What Does Scientific Theatre Do? Toward an Inquiry- based and Semiotic Theory through a Cultural approach

ZACHAROULA SMYRNAIOU
Department of Pedagogy
National and Kapodistrian University of Athens
Ilissia, 15784, Greece

GREECE
zsmyrnaiou@ppp.uoa.gr
and
MENELAOS SOTIRIOU
Science View
2 Misaraliotou str.,
Athens, 11742, Greece
sotiriou@scienceview.gr

and

SOFOKLIS SOTIRIOU
Research and Development Department, Ellinogermaniki Agogi
Dimitriou Panagea str.,
Pallini, Attica, 153 51, Greece
sotiriou@ea.gr

Abstract: The 'Learning Science through theatre' approach enables students to promote and reflect on the interaction between all types of cognitive systems and accomplish the cognitive transfer from Science to Art, in other words the transition from STEM to STEAM (Science, Technologies, Engineering, ARTS or ALL SUBJECTS, and Mathematics). This way students are enabled to develop their understanding of and engagement with both scientific and artistic ways of thinking through hands-on experimentation with real scientific data and development of art objects. This approach is compatible to Inquiry- based learning principles and enhances students' understanding of scientific inquiry. Students build their understanding on scientific concepts applying and developing knowledge from the whole curriculum (multidisciplinary approach) and become acquainted with the concept of learning science creatively. A key finding in this approach is that students manage to realize and reflect on peripheral issues that influence science such as the timeline of the development of scientific concepts, the contemporary time, and the socio- cultural factors that have an impact on science. As a result, students are significantly enhanced in developing the necessary skills to make some assumptions regarding the future scientific developments and their societal impact as well. In general, the 'Learning Science through theatre' approach follows a scientific approach while opening doors to experiencing new possibilities on several levels.

Key-Words: Scientific Theatre, Inquiry- based Learning, Cognitive systems, Art, Culture

1 Introduction

In the context of the 'Learning Science through theatre' project students build their understanding on scientific concepts applying and developing knowledge from the whole curriculum (multidisciplinary approach) and become acquainted with the concept of learning science creatively. This way they manage to develop creative skills in a spirit of cooperation and teamwork in which various groups will create a 'cognitive object' such as script, scenography, costumes, music or even a video composition. This process, which involves the co-existence of different semiotic systems, engages students in a highly motivating environment where they learn to recognize, analyze and imagine alternative explanations and models and communicate a scientific argument or issue in a creative and alternative way. The co- existence of multiple semiotic systems triggers students to reflect and explain the scientific concepts in a more descriptive way, whereas the Inquiry-Based Learning approach supports students in developing a more precise, holistic and scientifically accurate approach in their effort to represent the scientific concepts under negotiation in an alternative way. Therefore, every time students present a scientific approach and enrich it with theatrical elements, combining Science with all forms of Art, they reinforce their cognitive load.

Furthermore, the culture factor plays a crucial role in students' 'transfer' process as they have to link their knowledge to everyday life issues with scientific issues. In other words, students are engaged in following the main concept of the 'Learning Science through theatre' project which is 'learning about science through other disciplines' and 'learning about other disciplines through science'. This way, not only teacher quality can be improved but also students are enabled to deal with contemporary problems, such as new findings in research fields, societal challenges, gender issues, cooperation between people and countries at international level, employment etc. The results show that the students follow the IBSE principles and the acquisition of knowledge process successfully with the co-existence of multiple semiotic systems and their understanding of scientific concepts is greatly enhanced.

2 The 'Learning Science Through Theatre' Approach: The Interaction of Multidisciplinary Pedagogical Approaches

The Learning Science through Theatre project is based on a flexible and holistic theoretical framework which combines three pedagogical theories, thus enabling students to acquire knowledge in a different way:

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

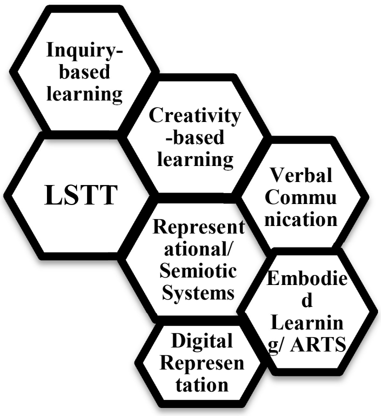

Fig. 1. A representational model of the 'Learning Science through theatre' approach

