The Learning Science Through Theatre initiative in the context of Responsible Research and Innovation

Zacharoula SMYRNAIOU & Elena GEORGAKOPOULOU
Department of Pedagogy, National and Kapodistrian University of Athens
Ilissia, 15784, Greece

Menelaos SOTIRIOU
Science View, 2 Misaraliotou str.,
Athens, 11742, Greece

and

Sofoklis SOTIRIOU
Research and Development Department, Ellinogermaniki Agogi
Dimitriou Panagea str.
Pallini, Attica, 153 51, Greece

ABSTRACT

Fostering Responsible Research and Innovation (RRI) is the next big step in the methodological teaching of Science. This is the solution towards an open classroom and innovation system of learning. The school science teaching needs to become more engaging. Science education should be an essential component of a learning continuum not only in classroom, but also for all, from pre- school to active engaged citizenship.

"The Learning Science Through Theatre" Initiative creates a network of knowledge and collaboration between different communities by learning about science through other disciplines and learning about other disciplines through science. Forty Three (43) theatrical performances during the school years 2014-2016 were organized by secondary school students (2000 subjects) which embed both scientific concepts and cultural/ social elements which are expressed by embodied, verbal interaction and analogies. The methodology constitutes a merging of qualitative, quantitative and grounded theory analysis. The data were classified into categories and they were cross- checked by registrations forms, filled by the teachers. Results show that the acquisition of knowledge is successful with the co- existence of multiple semiotic systems and the theatrical performances are compatible with the principles of RRI.

Keywords: Responsible Research and Innovation, Embodied learning, Inquiry, Creativity, Multiple representational Systems, STEAM.

1. INTRODUCTION

From STEM to STEAM: Combining Science and ARTS

It is worldwide known that scientists, researchers, teachers and students have to build bridges to different subjects in order to acquire the students' higher cognitive load and fully express their new knowledge. Contexts such as Science, Technologies, Engineering and Mathematics are offered to link students their knowledge to the real world and real needs. However, we have to accept that the students could not represent scientific notions without the interaction between different subject domains and the contribution of Arts. Therefore, it is really crucial to promote the interaction between all types of cognitive systems from different scientific aspects and the Arts, coming from STEM- period to STEAM: Science, Technologies, Engineering, ARTS or ALL SUBJECTS, and Mathematics.

The students will be able to develop an understanding of the world and scientific knowledge and an engagement with both scientific and artistic lines of thinking through hands-on experimentation with real scientific data. This is really important, as the students have the opportunity not only to transfer their new knowledge but also to express it in a different semiotic system by creating art objects. They can also actively participate in dialogical processes between science and Art, creativity and cognitive knowledge and develop a spirit of cooperation and teamwork through collaborative practice. Furthermore, the students develop positive attitudes, and especially trust in the norms, values and rules of scientific as well as artistic practice. Creating a bridge between the two disciplines is worthwhile since it can lead to a deeper understanding of each subject area. It also helps young people to think creatively and critically bringing second-level students from the arts and science curricula. The emotional dimension of learning is also really important, as students increase their self- confidence. The play's characters, costumes, music and dance, all represent potential ways of interpreting the students' inquiries. A complete, holistic activity, within both science and art, is based on students' creation and observation skills. [1]

2. HOLISTIC COGNITIVE REPRESENTATION THROUGH MULTIPLE SEMIOTIC SYSTEMS

As the embrace of Arts and Science can affect and strengthen the scientific meaning in today's society, the question "how the students can acquire scientific notions working in different semiotic systems" is really still interesting. Within science education, there have been attempts which focus on the consistencies of a semiotic system on others or on the connectivity of different semiotic systems. For example, Smyrnaiou and Weil-Barais (2005, 2003) give particular emphasis or importance to natural language for the understanding of scientific relations. Their research led them to suggest that if the student is not competent to understand the transformations relationally, in natural language, he/she is incompetent to do it with formal systems. Arts which allow

creativity and representation such as theatre, provide fertile ground for the expansion of Science Education [4], [5]. The combination of verbal expression, body movements and emotional involvement helps in the creation of cognitive shapes, which is really important for the representation of knowledge. The subject area of science affects the writing of a script and the integration of related scientific concepts in the form of conceptual field –as proposed by Vergnaud (2009) and the representation of these concepts through different semiotic systems. Additionally, the subject area of art affects the scientific performance. Art has its own rules that are "strange" to the scientific ones. It considers the initial stages of warming, theatrical techniques to express feelings and meanings which must be considered. These two areas Science and Art (S&A) must coexist harmoniously in this initiative and gain from each other.

Following pedagogical approaches, Embodied Learning constitutes a modern theory of learning, which emphasizes the use of the body in the educational practice and the student-teacher interaction both inside and outside the classroom and in digital or creative environments as well. Embodied Learning and the perceived stimuli can be transformed into a more stable memory and cognitive representations [7]. Given the aforementioned, it becomes obvious that Embodied Learning involves coordinated movements either of body parts or of the whole body in order for a learning goal to be achieved combined with the students' sensorimotor activity and their emotional involvement [8]. Consequently, the following parameters should be taken into consideration when designing an activity:

a) Cognitive involvement to the topic, cognitive processes, representation of a scientific notion
b) Body movements
c) Expression of the student's feelings
d) Clarity of instructions
e) Holistic design of activities
f) Student cooperation
g) Ability of students to apply acquired knowledge to new environments

Research results [8] in the field of Embodied Learning seem to agree that the representation of scientific concepts and the use of the body in the production of meaning may lead to higher quality cognitive results. These principles may promote reflection and a reconsideration of what learning is to each person, of what the role of the instructor and of the student is in all subjects.

