "movement towards argumentation" [16] and the use of the "attractive strategy" of controversies in educational praxis [17] (Klumkowsky, 2017) reinforce the importance of debates as an educational tool.
Debates become an important didactic method that contributes to the efficient

research and bilateral examination of scientific and/or socio-scientific issues [18]; [19], while they are linked to the development of life skills or the “ή 4C’s super skills [20], such as communication, critical thinking [21], creativity and collaboration. Additionally, it is supported that debates enhance students’ oral argumentative skills based upon evidence [22], sharp their reasoning and enrich the scientific content knowledge [23].

For all the above reasons, in USA debates have influenced, as important didactic techniques, the *Next Generation Science Standards-NGSS* [24]. In this way, it becomes clear that Science is not only “a group of facts” [25]. For example, according to NGSS standards students must be able to “evaluate claims, evidence and the reasoning behing the idea that electromagnetic radiation can be described either by a wave model or a particle model” and that for some situations one model is more useful than the other” (https://www.nextgenscience. org/topic-arrangement/hswaves-and-electromagnetic-radiation).

3. The European research project Erasmus+ KA2 *Oxford Debates for Youths in Science Education*

The European research project Erasmus+ KA2 O*xford Debates for Youths in Science Education*, which started in October 2018, aims at contributing:

a) to the research regarding the didactic use of debates in science education in Junior and High School (students of 13-19 years old) and
b) to enhance students’ reasoning skills through the cultivation of logic, scientific reasoning, the analysis and synthesis of scientific data.

Oxford Debates for Youths in Science Education consists of a strategic partnership between scientific institutions of four European countries: Poland, Greece, Serbia and Esthonia. In more, the project aims at:

a) increasing students’ interest in STEM topics,
b) contributing to the development of students’ communication skills in their mother tongue making practice of oral argumentation and delivery of public speeches in a debating context,
c) +encouraging educators and students to use debates within the daily school routines in Science education.

The above goals are closely related to the development of students’ rhetorical-communication skills. The presentation of scientific facts is converted from a wooden process addressed to a narrow circle of individuals with special interest in Science to a dialogic interaction open to all students. As in every communication circumstance, the ‘nascent scientist’ has to develop argumentative, persuasive skills and eloquence due to the correct use of language.

Also, students must be able:

a) to produce written texts where their scientific ideas must be clearly and precisely expressed and

b) to orally develop and share their scientific claims in a pleasant manner in front of an audience.

For achieving the above goals, students have to develop communication skills such as: active listening, critical examination and interpretation of opposite ideas, kind exchange of controversial scientific positions and negotiation skills. As we understand all the pre-mentioned skills refer to qualities of an active democratic citizen who is able of participating to public forums and contributing to the co-formation of the social, cultural, political and scientific becoming of each era.

The project lasts thirty (30) months and it will be implemented in five (5) phases:
a) Phase of preparation (October 2018 to July 2019). Within this period:
a) research relative to the topic will be conducted and,
b) the methodological framework of the stake-holders will be defined.
Also, during this period two methodological guides will be written as intellectual outputs. The methodological guides O3 and O4 aim at providing students and teachers with all the necessary knowledge about the implementation of *Oxford Debates* in school context, referring to the rules and principles of the debating contest. Lesson plans concerning the teaching of argumentation and the development of students' communication skills will be offered, while the goals of the project adapted to the national curriculum of each participant country will be provided. In more, the writing of twenty (20) educational packages on STEM topics will begin (intellectual output O8). Five (5) educational packages will be written in the mother tongue of each participant country, while all the packages will be translated in English.

b) Phase of Schools' declaration of interest in participating to the project (September 2019). During this period the recruitment of thirty-two (32) school-participants, at least, will be completed in Poland, Greece, Esthonia and Serbia.

c) Phase of pilot implementation of the project (October 2019 to July 2019). The third phase of the project implementation will include an experiential workshop for educators. Teachers will become acquainted with the rules and the principles of the debating process and they will be informed about the content of the educational packages and the resolutions of the debates. According to these rules, educators, based upon the prepared teaching material, will prepare their students for the upcoming debating contest. During the school year, the four scientific institutes will offer mentoring to the participant educators and students relative to the successful implementation of debates, while meetings with expert-scientists will be realized. In the end of the pilot phase, a debate contest among the participant schools will be organized in each participant country and the two semi-final winning debating teams of students will be selected.

d) Phase of the diffusion of the project (September 2020 to March 2021). During this period experiential workshops for educators and the organization

of a national conference will be realized. The thematic axes of the national conference will be relative to:
a) the presentation of good practices of the participant schools,
b) the presentation of the educational material,
c) papers regarding the role of debates in the STEM educational context.

Also, during the conference, the final debating contest among the semi-final teams will be conducted and the winning school will be announced. Within parallel experiential workshops, new educators will be trained to the debating process and to the educational material, while "mini-debates" of educators will be implemented.

e) Phase of project's evaluation. (January 2021 to March 2021). During this phase evaluative reports will be produced relative to the implemented activities, while proposals about the generalization of the teaching material and of good practices in all European schools will be presented.

4. Conclusions

The European project Erasmus+ KA2 *Oxford Debates for Youths in Science Education* aims at adding value to the teaching of STEM education for all European students due to its positive influence to teachers, students and educational institutions that will participate to its implementation.

Several expected benefits from the participation to the project can be highlighted, such as:
a) the increase of students' interest in Science and STEM education due to their active involvement in the inquiry and research process.
b) The significant improvement of students' argumentative, critical, dialogical, rhetorical and communication skills due to the free oral expression, the practice in the invention of the appropriate arguments for supporting the proposed scientific claims, the familiarization with the main principles of the debating process and the cultivation of the dialogical culture.
c) The revitalization of teaching STEM due to the existence and use of prepared educational material that will facilitate the implementation of debates in daily school practice and/or in the context of rhetorical scientific clubs of students.
d) The openness of the scientific and the educational institutions that will be involved in the realization of the project through the presentation of its results to a large audience that, probably, is not familiarized with the use of such a scientific vocabulary. More specifically, the participation to the project will provide all the participants with efficient tools and skills relative to the use of modern technological applications that enhance scientific and teaching aspects of their work.

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Art and Chemistry - a Source of Mutual Inspiration and Symbiosis
Inquiry-based learning as deeper understanding of curriculum in chemistry science through arts

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Abstract

Chemistry students are sometimes bored or turned off by a traditional approach to chemistry. Integrate chemistry and art with hands-on activities and fascinating demonstrations that enable students to see and understand how the science of chemistry is involved in the creation of art. Most importantly, the chemistry is taught with relevance to art topics. Art and chemistry are truly integrated into one subject [2].

In ancient times, chemical science has served art - it has studied the composition of colors. “We employed in our researches ultramarine of various qualities; but that used in the experiments from which we have deduced the approximate proportions of its constituent principles was of the greatest beauty”, wrote Desorves and Clement in 1806 in A Journal of Natural Philosophy, Chemistry and the Arts [4].

In turn, artists are inspired by chemical reactions, structures, crystals, diffusion and other visualizations. However, although we are capable of creating art at a young age, for many of us this inspirational, artistic and creative chapter of our lives ends as we move onto more “mature” endeavors.

How to keep inspiration for artistic creativity in the long run? The author shares the experience of getting inspiration from the results of chemistry experiments. As argues Prof. Omar Yaghi**: “**Metal–organic frameworks are some of the most beautiful compounds ever made**.** Their structures are intricate and the diversity of structural patterns and connectivity, to me, they are fascinating. I love looking at molecular structures and the periodic table, and how that translates into compounds, reactions, materials, and new chemistry.” [6].

Keywords

Art, Chemistry, Creativity, Symbiosis

1. Introduction

Art is a made of expression and craftsmanship. Science is the practice of making observations about physical properties of the world. The two disciplines are arguably distinct opposites from one another. The course combines theoretical science concepts with current art practices to provide a greater understanding of chemistry's role in art and show how the nature of color relies on chemical processes.

"The students actually do labs which are effectively art studio practices and then we talk about the science of the labs themselves," Coppage [1] said. "I bring in art conservationists, I've brought in a restorationist that has worked on $50 million paintings, anything that I can possibly get my hands on that talks about the intersection between science and art."

Coppage structures his class by giving a lecture on a type of art, its history and its uses in modern times. He then talks about the science of how the methods works, such as the elements of composition, recipes and different pigment compositions.

"For example, we did a ceramics lab in which we used a 5,000-year-old Egyptian faience recipe where they would make the little turquoise statues of the Egyptian gods," said Coppage. "I provided an adapted recipe for them, they molded their own statues. The students had to write up a lab report about the actual science of the material, what caused the color, how it was fired, why it was the color it was, how it was hard or petrified."

"For me, it's about education," he said. "If someone is interested in art I think that if they understand what they're doing a little bit more, it widens their perspective. All of a sudden, they're not confined to the small amount of rules they have set in front of them. They can go in any direction they want if they understand the parameters they have."

Through finding a medium between two fields of study that seem drastically different from one another, Coppage's students are encouraged to look for further correlation among their academic endeavors.