The literature of the science education offers important data to the science inquiry. The main characteristic of inquiry learning is that learners learn by acting as scientists [1]. A lot of effort has been put into how to improve students' inquiry skills [2]. It is expected that via methods similar to the scientific methods learners will approach the scientific problems under negotiation more deeply; an approach leading to a better understanding. The added pedagogical value of this approach is that students are enhanced to reflect on the nature of the scientific knowledge as well, including the involved processes of knowledge building. Towards this learning objective, students are supported by the pedagogical theories and didactics that frame the discipline of Arts; 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 [3].

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. Creating a bridge between the two disciplines bears a great pedagogical

importance since it can lead to a deeper understanding of each subject area.
In addition, the educators and teachers admit that they fail to design an inquiry- based activity. Research indicates that students have substantial problems with all of the inquiry processes [4]. They have difficulty choosing the right variables to work with, they find it difficult to state testable hypotheses, and they do not necessarily draw the correct conclusions from experiments. The most difficult step for students in the inquiry process is asking the appropriate questions [2]. Moreover, they can't translate theoretical variables from their hypothesis into manipulative and observable variables in the experiment [5].
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 students in inquiry based and creative activities they manage to understand the tentative nature of science and improve their cognitive skills. The implementation of the inquiry process in the 'Learning Science through theatre' approach can be traced in all stages of creating a theatrical performance. The students start by formulating a scientific concept-theatrical topic and then they try to find ways of representing this topic in an active and creative way. They formulate predictions and come up with alternative ways of thinking, and they try to determine which of their hypotheses, if any, is accurate and which is the best way to represent each scientific notion. Learners and teachers collaborate in seven different phases and they proceed their scientific-theatrical inquiry guided by scientifically oriented questions. Students give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. Then they formulate explanations from evidence to address scientifically oriented questions and finally they evaluate their explanations, particularly those reflecting scientific understanding.

Through this approach students can learn and act in purposive and imaginative activities, generating outcomes that are original and valuable in relation to their understanding of the world and the scientific rules that govern it. This is accomplished 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 [6], [7].

Furthermore, throughout this approach, verbal representation and language, Embodied Learning and multiple semiotic systems become an integral part of the learning process through which students represent scientific concepts and express reasoning and scientific meanings when they realize scientific theatrical performances [3], [8]. The cognitive co-text of verbal representation as a cognitive frame system and the key principles of Embodied Learning (whole body movements, gestures, emotional involvement and facial expressions) are co- examined and combined with Analogical Reasoning through Arts resulting in student's development of scientific meaning.
The driving force of this approach is the application of alternative and therefore more in depth pedagogical practices that move away from the individualistic and rigorous scientific framework of formalisms and adopt a collaborative creative paradigm for science. The embracing of art and science has the significant effect of strengthening the scientific meaning. In addition, creativity can strongly strengthen not only students' motivation but also their learning skills and equip them with the necessary critical competences that contemporary society requires. Within science education, there have been attempts to focus on the consistencies of a semiotic system on others or on the connectivity among different semiotic systems. For example, [9] Smyrnaiou and Weil-Barais (2005) give particular emphasis on the importance of applying natural language for the understanding of scientific relations. Their research led them to suggest that if the student is not able to understand the 'transformations', in natural language, he/she will not be able to appropriately express himself/herself with formal systems. 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/or in digital or physical environments as well. The use of the body is substantial in concept representation and communication. 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

In addition, analogical reasoning appeared effortlessly in theatrical performances. An analogy could simplistically be described as 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 which is referred as field "target". The analogy is not simply a comparison [10] between two cognitive domains - one familiar and one less familiar, but it is a special type of comparison which is determined by the order in which serving and on the type of information that connects. The power or success of analogy does not depend on the number of features that are common in the base areas and the objectives, but rather the coincidence of relational structures between the two sectors and the related information system that transmits, which was once delivered by Gentner (1983) [11].