In addition, we were interested in analogical reasoning appeared effortlessly in theatrical performances [8]. As an analogy could simplistically be described a comparison between two cognitive domains - one familiar and one less familiar. In literature, the sector concerned is referred to as a "vehicle", "base", "source" or "analog", and the less familiar area, or else the sector learning whose desire is referred to as field "target".

The distinctiveness in the theatrical performance discussed here is that it requires students to collaborate while they move about in order to interact embodied and verbally and play the scenario. In studying how could students play this collaborative theatrical performance, we were interested to understand what meanings they developed through language, isolated gestures, full body movements, students' emotional attachment, facial expressions and art representations and how these meanings are related to the science meanings and analogical reasoning [8].

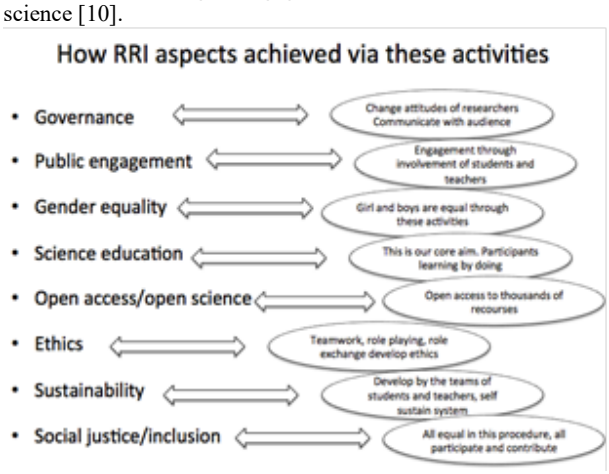
The idea transcending the Scientific Theatrical Performances has been to put into practice these theoretical frameworks and principles in order to form a test-bed for exploring and playing with different scenarios where representations and interactions embedded scientific concepts and other socio-cultural messages [9]. The programme we carried out aims to explore the kind of meanings generated by the students during theatrical performances according to embodied learning parameters such as gestural relevance, emotional deepening, cognitive and kinesthetic skills (sensorimotor activity), and coordinated movements of body parts or whole body.

3. "THE LEARNING SCIENCE THROUGH THEATRE" INITIATIVE PROMOTING RRI PRINCIPLES

Over the last decades many efforts have tried to reduce the distance between science and society, leading to a European-wide approach in Horizon 2020 called Responsible Research and Innovation (RRI) seeks to bring issues related to research and innovation into the open, to anticipate their consequences, and to involve society in discussing how science and technology can help create the kind of world and society we want for generations to come. The Learning Science through Theatre Initiative helps us to build a more inclusive, smart and sustainable society that focuses on the grand challenges that we face nowadays and to investigate people's and students' needs, values and expectations of future society.

The publication of the "Science Education for Responsible Citizenship" report [10] brings science education to the top of educational goals, but also answer to a significant question: "How could science education play an important role to address societal challenges and how can all the stakeholders open schools to society?". The school science teaching needs to become more engaging, based on inquiry based and problem solving methods and designed to meet the interests of young people. We also have to establish a new way of thinking, as science education should be an essential component of a learning continuum not only in classroom, but also for all, from pre- school to active engaged citizenship.

Young people have to be interested in societal challenges and find creative solutions. Open Schools to Open Societies means that nowadays schools work as ecosystems, which not only produce knowledge but also link this knowledge to real world and real needs. Moreover, collaboration between formal, non-formal and informal educational providers, enterprises, industries and civil society should be enhanced to ensure relevant and meaningful engagement of all societal actors with science [10].



Picture 1.

The Learning Science Through Theatre initiative plays an important role to these directions, as it can create a whole

network of knowledge and collaboration between different communities, in order to create new knowledge but also to realize that students have to link their knowledge to everyday lives by learning about science through all disciplines and learning about all disciplines through science. The science classroom opens and the educational community, even teachers, scientists, researchers from different fields, cooperate for a specific purpose, which is the dramatization of scientific notions by strengthening connections and synergies between science, creativity, entrepreneurship and innovation. This way, not only teacher quality can be improved but also we deal with modern problems, such as new findings in research fields, societal challenges, gender issues, cooperation between people and countries at international level, employment etc. (Picture 1.)

The initiative "Learning Science Through Theatre" (LSST-http://www.lstt.eu/) was initiated by Science View (http://www.scienceview.gr/) and National and Kapodistrian University of Athens, Faculty of Philosophy, Pedagogy and Psychology (http://en.ppp.uoa.gr/), during the school years 2014-2015, 2015- 2016 and 2016-2017. During the school year 2014-2015 attended thirteen (14) secondary schools from Attica and during the school year 2015-2016 attended twenty-nine (29) secondary schools from all over Greece with almost 2000 students.

During the year 2014-2015 the students (Secondary school-high school) dramatized scientific concepts and knowledge from the subjects taught, through a non-binding scenario titled "Parallel Worlds, which was consisted of five sections and concerned the disciplines of biology, astronomy and physics. Schools were asked to choose at least one section which dealt.