2. Historical view to symbiosis of Art and Chemistry

The history of chemistry began more than 4,000 years ago with the Egyptians who pioneered the art of synthetic "wet" chemistry. By 1000 BC, the ancient civilizations were using technologies that would form the basis of the various branches of chemistry. Extracting metal from their ores, making pottery and glazes, fermenting beer and wine, making pigments for cosmetics and painting, extracting chemicals from plants for medicine and perfume, making cheese, dying cloth, tanning leather, rendering fat into soap, making glass, and making alloys like bronze. In the Middle Ages that began around 500 AD and lasted until 1400 AD there was a “science” called alchemy - the forerunner of modern chemistry. The main objectives of alchemy were to find the appropriate combination of ingredients that would cure all illness and diseases, to find the chemical that would prolong life, and to convert lead into gold. Nowadays the above goals have not been neglected – possibly just realistically modified.

During the Renaissance, artists were chemists and chemists were artists. The close relationship between art and chemistry is still obvious to the artist and to the chemist, but todav there is little need for the artist to prepare his or her own materials. On the other hand, this relationship provides a viahle curriculum for an interdisciplinary approach to the teaching of chemistry.

In 1984 a one-year high school course “Art in Chemistry” was developed by Barbara Greenberg who was a teacher in the faculty of Willow Brook High School, Villa Park. The chemistry courses in the curriculum are approached through art topics: Color, Painting Surfaces, Clays and Glazes, Jewelry Making, Photography, Art History, and Chemical Hazards in Art. In each of these seven units, the students completed projects in the art class and carry out experiments in the chemistry class. There were a total of 20 chemistry experiments and two chemistry demonstrations. There were 11 art lessons, some including projects and questions. The art proiects employed the materials prepared in the chemistry experiments. Each of these units was original and could be supplemented with any general chemistry and introductory art textbook. A brief overview of each of these units is described in this paper.

The art teacher presents lectures on the historv -. of painting materials and art forgeries. Two chemistry experiments are done on this topic: “Art Forgeries-Radioactive Dating” and “Art Forgeries sectroscopy and Qualitative Analysis for Ions”. The first provides a basis for a discussion of halflife in radioactive substances and its use in radioactive dating. In the second lab, the student works with an “original” painting and an art “forgery”. The idea behind the experiment is to show a general technique for detecting art forgeries and to teach qualitative analysis. A paint chip is taken from each painting and put through flame tests. Next a chip is analyzed for lead (II), silver, and mercury (I) cations (V). The presence of lead ions can identify an “old painting since it is assumed that most artists no longer use lead-based paints. The final lesson in this unit is in art class dealing with the preservation and restoration of works of art. Much of the teaching is done through movies: “Art of the Conservator I and II”, “Once Upon A Wall”, “The Great Age Of Fresco”, and “Treasures of Florence”. A trip is scheduled to the Department of Conservation at the Art Institute of Chicago.

3. Color

The first unit is on Color. It includes art lessons on the nature and meaning of color and color relativity. The students prepare a color wheel with 12 hues, make a chart using light and dark values (degrees) of one hue, and learn about the nature, source, and traditional significance of each hue. To study color relativity, the students place colored squares on various backgrounds and note the effect of the comhination on the value of the square. This exercise leads into the first chemistry experiment entitled: “Why We See Color When Certain Atoms Are Excited”. The spectroscope is used to see spectral lines from excited atoms in the gaseous phase. The spectral lines are explained in a qualitative way. Atoms, neutrons, and electrons are discussed. Several paint-making experiments are then conducted. Pigments are prepared by precipitating aqueous ions, as a combustion prduct, from a mineral source and from reactions with organic and inorganic substances. This chemistry experiment teaches the students about chemical change, how atoms combine to make molecules, and about chemical formulas and equations. The students also learn how to filter and decant, how to use a Bunsen burner, and how to work safely in the lab. In the next experiment, the students compare the solubility of each prepared pigment in H_2O, oil, egg yolk, 6 M $NaOH$, and 6 M HCl. The third chemistrv lab involves the preparation of binders for oil paints, water paints, and egg tempera. The final exneriment in this color unit focuses on the preparation of by combining homemade replicas of commercial binders with the previously prepared pigments. Binders iuclude oil; a water, wax, and ($NaHCO_3$) combination; egg yolk; and a starch and cold water mixture. Some combinations form suspensions while others form solutions. This experiment is used to teach solutions, suspensions, colloids, and physical change. Since the Color Unit experiments include all classes of matter, it is appropriate to introduce classification of matter into heterogeneous mixtures, - homogeneous mixtures, elements, and compounds.

4. Painting Surfaces

The art lesson for the Painting Surfaces unit, includes forms of paints and the ways paints are applied to surfaces. Students compare the composition of watercolor, acrvlic, and tempera paints. They learn the procedure of stretching and preparing canvases and watercolor paper and discuss the properties of a gesso painting surface. In the chemistry section of the unit, student experiments include: preparation of grounds using whitening compounds to make gesso suspensions and the making of paper. A whitening compound, $CaCO_3$, is made by precipitation from 0.2 M Na_2CO_3 and 0.2 M $CaCl_2$. Slaked lime, $Ca(OH)_2$, is prepared from solid CaO and H_2O. These combinations illustrate double replacement and composition reactions. In the gesso preparation, $CaSO_4$. H_2O is used. These experiments afford a good opportunity to renew equation writing and classification of chemical reactions, and to define terms such as hygroscopic, efflorescence, deliquescence, hydrate, and anhydrous. Two methods of paper making are presented: making paper from lint and making paper from sawdust. The use of sodium hydroxide to digest the wood fibers provides the impetus for the discussion of acids and bases. After the paper is made, it is used in an art lesson to make a picture with the paints prepared in Unit 1.

5. Clays and Glazes

To learn about clays and glazes in art, the students study the nature of clay and ceramic techniques. They discuss clay as a natural polymer while preparing clay slabs and clay objects. In chemistry, the students study relative weights of dements, learn about the mole concept, and make simple conversions in preparation for the next experiment where they make glazes. These glazes are applied to the surface of the clay slabs, fired in the kiln and observed for color, shininess, and texture.

6. Texture and Line

In an art lesson on texture as an element of design, a plaster of Paris mold is poured, hardened, and a design is scraped into the surface. This mold is used in the next chemistry experiment: “Preparation of Polymers”. The students prepare Lucite, a glyptal resin, and nylon. The Lucite is poured into the mold and set. The nylon is used in their next art lesson: “Line as an Element of Design”. Here the students make a three-dimensional toothpick sculpture and incorporate the nylon filament into the sculpture. The final chemistry lesson of this unit on polymers is used as an introduction to organic chemistry.

7. Jewelry Making

In the Jewelry Making Unit, the first art lesson focuses on basic metal-working techniques. The students learn to solder, saw, file, and polish metal and to use tools properlv to prepare an original piece of jewelry. In chemistry, they examine the physical and chemical properties of metals including density, approximate melting point, metals, reactivity oxygen, HCI, H_2SO_4, and HNO_3. The chemistry discussion includes an inveitigation of the periodic table and the trends associated with the physical properties within the group,. An activitv series for the metals is developed from the observations of reactivity to acids. The next chemistry experiment is that of preparing alloys of metals and observing their properties. Jewelry is made through an electroplating experiment that introduces the students to electrochemistry. The parts of an electrolytic cell are presented, and red-ox reactions are introduced. In this activity the students use copperplate metal ohjects they have made in art class. For the last metal experiment, the students prepare four solutions that react with copper strips and change the color of the surface. Thev write equations to find the products that were responsible for the change in colors. Since jewelry is usuallv three dimensional. there are two chemistrv experiments chat relate to three-dimensional objects: “Making Molecular Models” and “Ion or Atom Arrangements of Crystals”. These introduce the topics of intramolecular bonding in molecuies and intermolecular and ionic honding in solid structures with the building of molecules and crystalline solids. The last art lesson for this unit on Jewelry Making is related to the principles of organization in two and three-dimensional works. Sculptures are studied for good composition stressine a successful arraneement of line. color, shape, contrast of light and dark area and texture: The molecule and crvstalline structures studied in the chemistry class are used as design motifs for sculpture construction.

8. Photography

Photography starts with two chemistry experiments. “Developing Film and Printing the Negative or Photogram”. The students prepare each solution necessary to develop film and to make prints. They learn the chemical principle behind each step in the print-making process. Students prepare photograms in the second chemistry experiment and use them for the art lesson, “Negative and Positive Space Organization”. A photogram is a photo made in the darkroom through direct exposure of objects on light-sensitive paper. A camera is not needed for this picture. A sulfide sepia toner and a brown toner are combined and applied to the photograms in the final chemistry experiment in this unit which is “Photography-Toning Prints”.

9. Chemical Hazards in Art

A combined chemistry and art presentation on chemicals used in art includes topics of toxicity and proper use of materials. Examples are given, i.e., metal working can produce toxic heavy metal fumes and acids used to etch metal surfaces are corrosive to eyes and skin. Solutions used in photography are extremely toxic if ingested and can irritate the skin upon contact. The students are told that chemicals can affect them by being inhaled or ingested or by being absorbed through the skin. Toxicity, however, does depend on the degree of exposure. There is a discussion on the ways to reduce-chemicai hazards. A presentation follows on ceramic materials and how the obiect should he handled during firing.

The course covers most of the topics taught in introductory art and the qualitative aspects of a beginning chemistry course. Accordingly, it does not deal with gas laws. percent composition of compounds, empirical and molecular fomulas, calculations, and other quantitative aspects of beginning chemistry. Materials described for each unit are dispensed as needed. The success of the course has resulted from the joint planning and interaction between the art and chemistry teachers who team teach the course.