These pedagogical principles are affected from students' cultural beliefs and what we call socio-cultural context. Culturalism [12], [13] is one of the approaches of mind and it takes its inspiration from the fact that mind could not exist isolated from culture. The reality is represented by a symbolism shared by the members of a cultural community and refers to the habits of the past, the present and the future habits. Culture in this sense is superorganic but it shapes the minds of individuals as well. Its individual expression inheres in meaning making [12], assigning meanings to things in different settings on particular occasions. Although meanings are "in mind", they have their origins and their significance in the culture in which they are created. It is this cultural contextualisation of meanings that assures their negotiability and their communicability. On this view, learning and thinking are always situated in a cultural setting and always dependent upon the utilization of cultural resources. The students' cultural environment is built both based on their subjective perceptions and based on the social and cultural environment in which they operate as subjects. This study mostly focuses on the social and cultural environments. The notion of culture here illustrates the ideas, actions and constructs the students have nowadays created or appear to signify the transfer of a time frame or the cultural environment of a scientist or whatever happens nowadays. As a result, culturalism seeks to bring together insights from psychology, anthropology, linguistics, literature, and other human sciences on a scientific context. The culture factor reflects the verbal, physical and social presence of students, a fact which verifies its direct connection to multiple representational systems as the conceptual field is approached scientifically and is also connected to everyday life at the same time. The culture factor contributes to the representation of scientific concepts since students depict the entire historical, social, cultural and scientific context while it is also linked to creativity, theatricality and Art.

We believe that dramatization of educational theatrical scenarios and the representation of scientific concepts and knowledge is a complex procedure which is based not only on the creativity and inquiry- based framework but also on the cognitive, holistic processes of acquiring learning. These processes are based on:

a) Inquiry- based procedures

b) Creative activities, combining scientific knowledge to Art and Theatre

c) Cognitive procedures, such as verbal expressions, embodied learning, arts, and digital representations: the representation of scientific content using cognitive processes, the student's sensorimotor involvement using their bodies or gestures, their emotional involvement, the brain-body-emotion coordination and the holistic use of the student's personality

d) Students' motivation

e) The role of culture, as we research the social interaction and communication between the students and the use of past experiences and creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors.

3 Methodology

The research methodology includes both qualitative, quantitative and grounded- theory methods. 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 allows 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. Quantitative research usually means the statistical analysis of collected standardized data. In qualitative research non-standardized data are obtained which are analyzed with the help of non-numerical (interpretive, hermeneutic) methods [14].

Through our analysis many attempts are made to blend these different techniques of data collection and analysis: one may, for instance, analyze non-standardized data with statistical methods by counting words or occurrences of words etc. Different methods entail separate methodological standards and quality criteria—a good qualitative analysis requires openness towards the (possibly idiosyncratic) perspectives and parlances of the actors in the field, whereas a main purpose of quantitative data collection is to obtain comparable and repeatable bits of information. Context-relatedness of data is a crucial issue for qualitative researchers and that is the reason why we prefer context- analysis and theoretical categories of the data. This methodology 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 [15]. The grounded theory as a methodology tool is, also, preferred, as it enables us to produce a theory from data- systematically obtained and analyzed. This comparative analysis consists of specific steps [16] by which we discover what concepts and hypotheses are relevant to the data. As a result, this new theory from the data provides us models of conceptualization for describing and exampling. The verification through the analysis feeds back into and makes us modify some categories of our analysis. First of all, we collect and analyze the data. Our data consists of the theatrical performances (94 performances) in which students have to deal with scientific subjects and represent scientific notions and the registration forms filled by their teachers during the whole procedure. Secondly, we collect and analyze 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 codes from data, not from preconceived hypotheses. This middle- range theory (Smith, 2015) helps us understand and explain behavior and processes, making comparisons to data- data and then data-codes and among concepts. The new theoretical construction derived from the data is tested again and we check the conceptual categories both by the theoretical framework and literature review and new categories from the medication of the theory.

The connection of multiple representational systems with the learning process and their combination with Art in the teaching practice/ theatrical performance constituted the central research question of other researches [3] and now combining the results of mixed analysis of the performances to teachers' opinions from the registration form, we research how the principles of Inquiry- based Learning and Semiotic Systems are confirmed to this initiative and what the contribution of culture is to the successful representation of scientific notions.