During the year (2015-2016) the students were able to create their own scenario based on all fields of natural sciences and mathematics. Each school was invited to take and implement the following activities (Script/directing group, Actor group, Music group, Dance group, Set/costumes group, Video group):

• Developing, processing and execution of the script
• Select / video production related to the theme of the script
•Selection/ composition and live performance of music framing the show
• Design and implementation of sets and costumes
• Create choreography if necessary

At first year at least one teacher per school was responsible for coordinating the work, but during the year 2015-2016 and 2016-2017 we tended to collaborations between teachers from different subject domains. Teachers could integrate the educational activities in the corresponding curriculum subjects (Physics, Astronomy, Music, Biology, Art) as project implementation and training groups performed at their school (theater games, music, etc.).

The Learning Science Through Theatre is an initiative, which offers students the opportunity to create a play through the dramatization of scientific knowledge and concepts, included in the curriculum. Students engaged in activities such as the writing of scientific stories (scenarios), composing music, designing sets, costumes and coming up with choreographies. Both students and teachers worked together with scientists from research centers and universities in order to better understand the scientific concepts and phenomena that they will dramatize. In this initiative students were asked to dramatize scientific concepts and knowledge from the curriculum of their courses. It followed a scientific approach while opening doors to experiencing new possibilities on several levels. Teachers along with students performed drama, music, dance and video (pupils can use existing videos provided they are licensed to). Each play required a different number of actors. School groups could choose the science field (physics, chemistry, mathematics, biology etc.) that would be included in their curriculum. The number of students that could participate was not fixed; the teacher could choose the number according to the needs (characters, script writers etc.). The activity could take place as part of the 'project' course of the curriculum (e.g. in Greek schools) or as part of the regular activities of school within the classroom. School groups should spend at least 2 hours per week to prepare and rehearse for the final performance. Teachers of each unique project were free to design the schedule and creative exercises according to their needs and capacities. Furthermore, teachers were supported in both the pedagogical part of the initiative and the directorial-artistic part from scientific collaborators (e.g. University) and directors, musicians and actors. The support to teachers and students was provided through visits to schools, online meetings and special workshops. In every school that participates working groups (e. g script writers, actors, musicians, dancers, stage and costume designers, video producers) were created which were assisted by professional organizers.

The Learning Science Through Theatre was based on the Pedagogical framework of meaningly three pedagogical theories, which are combined, so that the student can acquire knowledge in a different way:

• Inquiry-based learning (Inquiry Based Science Education)
• Creativity-based learning through development of art objects or performances
• Representational/ Semiotic Systems and Cognitive Load theories, Analogical Reasoning

Inquiry Learning could help students acquire a better understanding of the nature of science and handle different aspects of their life. However, students have limited opportunities to practice inquiry processes in the science classroom. By engaging in inquiry based activities and creativity students understood the tentative nature of science and improved their cognitive skills through the Learning Science Through theatre. This inquiry process can be seen in all stages of creating a theatrical performance. The students started by formulating a theme and then they started to find ways of representing this theme in an active and creative way. They then formulated predictions and came up with alternative ways of thinking, and they tried to determine which of their hypotheses, if any, is accurate and which is the best way to represent each scientific notion. Learners and teachers collaborated in seven different phases of Inquiry- Based Learning (Question, Evidence, Analyze, Explain, Connect, Communicate, Reflect) so as to be engaged by scientifically oriented questions. Students gave priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. Then they formulated explanations from evidence to address scientifically oriented questions and after the process they evaluated their explanations, particularly those reflecting scientific understanding.

Creativity is a purposive and imaginative activity generating outcomes that are original and valuable in relation to the learner. This occurs through critical reasoning using the available evidence to generate ideas, explanations and strategies as an individual or community, whilst acknowledging the role of risk and emotions in interdisciplinary contexts [18]. Dramatization of educational theatrical scenarios and the

representation of scientific concepts and knowledge is a complex procedure which is based on the following:
a) Representation of scientific content using cognitive processes:
b) Student's sensorimotor involvement using their bodies or gestures
c) Emotional involvement
d) Social interaction and communication between the students:
e) Use of past experiences and creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors: We claim that students recalling of past experiences and
f) Brain-body-emotion coordination, holistic use of the student's personality
g) Motivation
In the LSTT initiative, the scientific concepts were represented with highly original, imaginative and innovative ways. The Embodied Learning helped in most cases to describe the concepts in another way, more descriptive [17]. .During the dramatization of the students' scenarios, the result was robust when there was a connection between the embodied representation (in its entirety, including the factor of emotion), the scientific concept and verbal description. And it was excellent, if there was extra music or choreography as a representational or embodied system. Therefore, we argue that it is not important that most of the time we use a single representational system, but when the test concept is difficult to interpretation and explanation, students employ multiple representational systems. In addition, regarding the combination of Science with Art, there are three representational systems- languages (verbal communication), which are used to present, analyze and explain a scientific approach, Art (dancing, music, and painting) and Embodied Learning- which offers a more precise, full and faithful approach to scientific concepts.
It is also worth mentioning that all representational systems:
1. Have to be in complete balance and harmony, in order for the basic principles, techniques and philosophy of the two subjects to remain unaltered and for these subjects to be able to benefit one another
2. Have to coexist when a new concept is presented, and not to appear at different times, because in that case the necessary cognitive connections and conceptual connections between the characteristics of a concept and its rendition are not made.
Therefore, every time students present a scientific approach and enrich it with theatrical elements, combining Science with all forms of Art, then they reinforce their cognitive load, especially when they utilize the coexistence of representational systems and are lead to a more complete rendering of the scientific concept. It is worth mentioning that in an in depth analysis of representational systems, embodied representation is more efficient when it comes to understanding and building new knowledge compared to other representational systems. But we have to admit that the harmony of representational systems is still much more efficient in the understanding of knowledge.
The multiple semiotic systems, such as verbal interaction between the students, Embodied Learning and Analogical Reasoning in dramatization of theatrical performances can enhance students' cognitive skills. The coexistence of many representational systems leads to higher learning outcomes. Especially, when the learning process is enriched by creativity, analogical reasoning and the imagination of students and science combined with art, students can conquer the scientific discourse and scientific content to a greater extent than traditional forms of teaching.