10. Chemistry as source of mutual inspiration

Chemistry is the science concerned with the composition, structure, and properties of matter, as well as the changes it undergoes during chemical reactions. The latter is defined as “a process in which one or more substances are changed into others.”

Chemistry is generally divided into inorganic chemistry and organic chemistry where another division is physical chemistry and analytical chemistry. Chemical reactions are processes by which the original substances are changed into new ones by making or breaking of chemical bonds. Interesting reactions, not yet well understood, are those taking place in our brain. When we think a thought or feel a sensation from the outside world, it is the result of chemical reactions in our brain; drugs and food can have a significant effect upon our brain chemistry. Each chemical is characterised by a symbol or a formula derived from the scientific name of the element where a specific reaction is described as combination of the formula of the reactants and products, for example A B. It is interesting to note that also in the brain there are reactions caused by the brain cells, when for example we see something attractive. And finally, two additional basic definitions. Chemistry laboratory is defined as “a laboratory for research in chemistry” or “a workplace for the conduct of scientific research” where the chemist is “a scientist who specialises in chemistry”. The original physical chemistry laboratory was built in Oxford University in England [3]. In the following different aspects of chemistry are demonstrated by artworks.

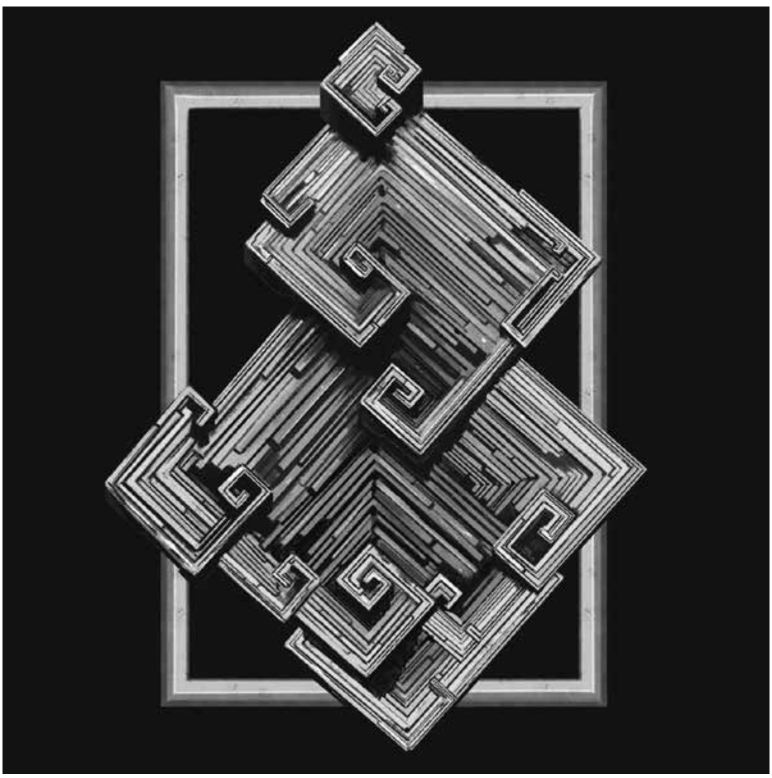

Figure 1

Figure (1) Bismuth is a heavy, brittle silver-white crystalline that transforms with tinges of pink to red. It naturally occurs with an iridescent oxide tarnish that reflects a full spectrum of colors including blue, yellow and green, as well. Bismuth crystals are typically laboratory grown where Bismuth is melted and a rod is placed in the molten metal and pulled up slowly, which allows crystals to form as it cools. [7]

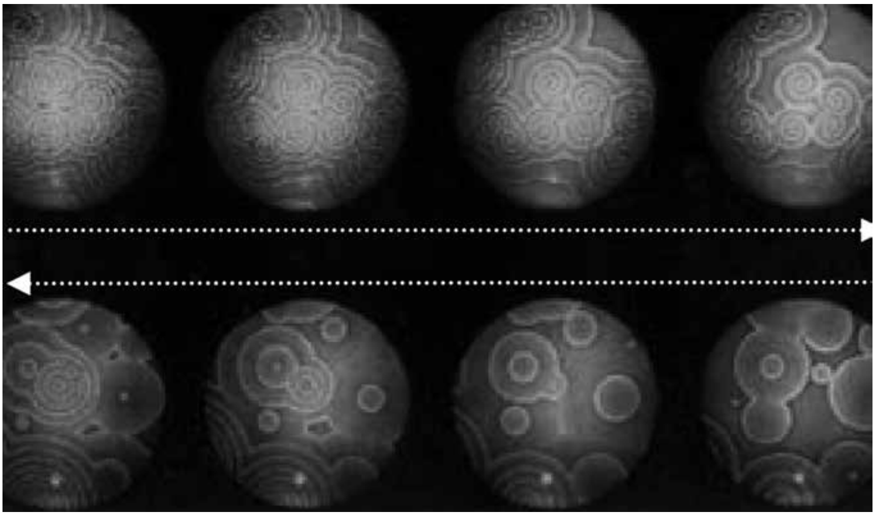

Figure 2

A cyclic process is demonstrated in Fig. (2). It is the Belousov - Zhabotinski "chemical cyclic reaction" [3] named after two Russian scientists where Belousov discovered the reaction in 1951. This chemical reaction occurs by mixing four compounds, which then create beautiful rings, which spread across the plate. The reaction oscillates back and forth between different colored states in rings, which move in rhythmic wave patterns. In the reaction ferroin continuously shifts and forms its oxidized form ferriin through different intermediate species. In the picture we see top views, at different times, of the surface of the apparatus in which the oscillatory chemical reaction takes place.

Figure 3

Another kind of chemical reaction, “The Firework”, which combines art and science, is demonstrated in Fig. (3). Fireworks are usually made out of the following mixture: an oxidizing agent, a reducing agent, coloring agent, binders and regulators. When these are mixed together and burned, they produce the spectacular effects.

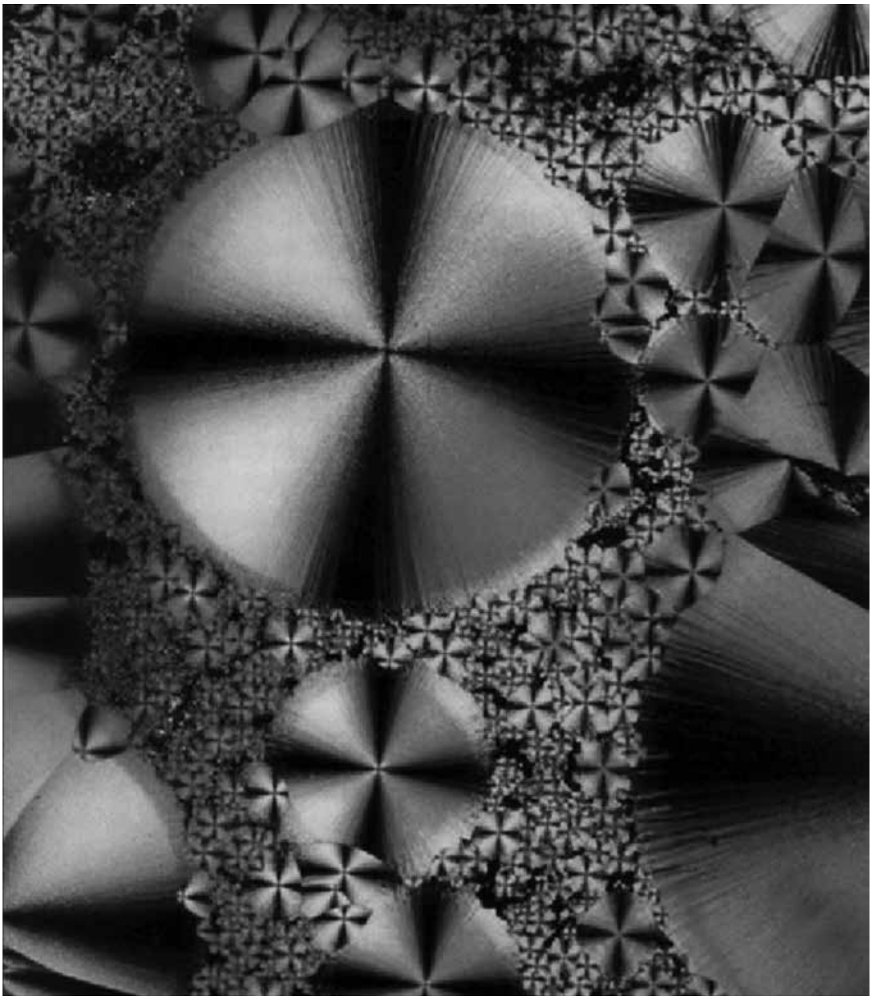

Figure 4

Fig. (4) demonstrate science creating art in images of different chemicals photographed by the research scientist Michael W. Davison through a microscope, or more commonly by photomicrography. This is a photograph of vitamin B1. [8]

11. My personal experience in Art and Chemistry

Personally I have grown bismuth crystals, made chemical gardens out of water glass and different kinds of salts, grown metal salt crystals and made crystal tree sculptures, used chemical reactions and diffusions for my artworks.

Growing bismuth crystals at home is far too dangerous because it requires to deal with molten metal. In the laboratory I took around 500g of bismuth and melted it in a porcelin bowl on a heating mantle to ensure even heat and covered in aluminium foil. It is then cooled slowly and evenly which is vital for creating crystals. After a solid crust of bismuth forms on top of the bowl it is then broken or punktured and the molten bismuth is poured out of the bowl in to a different container and you are left with some beautiful bismuth crystals. This experiment taught me that metals have crystal forms and that their crystal structure depends on the unitcell properties. This can also teach one of the most widely used purification methods of crystaline substances and it's recrystalisation.