Furthermore, questions regarding the meanings students deduct through embodied learning, verbal communication and the rest of representational systems are examined while the way these systems are combined, and whether the combination of more than one system is more effective in the process of learning are also discussed. The students' choices are tried to be justified by some elements of culture.

As it is mentioned the methodology employed to analyze scientific data gathered from the theatrical performances, constitutes a merging of qualitative and quantitative analysis [17]. The data were analyzed and classified into categories. This conceptual categorization takes 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 project. Student representation of scientific concept and the production of scientific meaning is studied using 3 categories.

1. Embodied Learning
2. Multiple representational systems (verbal, embodied, digital, kinesthetic representation, elements of Art)
3. Analogical Reasoning

These categories emerge from the theoretical framework and the scientific context. They are distinct yet interdependent as they answer the basic research question. Next, questions are further divided into subcategories for clarification reasons and are driven by the same data [18]. The data were categorized and these categories were analytic, as they combine different elements. They are, also, valid, as they are aligned with the theoretical framework. Their properties emerge from the data analysis [18]. 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. These subcategories were based on the theoretical framework of Embodied Learning, as the simultaneous co-existence and interaction of different body parts, the corresponding to the notion in question gestures, the facial expression and the student's emotional involvement are necessary. Each of these categories describes what is examined in each area and where the research focus lies. The relations between these different levels are distinct.

As a consequence, it becomes evident that a link is formed between the theoretical framework of this report, which offers the categories of analysis, and empirical data, with new categories emerging from data analysis which reconstructs the original theoretical framework. The 3 categories of analysis were regularly reformed and the basic research question is gradually validated both through the findings and through examining them in relation to new categories which have emerged after the analysis of the data. The procedure which was followed included the following steps:

i. Defining relevant properties
ii. Demonstrating their context
iii. Specifying the conditions in which these properties occur
iv. Conceptualization of phases
v. Explication of what contributes the stability and/change of a category
vi. Outlining the results

The third category of analysis which encourages student representation of scientific meaning in theatrical plays is Analogical Reasoning. It emerged as a distinct category after a comparative examination between empirical data (Grounded Theory). This categorization made evident that students use analogies, that is, models used to compare structures between 2 areas [19], which map the relations between a familiar field (base) to an unknown one (target). The FAR model [20] is used to represent the categories of Analogical Reasoning.

Embodied Learning	**Multiple representational systems**	**Analogical Reasoning**
whole body movements	verbal communication	Focus:
isolated gestures	non- verbal communication (Emdodied Learning)/ kinesthetic representation	Action
facial expressions	digital representation	Reflection
emotional involvement	Art	

Table 1.

During the final presentation event a registration form was used based on scientific criteria to ensure the procedure. The registration form, which was filled by the teachers, was designed to focus on sixteen main aspects of cognitive and learning process, during the process of theatrical performances. All of these aspects are really important for the progress of the initiative and the correspondence to the main Responsible Research and Innovation principles (RRI). These aspects are oriented to four main categories:

a) the Pedagogical/ educational and scientific framework of Inquiry-based Learning, Creativity, Embodied Learning and Multiple Semiotic systems of cognitive fields
b) the contribution of Art and Theatre to scientific concepts through Steam- principles,
c) the contribution of Science communication and Open Schooling to the learning process and
d) the significance of culture to the way students understand and approach science and link it to everyday life.

For our research we focused on five from sixteen categories above. Three of them show the cognitive processes and the inquiry- based procedures:

a) "Principles of Inquiry Learning: Describe the main principles of Inquiry Learning from the first moment until the completion of the first rehearsal/ Indicating what is happened to each stage",
b) "Sub categories of Embodied Learning (gestures, whole body movements, emotional involvement, facial expressions) in relation to the representation of scientific content (understanding, application in daily life). Was the Embodied Learning evident to the dramatization of scientific concepts? To which way?" and
c) "The use of multiple semiotic and representative systems (verbal, non- verbal, Art, digital). Indicating 2-3 examples of a scientific notion and each scientific representation through three cognitive systems"

Two of them are focused on the contribution of culture factor on the whole procedure:

a) "Demographics data such as school area, the teachers who take part on the project, the number of participants, the students' age etc."
b) "Culture: How are some features of the culture evident to the theatrical performances? (Evidence of today's society, evidence of scientist's time and society, evidence of an imaginative/ future society etc.)"