4. METHODOLOGY

Sampling
The Learning Science Through Theatre initiative is a large scale implementation activity in Greece based on the pedagogical framework which was developed by the European project CREAT-IT (http://creatit-project.eu/) [11] and continues to be implemented in the framework of the European Project CREATIONS (http://creations-project.eu/). This initiative follows the principles of the Science Education Declaration, of creativity, of effective and efficient research and aims at enhancing creativity in classroom (http://www.opendiscoveryspace.eu/community/culture-creativity-curiosity-413201, http://www.opendiscoveryspace.eu/community/learning-science-through-theater-841279) in the context of STEAM.
Forty Three (43) theatrical performances during the school years 2014-2016 were organized by secondary school students (2000 subjects) which embed both scientific concepts and cultural, social and comic elements which are expressed by embodied, verbal interaction and analogies.
Research Methods
The research methodology include both qualitative, quantitative and grounded- theory methods [12]. It is worth mentioning that this combination of methodological tools are required to the validity and reliability of the research. Moreover, a "mix- method design" can lead us to more specific results and offers for a mutual validation of both qualitative and quantitative results by providing a clear rationale for the choice of each method. It is worth mentioning that these different methodological approaches have to be combined, especially as we research the cognitive procedures which students follow in order to represent scientific notions in a rich way.
Context-relatedness of data is a crucial issue for qualitative researchers. The context- analysis combines the methodological oxymora or leads to the development of distinct research methodologies with own quality criteria and methodological standards like, for instance, Quantitative Content Analysis [13] The grounded theory as a methodology tool is, also, preferred, as it enables as to produce a theory from data- systematically obtained and analyzed [14].
First of all, we collected and analyzed the data. Our data consisted of the theatrical performances (43 performances) in which students should deal with scientific subjects and represent scientific notions. Secondly, we collected and analyzed our data by developing categories and codes from these data. Through the analysis procedure we realized that we can try to develop new categories and coeds from data, not from preconceived hypotheses. This middle- range theory [14] helped us understanding and explaining behavior and processes, making comparisons to data- data and then data-codes and concepts and concepts.
The conceptual categorization took into consideration the theoretical framework of this report along with empirical evidence gathered from the theatrical plays performed by students of the schools which participated in the programme. Student representation of scientific concept and the production of scientific meaning was studied using 3 categories: Embodied Learning, Multiple representational systems (verbal, embodied, digital, kinesthetic representation, elements of Art) and Analogical Reasoning. Each category is further divided into subcategories/ properties which are connected to basic features of Embodied Learning, of multiple systems of symbols, of

analogical reasoning. These characteristics were observed in all theatrical plays and shed more light on the basic categories of analysis. The "Embodied Learning" category includes: whole body movements, isolated gestures, facial expressions and emotional involvement. The Multiple representational systems category includes: verbal communication, non- verbal communication (Embodied Learning)/ kinesthetic representation and Art. The analogical reasoning category includes: Focus/ Familiarization with the base, Action/ Explanation of the similarities and Reflection/ Assessment of students to determine whether they understood the analogy.

During the procedure a registration form had held by scientific criteria so as the whole procedure was ensured. The registration form, which was filled by the teachers, was designed to focus on eight main aspects of cognitive and learning process, during the process of theatrical performances. Of all the forty- three schools, fifteen schools (34,8%) recorded the registration form. Having in mind that teachers are not used to write their descriptive comments about any procedure which take place on the school, this percentage of responses can be consider very good for the study. However it is worth mentioning that those who finally filled the form presented the best performances. The nine focus points in the registration form include the following questions / categories:

1. Demographics data such as school area, the teachers who take part on the project, the number of participants, the students' age etc: Through this question we tried to clarify the specific characteristics of the schools that participated on the project. The school culture plays an important role not only on the teachers' and students' choices but also on their expectations from this project. It was noticed that the best schools performances were held by students who collaborated with each other and by teachers from different cognitive fields, such as philologists, mathematicians, physicians, computer teachers, theatrologists etc.

2. Description of the time and the place where the rehearsals and the writing of the script were held: The planning and the implementation of the script took place on students' schools and teachers tried to collaborate with other teachers or to take some ideas from other school programs and projects which took place during the same year. Educational projects about environmental issues or social issues give the opportunity to teachers and students to combine the educational knowledge with their real life and real needs. At the same time, many students participated in workshops, or visited research centers (e.g. Observatory of Penteli). Throughout the duration of the program they also watched theatrical performances.

3. The starting point for writing a script (e. g scientific content, theatrical techniques, etc.): A scientific theory and its connection to the theatre constituted the initial starting point for writing the script. At the same time, many schools had an interdisciplinary approach to the scientific concepts by linking the main topic to other subjects.