Chemical garden is made out of the solution of sodium or potassium silicate (water glass) and different kinds of inorganic salts. When a metal salt, such as cobalt chloride, is added to a sodium silicate solution, it will start to dissolve. It will then form insoluble cobalt silicate by a double displacement reaction (anion metathesis). This cobalt silicate is a semipermeable membrane. Because the ionic strength of the cobalt solution inside the membrane is higher than the sodium silicate solution›s, which forms the bulk of the tank contents, osmotic effects will increase the pressure within the membrane. This will cause the membrane to tear, forming a hole. The cobalt cations will react with the silicate anions at this tear to form a new solid. In this way, growths will form in the tanks; they will be colored (according to the metal anion) and may look like plant-like structures. The crystals formed from this experiment will grow upwards, since the pressure at the bottom of the tank is higher than the pressure closer to the top of the tank, therefore forcing the crystals to grow upwards.

After the growth has ceased, the sodium silicate solution can be removed by a continuous addition of water at a very slow rate. This prolongs the life of the garden.[9]

I made this experiment in some little jars using copper(II) sulphate, iron(II) sulphate, cobalt(II) chloride and chromium(III) chloride. After the 5 years of being made it hasn't changed it's state. This experiment taught me of the double replacement reactions and on how it forms insoluble salts. The crystal growth upwards showed me the osmotic process and how pressure and density effects the growth rate. As shown in figure (5) but that is not a picture of my chemical garden, it is of Neda Glisovic.

Figure 5

To grow metal salt crystals in water you have to go through a similar path as with the previous two crystal growng methods mentioned in this topic. At first I chose a metal salt with a steady growth in solubility increasing the temperature. This ensures that whilst cooling the solution the crystals will have time to grow graduately so the biggest monocrystals form. At first I created a saturated solution at about the temperature of 80oC. In this beaker was then added one monocrystal of the same salt the solution was then cooled to room temperature and left for a couple of weeks. The monocrystal should then be at the bottom of the beaker. The crystal tree sculpture is made in the same way only in the hot solution instead of the monocrystal there is a tree shape structure submerged in the solution. The tree shaped structure is made out of wire which branches are wrapped with twine cowered with a bit of small salt crystals. The crystals ensure crystalisation centers. The monocrystals on copper(II) sulphate are shown in figure (6)[10] and figure(7) shows my crystal tree.

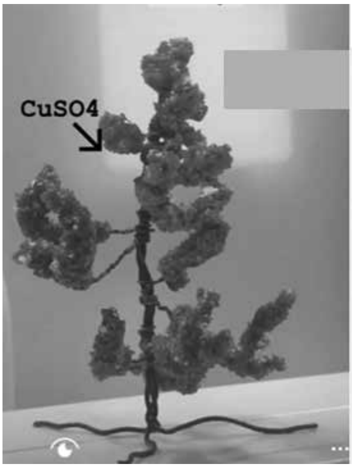

Figure 6

Figure 7

I have also used some chemical reactions or properties on paper to create art pieces. This would envolve using salt on a pool of watercolor, mixing paints of nonpolar and polar bases, combinging acids with carbonate salts and pigments on top of a piece of paper to form interesting patterns, textures and effects. These kinds of experiments taught me diffusion, acid reactions with carbonates, nonpolar and polar liquid properties etc. As shown in figures 8 watercolor with salt by Joe Millet and figure 9 acryllic paint pour with polar and nonpolar bases[11].

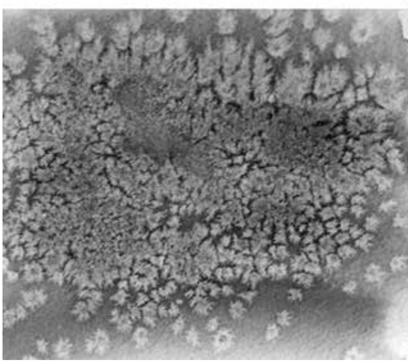

Figure 8

Figure 9

12. Conclusions

To conclude the observation, the author is fully agreed with Abraham Tamir that the presentation by artworks of the different areas in Chemical Engineering makes this profession clearer, more understandable, easy to percept as well as to remember, especially for students -beginners. One of the most impressive influence between chemistry and art is personnal experiance by working with materials and inspiration of chemical eksperiments – the aesthetic and artistic images of crystal lattices have inspired the creation of new works of art.

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BRAINs, bodies and materials: science education reshaped Creatively

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Abstract

The BRAINiaC project aims to apply innovative approaches and activities that enhance teachers' training, at a European level, by developing guiding methodologies and tools that promote scientific learning. The BRAINiaC project aims to exploit cognitive pathways in order to develop strategies for providing students with 21st century skills. In order to understand how these skills are developed, educators must first know how students best acquire, retain, and apply knowledge in creative ways. The aim of the BRAINiaC project is to combine science education methodologies (IBSE, Collaborative Learning, Problem Solving) with components of neuroeducation (Society for Neuroscience, 2008) and provide the needed support to educators by developing modular and simple to use tools that would enable educators to implement innovative techniques and methodologies in their teaching process and enhance learners' development of basic/transversal skills and deepen learning. The BRAINiaC framework based on the Brain-Targeted Teaching (BTT) approach will not be a linear guide to pedagogy but should be rather treated as an organic system that focuses on six distinct targets of the teaching and learning process

Keywords

Brain-Based learning, cognitive pathways, scientific learning, transversal skills, deepen learning

1. Introduction

The call for a new approach to teaching and learning is a crucial issue that continuously challenges the educational community and policymakers.

Although during the recent years there have been strong proclamations and great efforts on reshaping education by promoting the development of 21st century skills (National Research Council, 2012; European Commission, 2013) there is still strong debate on the identification of the relevant methodologies and techniques that can lead to this purpose. Developing 21st century skills and competencies in schools requires coordinated bottom-up efforts (involving reformations and policymakers' renewal of approach, educators' training, learners' empowerment) and demands synergies from certain scientific fields which study human behaviour and the principles of learning and understanding.

Although Neuroscience, Cognitive Psychology and Pedagogy are scientific fields that have been working in a collateral way, recently they have come up with emerging findings that highlight crucial points of intersection; identifying pathways and measurable techniques capable to promote and enhance the teaching and learning process.

2. Previous Researches – Cognitive approaches

A previous study (Smyrnaiou et al., 2014) based on the methodology of design-based research aimed to analyze step by step the creative design course of a candidate teacher of Physics, in order to achieve a cognitive mapping of the conceptual perceptions, in the way they occur, during the design process. This, frame by frame, in the form of snapshots cognitive mapping examined and analyzed through the dynamic pairs and interconnections of knowledge aspects (content knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK) / TPACK) (Koehler, M.J., & Mishra, P., 2008) as well as the Cognitive schematization frame (COSC). Our detailed study based on cross-analysis, aimed at recording the sequence and temporal specifications of the influences on the designer, which determined the way he interacts with the tool, as well as, his decisions in terms of semiotic projection and representation of scientific concepts. By tracking the designer's decisions on the creation of a tool, informed by the inquiry-based scientific approach, we perceived his own conscious and subconscious alignment with an inquiry-based course. In his effort to design hypothesis testing techniques through experimentation and conclusion drawing based on attained knowledge, the designer seemed to undergo the same inquiry process in combining the cognitive and TPACK principles as he interacted with the tool.

Our main goal was to determine to what degree the design process can be represented in the form of a pattern which could act as a point of reference and verification in a design process. The difficulty of the task lied in the fact that it examined nonlinear interconnected forces while aiming at their linear imprinting from the beginning of the genesis of the idea (also considering whether the design project, at the very beginning, is viewed holistically or analytically) and in the fact that it focused, during the analytical examination, on the study of isolated constructs - cognitive and representational - which are multi-dynamic products.

In another research (Smyrnaiou et al., 2012), we studied the meanings generated by the students as they worked with a Newtonian Physics microworld and how these meaning are mediated by the Metafora web Platform. The Metafora Platform (Dragon et al., 2012) was a completely web-based environment that is designed to support meaning generation processes and learning to learn together processes as groups of students -possibly in distance- collaboratively work on-line. Apart from a set of microworlds for mathematics and science, it also included two shared activity spaces: the Planning Tool and the Discussion/Argumentation Tool. The Planning Tool was a shared workspace developed to support a group of students working together in planning their activities in advance, attributing roles and assigning tasks to the members of the group. LASAD was an on-line tool designed to support synchronous discussions between collaborative learners. The students (working individually or in groups), may communicate their ideas with their peers by adding textual contributions inside a shared workspace.

In using this web-based environment (Metafora Platform), we wanted to investigate what students learned with respect to the concepts investigated and how the Metafora Platform was used by the students in order to collaborate and communicate in this process. In addition, we wanted to study the process of meaning generation in the context of learning to learn together (L2L2). L2L2 is an important aspect of collaboration as it refers not only to what the students learn, but to how they learn to collaborate and communicate with others inside a group and jointly reflect on their work and their functioning as a team. We perceived distributed leadership, mutual engagement, peer assessment and group reflection (Wegerif et al., 2012) as the four key concepts for L2l2 and we sought for ways that these key concepts facilitated or enhanced the meaning generation process. That means that we looked for studied the process in which meaning generation triggered one of the four L2L2 elements and/or how the different elements of L2L2 might have influenced and shaped the process of meaning generation.