4 Methodological Setting of the Approach

The project "Learning Science Through Theatre" (http://lstt2.weebly.com/ , http://www.lstt.eu/) is an initiative that is based on the pedagogical framework which was developed by the European project CREAT-IT (http://creatit-project.eu/) and continues to be implemented in the framework of the European Project CREATIONS ((http://creations-project.eu/). It 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. Forty Three (43) theatrical performances during the school years 2014-2016 were organized by secondary school students (2000 subjects) which embedded both scientific concepts and cultural/ social elements; expressed by embodied learning, verbal interaction and analogies. Fifty- one (51) theatrical performances were presented this year and more than a thousand of students (1000) and sixty teachers participated on this project in 2016-2017. The students were able to create their own scenario based on all fields of sciences and mathematics.

This Initiative offers students the opportunity to create a play through the dramatization of scientific knowledge and concepts, included in the curriculum. Students engage in activities such as the writing of scientific stories (scenarios), composing music, designing sets, costumes and coming up with choreographies. Both students and teachers work together with scientists from research centers and universities in order to better understand the scientific concepts and phenomena that they will dramatize. The whole process follows a scientific approach while opening doors to experiencing new possibilities on several levels. Teachers along with students will perform drama, music, dance and video (pupils can use existing videos provided they are licensed to). School groups can choose the science field (physics, chemistry, mathematics, biology etc.) that will be included in their curriculum. This educational and research projectbrings together all the cognitive subjects, such as Mathematics, Physics, Chemistry, Biology but also Literature, serving what we call "universal design of learning". It is very significant the fact that in cases there is implemented an interdisciplinary or/and a multidisciplinary approach, the scientific concepts are strengthened, as they are in a rich context where, apart from the Art and Science, Literature, Philosophy, Culture (for example highlighting the contrasting settings of the contemporary era and the era the particular Scientist lived) and Society are involved (for example a scientific theatre performance that made reference to the refugee issue, involving harmoniously all previous fields). In this context, science is promoted and enhanced through its 'embrace' with the Art. Science becomes a vehicle for cultural and social aspects and challenges as well. Students find connection between Science and Greek ancient Literature, History, Music, Theatre, mythology, environmental issues and Sociology. The number of students that can participate is not fixed; the teacher could choose the number according to the needs (characters, script writers etc.). The activity can 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. Teachers of each unique project are free to design the schedule and creative exercises according to their needs and capacities, following the IBSE principles. Furthermore, teachers are 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 is provided through visits to schools, online meetings and special workshops. In every school that participates will create working groups (e.g. script writers, actors, musicians, dancers, stage and costume designers, video producers) which will assist professional organizers.