4. The description of students' cognitive progress and examples which confirm it from the first moment until the completion of the first rehearsal: In order to examine the students' cognitive progress and development we asked teachers to notice which of the initial ideas were changed through the whole process. Some concepts remained unchanged, such as scientific terminology and definitions (e.g. the meaning of light, water cycle, angles). On the other hand, many students' ideas were developed during the action as they had discussed the scientific concept. For instance, students limited the initial discussion of scientific concepts and began focusing on the theatrical performance and mapping of the scientific theory. This suggests that students eventually connect scientific knowledge to their everyday life. Students started to think how they can represent the concept of time, a journey in space and gravitational waves in a more creative way. Some of their original ideas were rejected, especially those which were difficult to understand and thus represent in theatrical performance, those which were difficult to explain or had complex meanings, such as the concept of proof, vitamin C, Thales's views to the original material in the world, and God. On the other hand, the context of inquiry learning has led to several new ideas. The choreography of the planets around the sun, the physical representation of the journey of Thales in Egypt, the physical representation of the Theorem of Thales, a discussion between Science and Philosophy, the relevance of the concept of time, the representation of the relative speed, the dual nature of the concept of light (wave and particle) are some examples of a scientific and artistic representation.

5. Details of students' creativity: The teachers involved in the project supported their students in the inquiry phase and creativity. The students wrote their scripts working in groups in research projects at schools, while they were participating in other programs and they tried to combine their knowledge of different subjects. The action developed students' creativity, as students developed their imagination. They enhanced their creative thinking by writing original scripts. They used everyday materials to represent scientific concepts or they designed choreographies to enrich their scenarios. For instance, students designed a choreography to represent the sun and the moon during the eclipse or used fabric to represent sea waves. The students composed their own original music and created dance performances. At the same time, they created their own scenes to meet the needs of each performance. A typical example of students' creativity is a scene where the main actor invokes the help of Science and Art. This trick of the appearance of the two females (science and art) indicates the ancient greek appearance "deus ex machine".

6. Sub categories of Embodied Learning: Embodied Learning was evident in the theatrical performances. The students understood scientific concepts and represented the scientific content through their whole body, gestures, facial expressions, as they were also emotionally involved. The relevance of gestures refers to the analog or structural correlation of symbols and their meanings. Given the aforementioned, it becomes obvious that embodied learning involves coordinated movements either of body parts or of the whole body in order for a learning goal to be achieved combined with the students' sensorimotor activity and their emotional involvement. Teachers have noticed all of the characteristics of Embodied learning. The students used their whole body and facial expressions Also, the representation of meaning was only successful when students used their whole body. During the action the students cooperated and interacted with each other and combined the construction of knowledge in an entertaining way. Random or unconscious movements were not noticed, as students had fully understood the scientific content

7. Theatrical techniques: Regarding the theatre techniques or other techniques related to Art, most teams used a wide variety of theatrical techniques, linking the representation of scientific concepts to Art. Most students worked on teams and used multimedia and digital material. Many students participated in workshops, or visited research centers (e.g. Observatory of Penteli). Throughout the duration of the program they also watched theatrical performances. Some teachers used exploratory dramatization information (inquiry drama). Most

teachers used theatrical techniques such as inquiry drama, image theatre, flashback, narrative techniques or a special method called "Heathcote's five levels of meaning". The role-play, pantomime and improvisation were used by most schools. Free improvisations helped students to familiarize themselves with the concepts and to easily reconstruct some elements.

8. Details of students self-correcting: Moreover, it was observed that students corrected themselves several times. Their self- corrections and interventions were related to:

- The selection of the scene of the shooting sites, the construction of sets and materials
- The Embodied Learning and the representation of scientific concepts.
- Performance direction
- Costumes selection and scenery design
- Corrections to the script-writing stage. The students were trying to simplify parts of the text in order to represent the scientific concepts in a better way.

9. Details of students' improvisation: In most theatre performances the students improvised and they did not hesitate to deviate from the original design. Their final choice was equally excellent, suggesting that they had fully understood the scientific concept. Improvisation included the students' initiatives on:

- The materials used to represent the creative scientific concepts
- The soundtrack. In many cases the students composed original music.
- Choreography, different ways of speech, different ways of kinesiology. Students suggested ways to sufficiently represent each cognitive notion. Their interventions were characterized by relevance of gestures, as most movements were linked to scientific content.
- Script changes. Interactive and dialogic parts were added to serve the needs of the project. A typical example is a dialogue between Science and Art.
- The alternation of theatrical roles. Many students took roles, but they also did not hesitate to switch roles with other students, adapting each student's character and personality to each role. During rehearsals several students could find which role fit them best.
- Adding new roles. From the first meetings with teachers and during rehearsals many students expressed a desire to participate more actively. As a result the whole team created new roles to engage students' active participation.

Results

This research examines whether the "Learning Science Through Theatre" Initiative is in accordance with Responsible Research and Innovation (RRI) principles. Our main research question is to what extent this initiative serves the main RRI principles as an innovative research and educational programme. The results show that this Initiative serves the main RRI principles (Chart 1).