Finally, in another research (Smyrnaiou & Weil-Barais, 2005) we studied the learning of physics (mechanics) while using the 'MODELLINGSPACE' technology based learning environment. This learning environment is a technology based learning environment (Dimitracopoulou et al., 1999; Komis et al., 2001), designed to familiarize pupils with the steps of modelling. Using this learning environment, the students can build models of the evolution of physical, biological, economical systems, etc. Concretely, the user of the learning environment determines the constitutive entities of the system in which he is interested and the descriptors of these entities. He proposes then relations between these possible descriptors to account for the evolution of the system.

The interest of this technology based learning environment is that it makes possible to pupils to handle various semiotic systems, making possible to express the entities and their relations. By comparing the transformations of the entities (represented in a figurative way by dynamic images) associated with various expressions of the relations, it is possible to apprehend the compatibility or the incompatibility of the relational expressions. It is thus possible to exploit the possible mapping between various manners of representing the relations: graphic coding with arrows of variable size (which means the covariation of two descriptors), logical, mathematical expression, a graph, and a table of measurements.

3. The Brain-Targeted Teaching (BTT) model APROACH

The Brain-Targeted Teaching (BTT) model (Hardiman, 2012) is a unified pedagogical framework intended to provide educators with a cohesive, usable model of effective instruction to further pedagogical goals, including the development of 21st century skills, so that all students can become creative and innovative thinkers and learners (Rinne, 2011). The BTT model as a cohesive pedagogical framework that supports the implementation of Common Core State Standards and curriculum scope and sequences; it is the “how” of teaching (instruction) that supports the “what” of teaching (standards and content). Instructors in education settings can use the BTT model to improve emotional and physical learning environments, increase global understanding of the “big picture,” deepen mastery of content, encourage students to apply knowledge in real-world contexts, and benefit from appropriate feedback and evaluation techniques.

The pedagogical framework of the Brain-Targeted Teaching Model is not a linear guide to pedagogy but should be rather treated as an organic system that focuses on six distinct targets of the teaching and learning process: (1) Establishing the emotional climate for learning, (2) Creating the physical learning environment, (3) Designing the learning experience (4) Teaching for mastery of content, skills, and concepts (5) Teaching for the extension and application of knowledge—creativity and innovation in education (6) Evaluating learning

The pedagogical framework of the Brain-Targeted Teaching Model is an approach that allows for open innovation based on a set of activities of co-development and technological transfer where the research institutions (eg. universities) have to perform the task of generating a comparison between the end-users and the involved subjects. It creates a background capable of producing knowledge and excellent results and promotes the cooperation between the world of research, policymakers and end users.

4. The BRAINiaC project

The BRAINiaC project will focus on bringing together insights about the physical (mundane and science specific) environment and digital spaces and how these shape the conditions for learning, thus impacting on wellbeing and students’ emotional experiences at school.

The BRAINiaC coordination action aims to apply innovative approaches and activities that enhance teachers' training, at a European level, by developing guiding methodologies and tools that promote scientific learning. The BRAINiaC project aims to exploit cognitive pathways in order to develop strategies for providing students with 21st century skills. In order to understand how these skills are developed, educators must first know how students best acquire, retain, and apply knowledge in creative ways.

The main objectives that should be addressed are:

- To encourage the development of European working guidelines and framework that efficiently combines the findings of the intersecting sciences
- To support educator's professional development in becoming aware of innovative and creative techniques that promote the teaching process
- To facilitate students' development of basic and transversal skills
- To promote the creation and development of informed tools based on the Brain-Targeted Teaching (BTT) approach
- To co-work towards the creation of communities of innovators who will adopt the system proposed (Open Discovery Space)

In alignment with the above project objectives the following expected project results have been determined:

a) Encourage the development of European working guidelines to ensure equal quality standards in the management of the BRAINiaC framework.
b) Promote the creation with a bottom-up approach of tools for the management of the BRAINiaC framework.
c) Development of Demonstrators based on the BRAINiaC approach acting as exemplary cases of the proposed framework/strategies.
d) Encourage the adoption of the BRAINiaC framework working paths by schools at European level
e) Promote the creation of communities of innovators who will adopt the system proposed e-mail addresses. Follow the author information by two blank lines before main text.

In addition, the BRAINiaC approach aims to act as a hub combining the intersecting methodologies of the interacting sciences (neuroscience, science of education, cognitive psychology and cognitive science) (Report by the Royal Society, UK, 2011; Kandel, 2006; Brabeck, 2008; Sylvan et Christodoulou, 2010; Φλουρής κα., 2015) to create modular and simple to use tools that would enable educators to implement the scientifically informed techniques and methodologies in their teaching process and enhance learners' development of basic and transversal skills. The neurotechnology-driven, BRAINiaC approach enables personalized education implementing innovative teaching and learning techniques and allows more students to achieve mastery of a larger range of skills and creates new ways of thinking (Bransford, et.al. 2006· Kandel, et. al., 2006· Kandel, 2006· Martin, 2011; Kalantzis & Cope, 2013).

5. Methodologies Adopted

BRAINiaC, starting from the successful experiences already realized (METAFORA, CREATIONS), develops an innovative Theoretical Framework that empowers teachers in applying an interdisciplinary scientific approach in science teaching and enhances students' creative and scientific learning. Responsible Research and Innovation constitutes the main framework for defining and implementing interdisciplinary methodologies in BRAINiaC. RRI implies that societal actors (policy makers, artists and scientists from different disciplines, teachers, students, research institutions, etc.) work together during the research and innovation process in order to better align both the process and its outcomes with the contemporary teachers' and learners' values, needs and expectations. All these methodologies will be applied to the 4 Intellectual Outputs:

- (IO1) Development of the BRAINiaC Pedagogical Framework that builds on the basic features of Brain-Targeted Teaching approach, enriched with Essential Theories of Science Education (ETSE).
- (IO2) Development of the BRAINiaC Demonstrators, a series of initiatives that successfully introduce the scientific methodology in school science education
- (IO3) Development of Implementation "toolkit" and guidelines for BRAINiaC and training material addressing teachers (in service /pre-service) and trainers
- (IO4) Evaluation and Assessment Plan for evaluating the skills acquired by students during the paths of the BRAINiaC approach.

These IO are expected to result in:
a) the effective integration of science education through monitored-for-impact innovative activities, which will provide feedback for the take-up of such interventions at large scale in Europe
b) developing a roadmap that will include guidelines for the design and implementation of innovative educational and outreach activities that could act as a reference to be adapted by stakeholders in both scientific research outreach and science education policy, and
c) training teachers to create, apply and share in an innovative way meaningful educational activities that build on the strengths of formal and informal learning, that promote creative inquiry based learning.

6. Conclusion – Discussion

Education is just beginning to acknowledge that successful learning isn't just a process of taking in facts; it's also about strengthening and developing the brain itself. In order to facilitate the use of research in instructional practice, teachers need a framework and a coherent strategy to support them- with planning, implementing, and assessing a sound program of instruction. The BRAINiaC project will apply the main principles of the BBT model to develop guiding templates that will facilitate educators' access and implementation of empowering teaching techniques.

The brain-based approach enables personalized education implementing innovative teaching and learning techniques and allows more students to achieve mastery of a larger range of skills and creates new ways of thinking. The underlying processes students go through while studying are as important as traditional or modern study skills themselves, if not more so.

The processes such as identifying important information, attention allocation, and comprehension monitoring are very important in the BRAINiaC project.

7. Acknowledgements

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Assessing Deeper Learning in Detail – The Case of iMuSciCA in Greece

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Abstract

This Paper highlights the main piloting results of the H20202 project iMuSciCA (www.imuscica.eu) as reported by teachers and learners while interacting with the Workbench and applying the Educational Scenarios of iMuSciCA in real teaching and learning environments. It details the received feedback of teachers and learners alike about the service portfolio of iMuSciCA. It furthermore reports on the quantitative and qualitative data collected in the three piloting countries i.e. Belgium, France and Greece about the influence of iMuSciCA on the Knowledge Acquisition, the Motivation & Attitudes towards Science Learning as well as on the development of Deeper Learning Competencies of students around Europe.

1. Introduction

iMuSciCA is part of the educational movement of STEAM, which is bringing Arts to the heart of the school curriculum to cultivate creative skills of young people alongside with the knowledge they acquire in STEM fields (i.e. in Science, Technology, Engineering and Mathematics). iMuSciCA is promoting new pedagogical methodologies and is developing innovative educational technologies to support active, discovery based, personalised and more engaging learning. It is at the same time providing students and teachers with new opportunities for collaboration, co-creation and collective knowledge building.

The teaching and learning activities of iMuSciCA are guided by a set of dedicated Educational Scenarios and concrete Lesson Plans for European STEAM teachers and learners in Lower and Upper Secondary Education. These include amongst other:

- Sound & Tone;
- Standing Waves & Resonant Frequencies;
- Synthesize the Timbre of your preferred Instrument;
- Create a Piece of Music using Geometric Symmetries;
- Design & Play a Guitar in Your Own Tuning;
- Create Music with Intervals & Simple Mathematical Proportions;
- Let's hear Thales' Theorem;
- Investigating the Monochord;
- Instruments of Speech;
- The House of Chords;
- Listen to your Math;
- Let's play Sectio Canonis;
- Timbre & Power Spectra;
- Defining the Octave.