5 Problem Solution

This initiative is compatible to Inquiry- based learning principles. Students are asked to dramatize scientific concepts and knowledge from the curriculum of their courses. It follows a scientific approach while opening doors to experiencing new possibilities on several levels. In phase "Question" learners and teachers collaborated in seven different phases so as to be engaged by scientifically oriented questions. For example the teachers tried to motivate their students and they discussed their students' interests. In phase "Evidence" students gave priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions. All the students (100) researched and studied the scientific notions. This procedure usually takes a long time, as the students discussed which scientific notion they would represent, from which cognitive field they were influenced by, how they could combine together different scientific notions from different cognitive subjects. They studied the cognitive concept from different scientific sources and they also criticized the school books, because they do not provide more details about each notion. For example, the students studied about the light from different scientific resources, as they did not find enough information on their school books. Then they discussed their findings with their teachers and they started to search for scientists' life and personality. This new aspect derived from these registration forms for the first time which is really important. This year students seem to be interested not only in the scientific knowledge but also in the cultural concept in which this knowledge is developed and influenced by. In the phase "Explain" and "Connect" students formulated explanations from evidence to address scientifically oriented questions and after the process they evaluated their explanations, particularly those reflecting scientific understanding. They used argumentation and dialogue to decide on the relative merits of the explanations they formulate, playing with ideas. Students evaluated their explanations in light of alternative explanations, particularly those reflecting scientific understanding. The students wrote their scripts and they tried to explain scientific notions through different semiotic and representational systems. For example a group of students found information about Mendeleev's life and work. This information helped the students to continue their script, as they tried to write the chemical elements on cards and played solitaire in some way. As they also wanted to add a love dialog or a rivalry dialog between the chemical elements, the students started to write a script for a fight between chlorine, sodium and hydrogen. Other students studied and discussed not only the positive but also the negative aspects of a scientific discovery, developing some ethical issues. Students connect explanations to scientific knowledge, using different ways of thinking and knowing ('knowing that', 'knowing how', and 'knowing this'). They explored the topic spherically and found connections with other disciplines (e. g arts, theatre, music, technology). Students investigated on the science theatre design and implementation. The students wrote their scripts and they tried to explain scientific notions through different semiotic and representational systems. It is also worth mentioning, that this process is really helpful for the teachers, as well. Most of them wanted to expand their knowledge by attending e-learning courses, by discussing with their colleagues or by asking for advice. In the phase "Communication" students communicated and justified their explanations, by exchanging ideas, possibilities, and justifications. Such communication is crucial to an ethical approach to working scientifically. Students communicated with professionals (directors and musicians) in order to get help about their scientific scripts, the direction and the music. As our results have shown, the scientific notion has to be represented through the co- existence of different semiotic systems in order to be fully understandable. However, they suggested different ways of how they can analyze their data and represent their performance to the audience. In the final phase of "Reflect" students reflected on the inquiry process and their learning. Students are evaluated by the evaluators of the final event (scientists, professional artists, science communicator experts). They are also evaluated by the general public of their theatrical play. Having received their prizes and awards, they discussed with each other and with the teacher about the characteristics of their success (stage design, music composition, group dialogue, ethical decision-making regarding inclusion of all students in the creative process, etc.) and the factors that contributed to some potential unfortunate incidents. All of the schools mentioned that they followed the IBSE principles and they also indicated specific examples to each stage. All of the schools worked on the following steps, by defining the project goals, working on team groups, searching for scientific information and evaluating their sources, discussing with each other, finding innovative ideas, writing their scripts and finding innovative ways to represent and present their knowledge and their creativity. As the results of the registration forms show, all the schools followed a scientific and research approach, as they begin with a central question, then they try to find answers, collecting data from different sources, they discuss their finding and last but no least they try to represent the scientific concept on a creative way, using their imagination.

The connection of multiple representational systems with the learning process and their combination with Art in the teaching practice/ theatrical performance constitutes the central research question of our researches [3]. Furthermore, questions regarding the meanings students deduct through embodied learning, verbal communication and the rest of representational systems are examined while the way these systems are combined. Students employed scientific concepts in all of the plays. 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. It is significant to mention that students were able to use simple language to explain scientific terminology at the same time they were using this terminology provided they had understood the scientific concept in question. In most cases, they used simple everyday objects, which verifies that they gained, built and appropriated knowledge. This means that they managed to successfully connect newly gained knowledge with everyday life and to use it in an everyday environment. 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. 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. In order to analyze the data in relation to student emotion and progress we chose to focus on their expressions by pausing the videotaped theatrical plays and by the subsequent examination of their facial expressions in relation to their voice. Despite the fact that it is not easy to capture the emotional fluctuation of students, there are some cases in the sample where student emotion emerges. All the teachers mentioned that the students could better understand the scientific concept when they represented it with different semiotic systems and especially their whole body and emotional involvement. As a result, the representation of meaning was only successful when students used two or all the characteristics of the Embodied Learning. During the action the students cooperated and interacted with each other and combined the construction of knowledge in an entertaining way. This leads us to believe that during this project the students were able not only to understand scientific knowledge but also to make it more understandable to others, explaining the basic scientific notions. Random or unconscious movements were not noticed, as students had fully understood the scientific content. A main difference between this registration form and the previous one is that we are now focusing only in the key features of Embodied Learning concerning to scientific concept. It was clear from the previous registration forms that the school community were entertained combining scientific theatre with entertainment. Now we want to examine how the Embodied Learning contributes to the cognitive load. For example, a student who represented the ferrum showed their arms, o when the bromine chemical element appeared, all the students held their noses because of the bad smell or a student who represented the electron moves around the hydrogen. 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.