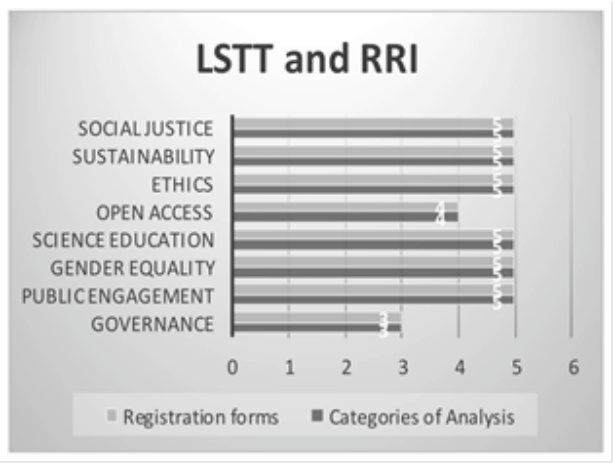


Chart 1.

The science education is the main aim of the programme. Almost all the teachers (95% from the answers of the registration forms) mentioned that the students learn how to negotiate with scientific notions. The results show that students do not only learn "by doing" but they also increase their cognitive load and science capital perspective [15]. In the vast majority of cases, a scientific theory and its connection to theatre constituted the initial starting point for writing the script.

Both the students and the whole of the school community (100%) participated in the programme collaborated harmonically with each other (public engagement). Each of them contributed in a different way to each aspect of the whole procedure (social justice/ inclusion) and controlled each step of the performances (sustainability). All the educational, cognitive, scientific and entertaining principles had been taken into consideration throughout the programme (ethics). As far as open access concerned, we have to mention that the school community had access to recourses (70% of the schools) despite any economic difficulties. Therefore, we also encouraged students to participate even with recorded performances. The registration forms indicate that an equal number of boys and girls participated in the programme. Students started to communicate with researchers and research centers (65% of the schools visited a research center or communicated with a researcher), but more efforts need to be made in order for the school community to communicate its performances with the audience and establish a different way of teaching (governance). At the beginning of the process we tried to clarify the specific characteristics of the schools that participated on the project. The school culture plays an important role not only on the teachers' and students' choices but also on their expectations from this project. It was noticed that the best schools performances were held by students who collaborated with each other and by teachers from different cognitive fields, such as philologists, mathematicians, physicians, computer teachers, theatrologists etc. The planning and the implementation of the script took place in students' schools and teachers tried to collaborate with other teachers or to take some ideas from other school programs and projects which took place during the same year. Educational projects about environmental issues or social issues give the opportunity to teachers and students to combine the educational knowledge with their real life and real needs. As a result, both teachers and students exchanged their new knowledge and they could be inspired by these school projects. At the same time, many

students participated in workshops and student conferences, or visited research centers (e.g. Observatory of Penteli, Virtual visits to CERN's experiment CMS). Throughout the duration of the program they also watched theatrical performances.

This initiative deals with scientific issues, but the participants were really free to discuss, choose and present whatever scientific notion they want, combining this concept to their real needs and to social issues, too. That is what we call Open Schools for Open Societies, as schools work as sustainable ecosystems in order to deal with everyday problems. The teachers and the students could choose the topic they wanted to focus on, depending on their interests and depth of knowledge. In order to examine the students' cognitive progress and development we asked teachers to notice which of the initial ideas were changed through the whole process. Some concepts remained unchanged, such as scientific terminology and definitions (e.g. the meaning of light, water cycle, angles). On the other hand, many students' ideas were developed during the action as they had discussed the scientific concept. For instance, students limited the initial discussion of scientific concepts and began focusing on the theatrical performance and mapping of the scientific theory. This suggests that students eventually connect scientific knowledge to their everyday life. Students started to think how they can represent the concept of time, a journey in space and gravitational waves in a more creative way. Some of their original ideas were rejected, especially those which were difficult to understand and thus be represented in theatrical performance, those which were difficult to explain or had complex meanings, such as the concept of proof, vitamin C, Thales's views to the original material in the world and God. On the other hand, the context of inquiry learning has led to several new ideas. The choreography of the planets around the sun, the physical representation of the journey of Thales in Egypt, the physical representation of the Theorem of Thales, a discussion between Science and Philosophy, the relevance of the concept of time, the representation of the relative speed, the dual nature of the concept of light (wave and particle) are some examples of a scientific and artistic representation.

As far as the representation of scientific concept and the creation of meaning are concerned, students seemed understand all sub-elements and basic characteristics of each concept. They managed to render the general meaning of the concepts and to explain simple scientific terminology. In many cases, students appropriated scientific knowledge and tried to render the scientific concept more fully in a simple manner, without the use of complicated vocabulary. This means that they managed to successfully connect newly gained knowledge with everyday life and to use it in an everyday environment. It is important to mention that most of the times there was the use of two or more representational systems when the concept in question is hard to explain. It is also worth mentioning that all representational systems have to be in complete balance and harmony, in order for the basic principles, techniques and philosophy of the two subjects to remain unaltered and for these subjects to be able to benefit one another and have to coexist when a new concept is presented, and not to appear at different times, because in that case the necessary cognitive connections and conceptual connections between the characteristics of a concept and its rendition are not made [8]. Therefore, every time students presented a scientific approach and enrich it with theatrical elements, combining Science with all forms of Art, then they reinforced their cognitive load, especially when they utilized the coexistence of representational systems and were lead to a more complete rendering of the scientific concept. It is worth mentioning that in an in depth analysis of representational systems, embodied representation is more efficient when it comes to understanding and building new knowledge compared to other representational systems.

Moreover, this educational and research programme brings together all the cognitive subjects, such as Mathematics, Physics, Chemistry, Biology but also Literature, serving that we call "universal design of learning". Students combined several scientific concepts at the same time, apart from representing a single concept in most plays, highlighting the importance of this combination for the construction of a fully developed and complete theory. Hence, it is evident that the construction of a conceptual field by students constitutes a higher cognitive process, as students are not only asked to reproduce scientific terminology but also to harmonically link scientific concepts together.