The overarching conceptual as well as practical approach of iMuSciCA is illustrated in Figuer 1 below.

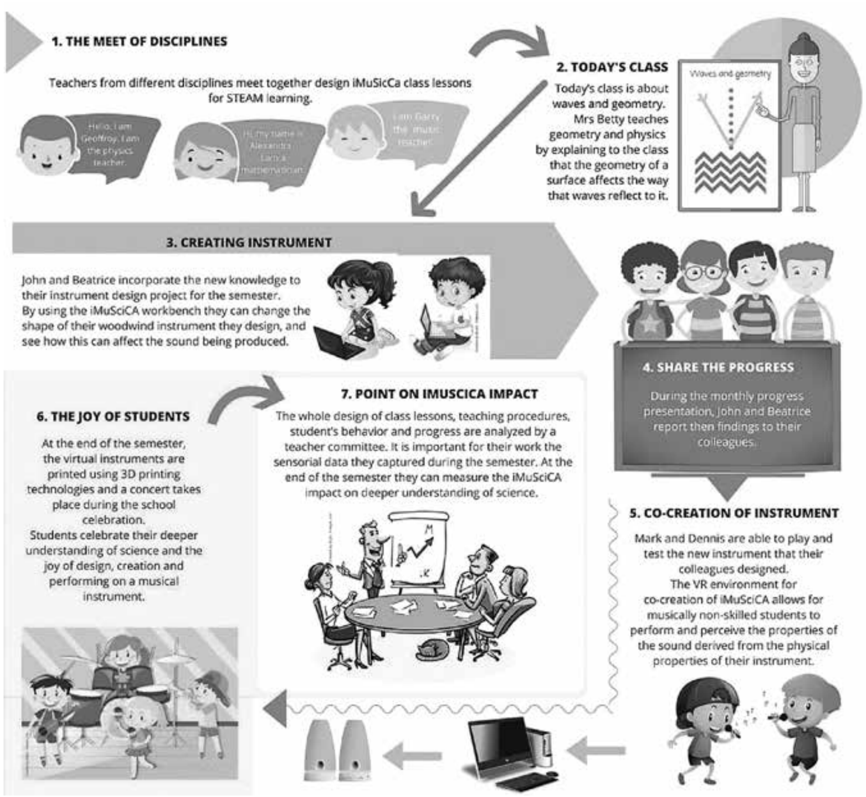

Figure 1: Overarching Use Case Scenario of iMuSciCA

The seven elementary steps of the integrated iMuSciCA Deeper Learning & Teaching Process are the following.

1. The meeting of the disciplines (i.e. to co-create interdisciplinary Educational Scenarios);
2. Actual teaching in class;
3. Creating, testing and playing a virtual instrument on the iMuSciCA Workbench;
4. Share the progress with peer students and exchanging knowledge and experience;
5. Co-creation of a (real) Instrument through 3D-printing;
6. The joy of students and the final concert;
7. Assessing the impact of iMuSciCA on the deeper understanding in STEAM.

The Workbench of iMuSciCA in turn is the central access point to several Activity Environments and supporting Tools such as:

- DrAwME: The Musical Whiteboard;
- Performance Sampler;
- Tone Synthesizer;
- 3D Instrument Design, Printing & Interaction;
- Acouscope;
- Sonification;
- Math Editor;
- Algebra & Geometry;
- Pitch Wheel;
- Tuner;
- 2D & 3D Sound Visualization;
- Snail;
- Metronome.

2. European Piloting Environments & Assessment Methodology

The pilot testing of iMuSciCA in Belgian, French and Greek schools was conducted under two paradigms i.e. by an 'in-depth' implementation, mostly during extra-curricular activities and 'heavy' (i.e. longer term) as well as 'lighter' (i.e. shorter term) activities in real classroom settings. The details are specified in Table 1 below.

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

	Light in Classroom Settings (< 8 Lesson Hours; Proof of Concept)	**Heavy in Classroom Settings** (~ 8 Lesson Hours incl. Standard Evaluation)	**Heavy in-depth** (> 8 Lesson Hours incl. Standard Evaluation)
Belgium	Several Schools	IKSO Hoeselt Sint-Vincentius-mid-denschool Lanaken	
Greece		Ellinogermaniki Agogi (EA Evangelical School of Nea Smyrni	Summer Camp for Students at EA iMuSciCA Workshop at MINT-EC at EA Special School of Ilioupolis
France		Collège Jules Vallès	

The main Assessment Instruments of iMuSciCA for educators have been the following:

- Summary Evaluation Questionnaire - addressing aspects of Access, Competences, Motivation and Experiences (i.e. the A-C-M-E model of e-Inclusion);
- System Usability Scale (SUS) - an easy to be implemented, yet reliable instrument to measure the usability of software and/or systems by users;
- Interviews or Focus Groups;
- Classroom Observations;
- Audio/Video Recordings & Photos as Reflective Tools.

Figure 2: Impressions from the iMuSciCA Piloting in Greece

During the Piloting of iMuSciCA the following assessment instruments for students have been deployed:

- Deeper Learning Competencies;
- Motivation and Attitudes towards Science Learning;
- Acquisition of Academic Knowledge (i.e. customised tests with false and correct answers; performance-based assessments);
- Biometric Assessments i.e. Eye Tracking, Facial Expressions Analysis, Galvanic Skin Response (GSR) and Electroencephalography (EEG);
- Interviews or Focus Groups;
- Classroom Observations;
- Audio/Video Recordings & Photos as Reflective Tools.

3. Selected Results of the Piloting of iMuSciCA

During the Piloting iMuSciCA the following number of students and teachers as listed in Table 2 participated in the piloting activities of iMuSciCA.

Table 2: Participants in Piloting Activities of iMuSciCA in Belgium, France and Greece

Implementation in Real Classroom Settings				
	Total	Greece	Belgium	France
Students	**640**	226	364	50
Teachers	**91**	40	40	11
Summer Camp for Students				
Students	**17**	17	-	-
Summer School / Webinars / Workshops for Teachers				
Teachers	**82**	23	59	-

4. Evaluation
4.1 Evaluation by Teachers

The participating educators in the Piloting of iMuSciCA describe themselves as experienced or very experienced in using Information and Communication Technologies (ICTs) for STEM and STEAM teaching (see Figure 3).

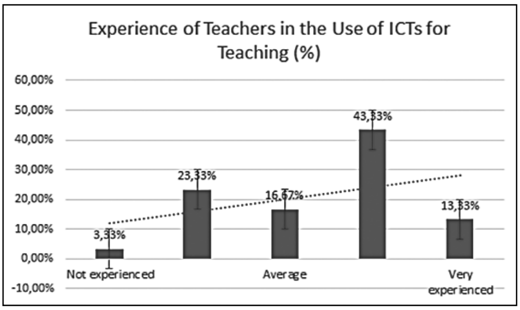

Figure 3: Experience of Educators in the Use of ICTs for Teaching

The following Figure 4 indicates that the great majority (approximately 70%) of the participating teachers regarded the use of music to teach STEM as useful or very useful.

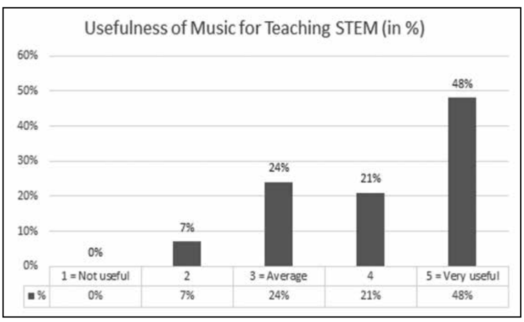

Figure 4: Perceived Usefulness of Music for Teaching STEM

The majority of teachers (almost 80%) are furthermore convinced that the solutions of iMuSciCA will significantly increase the motivation of students to engage in STEM subjects (see Figure 5).

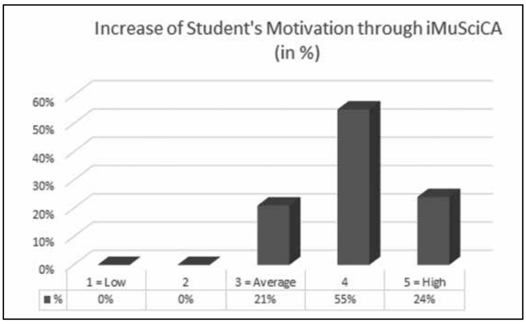

Figure 5 Perceived Increase of Student's Motivation

Overall educators also believe that it is easy to use the iMuSciCA Workbench, that it is well integrated and thus potential users will learn how to use the iMuSciCA Workbench equally easily (see Figure 6).

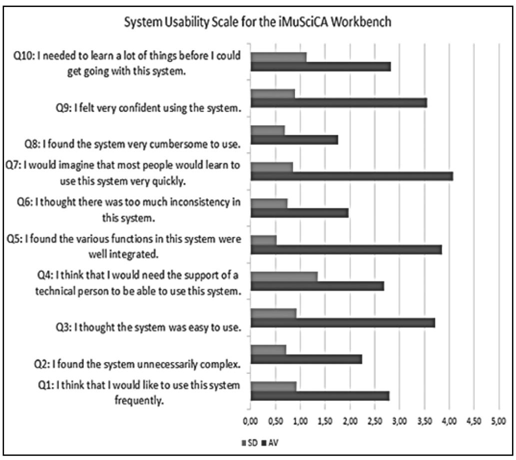

Figure 6: Perceived Usability of the iMuSciCA Workbench by Educators

In summary teachers described their experiences with the iMuSciCA as follows:

"I have learned much about music and physics and gained experience teaching STEAM".
"The lessons form a complete concept and are properly worked out".
"Music turns learning science into fun!"