Sometimes students only used isolated gestures. 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. For this reason, most of the times there is a simultaneous use of multiple representational systems, that is the use of both verbal description and of nonverbal communication, of Embodied Learning. This connection of two or more representational systems leads to the creation of deeper meanings. It is important to mention that most of the times there is the use of two or more representational systems when the concept in question is hard to explain. That is why students' cognitive load are increased.

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. The semiotic systems have also 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. As far as the use of Analogical Reasoning is concerned, students proceeded to link different fields, transferring knowledge from one field to the other with the final aim of reframing scientific knowledge. Students in order to be able to more fully illustrate a scientific concept, either attempted to compare it to other concepts or to explain it using elements from their daily life. The scientific concept/field is mapped, the common elements it shares with the simpler concept/base are recognized and after all necessary matches, the parts of which field which match are linked. The matches are structural in order for scientific knowledge to successfully become a model since it is not about simple comparisons, metaphors or similes. 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. The comparison can be verbal or virtual, but the combination of language with Embodied Learning can enhance even more the dynamics of analogical inferences and the level of their enrichment, along with the students' cognitive strategies. As a consequence, it is suggested that Embodied learning and analogical reasoning may lead to scientific learning outcomes of a higher quality while at the same time it may reinforce student communication and motivation in scientific topics. It is also suggested that the coexistence of three or more semiotic systems can reinforce students' cognitive representations. The interaction or cooperation of two or more frameworks produce a combined effect greater than the sum of their separate effects.

In order to examine the students' cognitive progress and development we had 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.

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. Through this question we want to examine different semiotic systems. 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.

As far as the influence of culture concerned, through the demographics question we tried to clarify the specific characteristics of the schools that participated in the project. The school culture plays an important role not only in the teachers' and students' choices but also in their expectations from this project. It was noticed that more and more schools located in remote areas participated in the project. This initiative can serve the vision of open schools and open classrooms, as these schools can also have access to scientific knowledge and new scientific perspectives. Almost half of the schools that have filled the registration form till now are located in remote areas. In addition, more and more teachers from different cognitive fields, such as philologists, mathematicians, physicians, computer teachers, theatrologists etc. collaborated with each other. We have to mention that there are some schools where philologists and theatrologists participated in the program, without a physician's or a mathematician's help. Moreover, the participation of teachers of different cognitive fields is higher than that of the previous year, for example there are not only philologists, mathematicians, physicians, computer teachers and theatrologists but also biologists, geologists, professors of chemistry, sociologists, trainers, and Art teachers among others. The students' cultural environment is build both based on their subjective perceptions and based on the social and cultural environment in which they operate as subjects. The notion of culture here illustrates the ideas, actions and constructs the students have nowadays created but also it appears to signify the transfer of a time frame or the cultural environment of a scientist. Almost all the schools are inspired by the past (scientist's time), by the present (what do students live nowadays?, what are their beliefs? , what are the main characteristics of our time?) and they made hypotheses for the future, concerning the development of technology or making statements about some ethical issues. For example, a student playing a grandmother seems to have superstitions about science, whereas a student playing Dr. Meitner mentions the beliefs of European countries and societies for the position and social status of women in the late 19th and early

20th century. The students, also, represent the "persecution" suffered by the scientific world of central Europe from the nationalistic perceptions of Nazi Germany in the project is also presented. The culture factor reflects the verbal, physical and social presence of students, a fact which verifies its direct connection to multiple representational systems as the conceptual field is approached scientifically and is also connected to everyday life at the same time. The culture factor contributes to the representation of scientific concepts since students depict all the historical, social, cultural and scientific context while it is also linked to creativity, theatricality and art.

6 Conclusion

As we can realize, the Learning Science through Theatre Programme is able to promote a culture of scientific thinking by inspiring teachers and students and to empower an intensive interest to what happens not only inside but also outside the classroom in an entertaining way [8.]. Young people have to deal with societal problems but also create new ideas and promote research and innovation for affecting change and better life. Inquiry- based activities and the emphasis on the multiple cognitive ways of learning can help to this direction by making the school community an active agency of knowledge.

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