It is also worth mentioning that where there was implemented an interdisciplinary and multidisciplinary approach, the scientific concepts were strengthened, as they were in a rich context where, apart from the Art and Science, Literature, Philosophy, Culture (for example this season, or season that Scientist lived) and Society were involved. This interdisciplinarity is really crucial and important especially in young people who have to enhance their learning, cognitive, scientific and social skills. For example a scientific theatre performance made reference to the refugee issue, involving harmoniously all previous fields. A scientific theory (43/ 43 schools, 100%) and its connection to the theatre but also social issues combined to science constituted the initial starting point for writing the script. In this context, science win from the embrace with the Art. Science becomes a vehicle for scientific, social and other messages and challenges. In addition, science acquires emotion and vitality through multiple representations (embodied, verbal, etc.). For this reason, students were asked to approach concepts, properties of concepts or phenomena with the use of Embodied Learning and Analogical Reasoning. In this case it was observed that a single representational system (nonverbal communication only, using isolated movements/gestures) cannot suffice to understand and apply the concept. This connection of two or more representational systems leads to the creation of deeper meanings. We need to underline that not only does Analogical Reasoning constitute part of Art, as it encourages creative knowledge but also it is linked to building new knowledge through multiple noting systems, as a successful comparison requires the combination of many representational systems. Moreover, the significance of Art is obvious through the results of the registration form. Asking for details of students' creativity such as imagination, originality, innovation, the teachers involved in the project supported their students in the inquiry phase and creativity. The students wrote their scripts working in groups in research projects at schools, while they were participating in other programs and they tried to combine their knowledge of different subjects. The action developed students' creativity, as students developed their imagination. They enhanced their creative thinking by writing original scripts. They used everyday materials to represent scientific concepts or they designed choreographies to enrich their scenarios. For instance, students designed a choreography to represent the sun and the moon during the eclipse or used fabric to represent sea waves. The students composed their own original music and created dance performances. At the same time, they created their own scenes to meet the needs of each performance. A typical example of students' creativity was a scene where the main

actor invoked the help of Science and Art. This trick of the appearance of the two females (science and art) indicated the ancient greek appearance "deus ex machine". Another part of artistic perspective derived from the registration forms is the theatrical techniques. Most teams used a wide variety of theatrical techniques, linking the representation of scientific concepts to Art. Most students worked on teams and used multimedia and digital material. Many students participated in workshops, or visited research centers (e.g. Observatory of Penteli). Throughout the duration of the program they also watched theatrical performances. Some teachers used exploratory dramatization information (inquiry drama). Most teachers used theatrical techniques such as inquiry drama, image theatre, flashback, narrative techniques or a special method called "Heathcote's five levels of meaning". The role-play, pantomime and improvisation were used by most schools. Free improvisations helped students to familiarize themselves with the concepts and to easily reconstruct some elements. In most theatre performances the students improvised and they did not hesitate to deviate from the original design. Their final choice was equally excellent, suggesting that they had fully understood the scientific concept. Improvisation included the students' initiatives on: the materials used to represent the creative scientific concepts, the soundtrack. In many cases the students composed original music, choreography, different ways of speech, and different ways of kinesiology. Students suggested ways to sufficiently represent each cognitive notion. Their interventions were characterized by relevance of gestures, as most movements were linked to scientific content, script changes, interactive and dialogic parts were added to serve the needs of the project, the alternation of theatrical roles. Many students took roles, but they also did not hesitate to switch roles with other students, adapting each student's character and personality to each role. During rehearsals several students could find which role fit them best, adding new roles. From the first meetings with teachers and during rehearsals many students expressed a desire to participate more actively. As a result the whole team created new roles to engage students' active participation. It was observed that students corrected themselves several times. Their self-corrections and interventions were related to: the selection of the scene of the shooting sites, the construction of sets and materials, the Embodied Learning and the representation of scientific concepts, performance direction, costumes selection and scenery design, corrections to the script-writing stage. The students were trying to simplify parts of the text in order to represent the scientific concepts in a better way.

Moreover, students had to cooperate with their teachers, but also were provided with open access to research centers in order to use up-to-date information of science and communicate with researchers. Pupils can also use their collaboration with Research Centers in order to understand basic concepts or explore specific topics of interest in greater depth. During the whole process, the educational community had to interact and collaborate with other agencies, for example parents, local industries etc., in order to get some advice (such as actors, directors etc.) but also to advertise their theatrical performances and find additional help for their activities (such as their customs, the music of the performance etc.). This way, school becomes a central power which guides as many agencies as possible to achieve a common goal.

At the same time, all these factors and agencies have a responsibility to embed social, economic and ethical principles into their teaching in order to prepare students for active citizenship. The dramatization of scenarios is a long process, in which all the members of each community (politic, research, educational, industry) can directly be involved in science research, can exchange ideas and help each other to connect their knowledge to different fields. At the end of the process all the members watch students' performances, discuss with each other and share and disseminate research outcomes with society.