4.2 Evaluation by Students

Motivation & Attitudes towards Science Learning
The adapted and abridged questionnaire on Motivation & Attitudes towards Science Learning included elements such as:
• Self-efficacy;
• Active learning strategies;
• Perceived value of science learning;
• Goal performance and achievement;
• Stimulating learning environments.

In the following some selected results from the 'heavy' piloting in Greece are presented. Three points of measurement have been applied: after teaching mathematics (i.e. geometry) without iMuSciCA and after a longer elapse time a pre- and post-test when using the Workbench of iMuSciCA teach the same content following developed STEAM Lesson Plan. As depicted in Figure 7, all observed Averages exceed the theoretical Average largely and are showing narrow Standard Deviations.

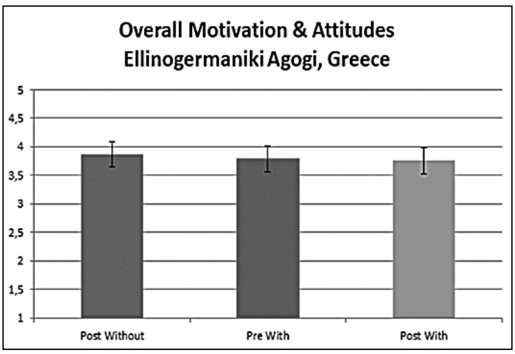

Figure 7: Overall Motivation & Attitudes towards Science Learning at Ellinogermaniki Agogi

In addition, iMuSciCA has been applied in a School for Students of Special Needs combining the visit of a Science Museum, an in-depth introduction to the iMuSciCA Workbench and STEM Teaching in the classroom allowing an extended exposure and experience with iMuSciCA.

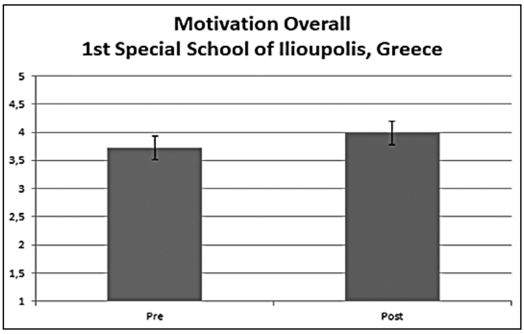

Figure 8: Overall Motivation & Attitudes' towards Science Learning of Students with Special Needs

The above figure displays a 7% increase in students' Motivation and Attitudes after the implementation of iMuSciCA.

Deeper Learning Competencies

The Deeper Learning Competencies of students were investigated using an integrated questionnaire building upon concepts of the Hewlett Foundation and the National Research Council (NRC) of the USA.

	Cognitive (thinking and reasoning)	**Interpersonal** (expressing information to others and interpreting others)	**Intrapersonal** (self-management to reach goals)
Deeper Learning Competencies	Thinking critically	Working collaboratively	Learning to learn
	Mastering rigorous academic content	Communicating effectively	Developing academic mindsets

Figure 9: Classification of Deeper Learning Competencies

Deeper Learning normally refers to the combination of a deeper understanding of core academic content, the ability to apply that understanding to novel problems and situations, and to the development of a range of competencies, including people skills and self-management.

In Greece, the Deeper Learning Competencies of students has been assessed in two ways: in real classroom settings (with approx. eight hours of teaching hours) at three observation points as well as before and after the iMuSciCA Summer Camp 2018 (with more than 20 hours teaching hours; see also Figure 9 for some impressions).

In line with the observations of the Motivation and Attitudes of students towards Science Learning, during the implementation of iMuSciCA within the regular curriculum hours all observable Averages are again in the positive range. The results indicate that there is a stable trend in Deeper Learning Competencies of the participating students while learning with STEM with iMuSciCA. An increasing trend is observed when it comes to the preference of students in teaching Science and Math with music, which might imply that there are mutual benefits for and between students in art and in science.

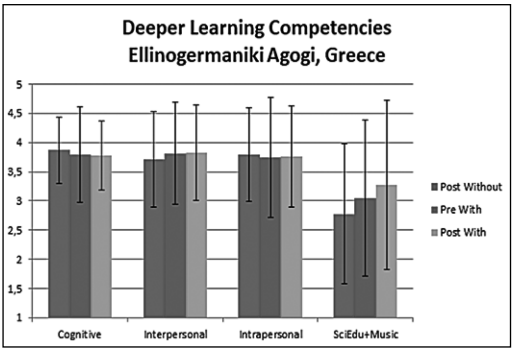

Figure 10: Development of Deeper Learning Competencies at Ellinogermaniki Agogi

As mentioned earlier the iMuSciCA Summer Camp took place in July 2018 at the premises of Ellinogermaniki Agogi (see Figure 10) and allowed a longer-term exposure to and exploration of the solutions developed by iMuSciCA.

Figure 11: Impressions from the iMuSciCA Summer Camp at Ellinogermaniki Agogi in Greece

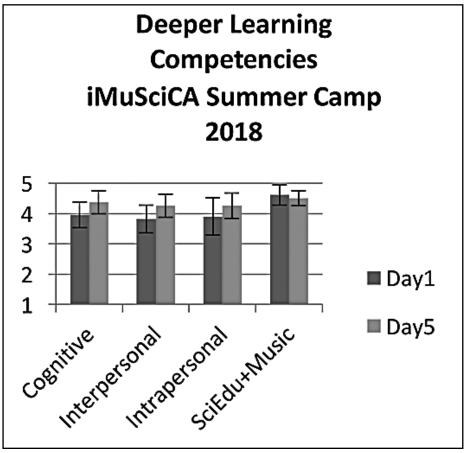

Figure 12: Development of Deeper Learning Competencies during the iMuSciCA Summer Camp 2018

This intensive experience with the iMuSciCA Workbench guided by an overarching Educational Scenario resulting in a Final Concert of the participating students using real, virtual and nely created instruments showed a systematic increase of approximately 10% in three areas of Deeper Learning Competencies i.e. i) cognitive, ii) interpersonal, iii) intrapersonal competencies, whereas a stable effect is observed regarding their perception of the connection between Science Education and Music. The latter effect might be attributed to the balanced distribution of science- and music-oriented students during the Summer Camp.

Knowledge Acquisition

Based on a custom-made questionnaire around geometry in mathematics and music applied after before and after teaching with iMuSciCA in the classroom an overall increase in the aggregated Knowledge Acquisition of students of Ellinogermaniki Agogi in the magnitude of 10% has been observed (see Figure 10).

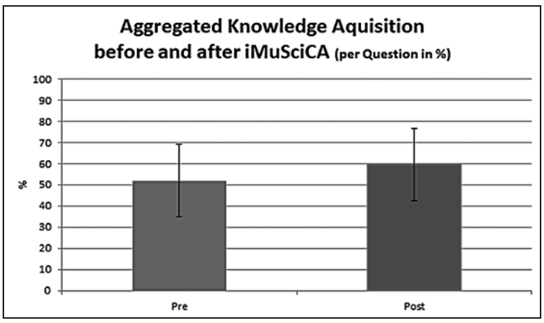

Figure 13: Aggregated Knowledge Acquisition of Students of Ellinogermaniki Agogi

A similar increase in the Knowledge Acquisition of students on even higher levels have been recorded during the iMuSciCA Summer Camp 2018.

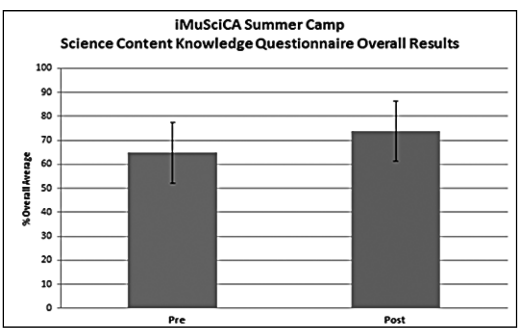

Figure 14: Average Knowledge Acquisition during the iMuSciCA Summer Camp

5. Conclusions

In summary the Piloting of iMuSciCA showed that the Activity Environments and Tools on the iMuSciCA Workbench as well as the guiding Educational Scenarios and Lesson Plans lead to innovative Inquiry Based Science Education (IBSE). It also became obvious that music is an important facilitator and catalyst for better and Deeper Learning across many STEAM fields i.e. through exploring, asking questions, investigating, analysing and communicating their inquiries and findings to peers. In addition iMuSciCA provides flexible and adaptable solutions for various educational settings and instances, which have been appreciated by teachers and learners alike. However, the implementation of iMuSciCA in everyday teaching throughout the curriculum has been at the same proven rather demanding and challenging.