As far as ethics concerned, we have to mention than the notion of responsibility means that someone (an actor, e.g. a scientist or an engineer) assumes responsibility for something (such as the results of actions or decisions, e.g. for avoiding safety or security problems) relative to a body of rules (laws, norms, principles, values and customs) and relative to the quality of available knowledge about the consequences of the actions [16].Therefore, we argue that we followed general and specific, strict regulations in order to ensure the validity of the results. Parental consent was required for the children to participate in the project and was obtained for each step in the activity (e.g. children's involvement in evaluation studies, videos, photographs). Besides the child protection, we also tried to handle the user's personal data. We tried to protect the students, to secure privacy, security and ethical conduct in all our field and evaluation studies. All researchers were required to have school-verified identification and a school liaison person available at all times during school visits and were aware of essential health and safety issues concerning students on school premises.

Gender equality is a crucial issue, too. This initiative recommended participating both boys and girls, by working collaboratively as a team. Therefore, it utilizes cooperative and collaborative work, encourages active participation from the students, and provides personal engagement and foster students' confidence.

5. CONCLUSIONS

As we can realize, the Learning Science Through Theatre Initiative is able to a culture of scientific thinking by inspiring teachers and promote students to open their traditional classrooms, to develop cooperative skills to achieve a common goal and to empower an intensive interest to what happens not only inside but also outside the classroom in an entertaining way [17], where young people have to deal with societal problems but also create new ideas and promote research and innovation for affecting change and better life.

6. AKNOWLEDGEMENT

The "Learning Science Through Theatre" (LSTT) project (http://www.lstt.eu/), the Science View Organization (http://www.scienceview.gr /) responsible for the organization of the "Learning Science Through Theatre" in Greece.

CREAT-IT (2012-2015) 539818-LLP-1-2013-1-NO-COMENIUS-CMP.

CREATIONS (2015-2018), H2020-SEAC-2014-1 CSA, 665917.

7. REFERENCES

[1] K. Chappell, L. Hetherington, H. Ruck Keene, C. Slade, M. Cukorova, D2.1 The features of inquiry learning: theory, research and practice, **Deliverable 2.1 EU project Creations, p.31.** http://creations-project.eu/wp-content/uploads/2016/09/Download-3.pdf

[2] Z. Smyrnaiou, & A. Weil-Barais, **Évaluation cognitive d'un logiciel de modélisation auprès d'élèves de college**, 2005.

[3] Z. Smyrnaiou, & A. Weil-Barais, **Cognitive evaluation of a technology-based learning environment for scientific education. Teaching and learning**, 2003.

[4] K. H. James, & S. N. Swain, "Only self-generated actions create sensori-motor systems in the developing brain" **Developmental Science**, Vol. 14, No. 4, 2011, pp. 673–687. doi:10.1111/j.1467 7687.2010.01011.x.

[5] P., Atkinson, R. Watermeyer, & S. Delamont, "Expertise, authority and embodied pedagogy: operatic masterclasses", **British Journal of Sociology of Education**, Vol. 34, No. 4, 2013, pp. 487-503.

[6] G. Vergnaud, The theory of conceptual fields. Human development, 52(2), 83-94, 2009.

[7] D. Abrahamson, J. Gutiérrez, T. Charoenying, A. Negrete & E. Bumbacher, "Fostering hooks and shifts: Tutorial tactics for guided mathematical discovery". **Technology, Knowledge and Learning**, Vol. 17, No. (1/2), 2012, pp. 61–86.

[8] Z. Smyrnaiou, Sotiriou, M., Sotiriou, S. & Georgakopoulou, E. Multi- Semiotic systems in STEMS: Embodied Learning and Analogical Reasoning through a Grounded- Theory approach in theatrical performances. **Journal of Research in STEM Education** (submitted), 2017.

[9] Deliverable 3.1.2 EU Project Creations, Learning Science through theatre

[10] E. Hazelkorn et al., Science Education for Responsible Citizenship, 2015. Retrieved from: http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

[11] A. Craft, O. Ben Horin, M. Sotiriou, P. Stergiopoulos, S. Sotiriou, S. Hennessy, K. Chappell, Ch. Slade, M. Greenwood, A. Black, E. Lale Dobrivoje, Đ. Timotijević, A. Drecun, A. Brajović, C. Belmontecinzia, G. Conforto, "CREAT-IT: Implementing Creative Strategies into Science Teaching", **New Developments in Science and Technology Education**, Springer, Innovations in Science Education and Technology Vol. 23, 1, 2016, pp. 163-179, doi 10.1007/978-3-319-22933-

[12] G. Gobo, "The Renaissance of Qualitative Methods". **Forum Qualitative Social Research**, Vol. 6, No. 3, Art. 42., 2005. Retrieved from: http://www.qualitative-research.net/index.php/fqs/article/view/5/11 .

[13] K. Krippendorff, Content analysis: An introduction to its methodology. Sage, 2004

[14] J. A. Smith, (Ed.), Qualitative psychology: A practical guide to research methods. Sage, 2015

[15] A., Louise, et al. ""Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts." Journal of Research in Science Teaching 52.7, 2015, pp. 922-948.

[16] A Grunwald, "Responsible innovation: bringing together technology assessment, applied ethics, and STS research", **Enterprise and Work Innovation Studies**, 31, 10-9. 2011.

[17] Z. Smyrnaiou, M. Sotiriou, E. Georgakopoulou, O. Papadopoulou, "Connecting Embodied Learning in educational practice to the realisation of science educational scenarios through performing arts", **International Conference "Inspiring Science Education"**, Athens 22-24 April, 2016, pp. 37-45.

[18] A. Craft, et al. "Teacher stance in creative learning: A study of progression." **Thinking Skills and Creativity** 2.2 2007. : 136-147.