In summary Deeper Learning with iMuSciCA has showed better effects on the Knowledge Acquisition of students and at the same time stable effects on Deeper Learning Competencies as well as on Motivation and Attitudes towards Science Education

Taken into account the limited sample sizes and piloting periods, the results of the Piloting of iMuSciCA are encouraging:

- Almost all Average Values (AV) in the three applied Questionnaires across were positive, only some Standard Deviations (SD) went below average;
- Knowledge Acquisition is actively supported by iMuSciCA even through light interventions;
- Neither positive nor negative effects over time have been observed in light i.e. short-term interventions except for Knowledge Acquisition;
- Partly significant effects have been observed during a longer exposure to iMuSciCA through heavy, in-depth and longer-term implementations of iMuSciCA e.g. through the iMuSciCA Summer Camp 2018 or at the School for Special Needs in Greece;
- Teachers emphasised that iMuSciCA is i) helpful to teach STEM; ii) increasing the motivation of students; iii) useful for the Continuous Professional Development (CPD) of educators; and finally iv) supports the institutional development/ learning and organisational innovation in schools;
- The usability testing of the iMuSciCA Workbench through teachers yielded positive to very positive results.

The above results are largely confirmed by the findings in similar fields of investigation e.g. in Inquiry Based Science Education (IBSE).

In summary iMuSciCA has a verifiable effect concerning the Knowledge Acquisition of students, however significant effects on improving Deeper Learning Competencies and changing Motivation and Attitudes of students are only traceable in longer term interventions. Again, in accordance with literature in Educational Psychology and Pedagogy, attitudinal and behavioural changes need time, space, a stimulating learning environment and above all engaged and motivated teachers.

The quantitative and qualitative results of the Piloting of iMuSciCA unanimously suggest that these effects could be best realised through longer term interventions e.g. through longitudinal activities within the curriculum (e.g. 2 hours per week during the entire school year) or through extra-curricular activities (e.g. dedicated Student’s Camps in vacation time or Student’s Camps as additional afternoon activities).

Throughout the Piloting additional indications have been observed that students interested in music may profit more than science-oriented ones from the solutions of iMuSciCA. Although hard statistical evidence is missing, these observations were mentioned during Focus Group Discussions and Interviews with teachers and students.

Furthermore students with special needs seem to benefit from the iMuSciCA’s solutions (even applied only in parts), especially when it comes to haptic and senso-motoric learning. It is therefore suggested that these encouraging effects and influences should be further explored using larger sample sizes of students with special needs across Europe.

On the other hand, teachers reported a number of serious and substantial barriers, which are hampering or slowing down the implementation of iMuSciCA in schools and within the school curricula. Amongst them are most prominently:Lack of technical infrastructure and support;
• Lack of time;
• Lack of funding;
• Lack of institutional/collegial support;
• Lack of training;
• Fear of falling behind.

Of specific importance is the alignment and integration of the Educational Scenarios/Lesson Plans of iMuSciCA to national/federal curricula as well as modularity and customisability of Educational Scenarios/Lesson Plans and related Activity Environments and Tools of the Workbench to be easily integrated into one lesson hour. Educators also recommended the integration of Blended, Peer and Collaborative Learning approaches and activities Educational Scenarios/Lesson Plans of iMuSciCA.

The above barriers are confirmed by various studies on the introduction of Technology Enhanced Learning & Teaching (TEL&T) in educational settings conducted in previous years worldwide.

6. Acknowledgements

The iMuSciCA project has received funding from the European Union’s Horizon 2020 Research & Innovation Programme under Grant Agreement No 731861.

Symposium on Implementing Deeper Learning in the School Curriculum: The Story of STORIES OF TOMORROW at Ellinogermaniki Agogi STORIES OF TOMORROW Students Award Ceremony

In the framework of the conference, “The Story of the STORIES OF TOMMOROW” symposium took place. The Symposium focused on the implementation process of the STORIES OF TOMORROW at Ellinogermaniki Agogi primary school and it gave insights into the way the school community embraced and implementthe idea. It presented the way that the school integrated the project into the school curriculum and created the opportunities for the students to gain scientific experience, develop inquiry skills and cultivate imagination and creativity. The symposium as well also gave the opportunity for students to present their aspirations and experience.




During the “Story of STORIES OF TOMMOROW symposium, 9 students’ teams that provided samples of exemplary work in the framework of the project were awarded. In detail, 6 teams from the 5th grade of EA primary school were awarded for creating the best digital stories about a future mission to Mars and the building of a human colony there. More over 3 teams from primary schools of Attica and Peloponnese, specifically the 7th Primary School of Acharnes, the 7th Primary school of kaisariani and the Primary School of Vytina were given awards for their robotics projects in the national WRO contest, in the “STORIES OF TOMORROW” open category for primary schools. The prizes in both cases were awarded to the students by the keynote speakers of the conference in the name of EDEN - the European Distance and E-Learning Network.

Workshops

Workshop 1
Schools – Earthquakes – Actions

Organizer: **Dr Gerasimos Chouliaras**, *National Observatory of Athens (NOA)*

The National Observatory of Athens (NOA) and Ellinogermaniki Agogi (EA) organized a workshop for teachers interested in organising actions related to earthquakes in their schools. The seismologist Dr Gerasimos Chouliaras, coordinator of SNAC (School Networks Alert Citizens Protection) provided information to the participants about the operation and use of the existing school network of seismometers and its data platform as well as the installation of the new Raspberry Shake seismographs from the new school year on.

Workshop 2
The iMuSciCA Experience: Learning Science through and with Music

Organizer: **Petros Stergiopoulos**, *Ellinogermaniki Agogi* & **Dr Vassilis Katsouros**, *ATHENA Research & Innovation Center, supported by LEOPOLY, Hungary and CABRILOG, France*

iMuSciCA aimed at bringing Arts to the heart of the school curriculum to cultivate creative skills of young people alongside with the knowledge they acquire in STEM fields (i.e. in Science, Technology, Engineering and Mathematics). iMuSciCA focused on the systematic integration of a suite of Software Tools and Services with especially designed Educational Scenarios for teaching and learning STEAM in Lower and Upper Secondary Education. The Workbench of iMuSciCA was the central access point to several applications such as DrAwME; Performance Sampler; Tone Synthesizer; 3D Design, Printing and Interaction; Sonification; Math Editor; Geometry & Algebra a well as supporting music and sound analysis and visualization tools. The Workshop of iMuSciCA provided the participants with hands-on and interactive experiences of the Activity Environments and Educational Environments.

Workshop 3
Evaluating the STORIES OF TOMORROW

Organizer: **Dr Zacharoula Smyrnaiou**, *National and Kapodistrian University of Athens (NKUA), Greece*

This workshop presented the development of three scientific, research tools of Scientific Creativity through Digital Story Telling. This model of three practice tools was constructed in order to combine the basic principles of scientific creativity as they are presented and researched through CREATIONS and STORIES European Research Programs. The first tool ‘From Inbox to Newbox tool’ is a theoretical tool, based on features of Creativity as they are developed on CREATIONS Program, the Scientific Creativity Structure Model (SCSM) (Hu, 2002) and the TTCT Figural Subscales in Relation to Creative Thinking Skills and Creative Attitudes (Kim, 2017). The second tool ‘Students’ Creativity Evaluation Model’ tried to combine different cognitive domains through interdisciplinary approach to the representation of scientific notions through ICT Tools and different semiotic systems, such as visualization and models, researching expected, original and innovative ways of students’ thinking. The third tool ‘Experts’ Creativity Evaluation Model’ examined the role of experts’ thinking on writing a story and it aims to track experts’ model of thinking and be viewed in comparison to students’ creative model of thinking. Some stories were analyzed indicatively with these research tools by the participants.

INTERACTIVE MUSIC SCIENCE COLLABORATIVE ACTIVITIES

iMuSciCA is a pioneering approach using music to foster the creativity of young people, to cultivate Deeper Learning, alongside with the knowledge and skills they acquire in STEM. The online Workbench of iMuSciCA is the central access point to several Activity Environments and supporting Tools for STEAM education. The teaching and learning activities of iMuSciCA are guided by Educational Scenarios and concrete Lesson Plans bringing the Workbench into the classrooms of Lower and Secondary Education. iMuSciCA is thereby setting new grounds in European STEAM curricula.

www.imuscica.eu

STORIES OF TOMORROW – STUDENTS' VISIONS ON THE FUTURE OF SPACE EXPLORATION

STORIES OF TOMORROW is specifically designed for teaching professionals in Science, Technology, Engineering and Mathematics (STEM). It introduces teachers to the concept of Digital Storytelling and to Inquiry Based Science Education (IBS) in order to develop, improve and enhance their teaching skills and practices. The online platform uses digital technologies like Augmented and Virtual Reality as well as Learning Analytics. Through a professional game engine and an intuitive interface, teachers and students become creators of content by imagining, designing, developing and publishing stories about a Mission to Mars, building their own 3D-Rockets and setting up a sustainable colony on the Red Planet.

www.storiesoftomorrow.eu

DIGITAL FABRICATION AND MAKER MOVEMENT IN EDUCATION: MAKING COMPUTER - SUPPORTED ARTEFACTS FROM SCRATCH

eCraft2Learn is researching, designing, piloting and validating an ecosystem based on digital fabrication and making technologies for creating computer-supported artefacts. The project aims at reinforcing personalised learning and teaching in STEAM and to assist the development of 21st Century Skills.

https://project.ecraft2learn.eu

EXPLOITING THE BEST SENSORY MODALITY FOR LEARNING ARITHMETIC AND GEOMETRY AT PRIMARY SCHOOL

weDRAW is creating and evaluating a new methodology for teaching and a novel technology for Deeper Learning of arithmetic and geometry at elementary schools. The main novelty is the renewed understanding of the role of communication between sensory modalities during development and that specific sensory systems have specific roles for learning specific concepts.

www.wedraw.eu

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