Multi- Semiotic systems in STEMS: Embodied Learning and Analogical Reasoning through a Grounded- Theory approach in theatrical performances

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Abstract: - In this paper we study Language, Embodied Learning and other semiotic systems as an integral means through which students express emotions, reasoning and scientific meanings when they realize scientific theatrical performances. Four characteristics of Embodied Learning examined, those of gestures, whole body movements, emotional involvement and facial expressions combined with two semiotic systems, verbal communication and Art, as well as Analogical Reasoning. Our research question focuses on how students represent scientific contexts and if there is any connection between different semiotic systems, so as students can hold cognitive fields of each notion. Analyzing students' representations both by quantitative and qualitative methods and grounded theory as well as they performed the scientific theatrical performances, we focused on their scientific representations expressed a) verbally, b) through Embodied Learning, c) through Art and d) through Analogical Reasoning in order to make sense of the scientific concepts embedded to the scenarios. This article presents the results from a large scale implementation activity in Greece within the framework of the "Learning Science through Theatre" (LSTT – http://lstt2.weebly.com/) initiated by Science View (http://www.scienceview.gr/) and National Kapodistrian University of Athens during the school year 2014-2015. The Initiative 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/). 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. We also identified that it is the simultaneous coexistence of all semiotic systems that enhances the meaning generation process.

Key-Words: - Meaning generation, scientific representation, semiotic systems, Embodied Learning, Art, scientific theatrical performance, Analogical Reasoning

1 Introduction

In this paper we study Language, Embodied Learning, Art and Analogical Reasoning as an integral means through which students express emotions, reasoning and meanings when they realize scientific theatrical performances. In this context, we approach different semiotic systems as a whole, in order to research if the harmonic coexistence of these semiotic systems can lead to higher learning results and an increase of students' cognitive load. These theatrical performances realized in a large scale implementation activity in Greece within the framework of the "Learning Science through Theatre" (LSTT - http://lstt2.weebly.com/), initiated by Science View (http://www.scienceview.gr/) and National Kapodistrian University of Athens during the school year 2014-2015. The Initiative 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/). 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).

Thirteen (13) theatrical performances during the school year 2014-2015 were organized by secondary school students (500 subjects) which embed both scientific concepts and cultural, social and comic elements which are expressed by embodied, verbal interaction and analogies.

In designing this initiative, we wanted to move away from the individualistic and rigorous scientific framework with formalisms and adopt a collaborative creative paradigm for science. We claim that the embrace of art and science will have the effect of strengthening the scientific meaning. We also believe that creativity can strongly influence not only students' motivation but also their learning skills in today's society. Moreover, in such contexts other messages such as cultural and social are carried except of scientific contexts.

Within science education, there have been attempts which focus on the consistencies of a semiotic system on others or on the connectivity different semiotic systems. For example, [1] Smyrnaiou and Weil-Barais (2005) 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. It is also recommended [2] that inquiry- based scientific context is a way of enhancing students' skills and promoting their construction of knowledge. Verbal representation of scientific issues means that each student can adequately analyze a topic and explain each notion of the topic both by using scientific terminology but also vocabulary in a simple and understandable way. The use of examples from everyday life, can also certify the acquisition of knowledge.

Several experiments have been organized and carried out on how children learn as they interact with tangible interfaces of learning environments for children [3], [4] in order to express mathematical and scientific meanings [5], [6]. There have also been interesting efforts to use gesture by students and kinesthetic interfaces [3], [7], and [8] and to connect Embodied Learning in educational practice to the realization of scientific scenarios through performing arts [9]. There have also been interesting procedures to inscribe body, motion and senses as representational means with which humans express thoughts and reasoning [10]. In this research the embodied interaction was mainly based on emotional involvement, the facial expressions and hand gestures showing persuasion. Their role was emphatic to strengthen the arguments. Natural effect, someone could say, thinking a politician who speaks to communicate arguments to the public.

In addition, we were interested in analogical reasoning appeared effortlessly in theatrical performances. We believe that the analogy is not simply a comparison [11] 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. We agree with the view that the power or success of analogy does not depend on the number of features that have common the base areas and the objective, but rather the coincidence of relational structures between the two sectors and the related information system that

transmits, which was once delivered by [12] Gentner (1983).
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 question that we addressed in our research study was how to employ such essential supporting structures (frameworks) in synergy in order to approach the creation and realization of scientific theatrical performances, by addressing all these representational means for human expression in a holistic way. We make the hypothesis that the interaction or cooperation of two or more frameworks produce a combined effect greater than the sum of their separate effects.
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 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.

2 Problem Formulation

2.1 Embodied Learning

However, it is worth mentioning that verbal communication by itself may sometimes not be strong enough to structure students' cognitive reflexes. Embodied Learning therefore uses knowledge semiotic systems too, since it connects reality to symbolic and mental representation. Though envirant operation, the brain maintains a steady way of understanding and interpreting notions and therefore a circular notion is followed. Each time the student acts in reality, he/she reforms it and this act leads him/her to continuous actions. Then envirant operation is created as the processes are imprinted on the brain and vice versa, and since the information has been imprinted on the brain the student acts differently. In order for the student to create cognitive shapes he/she needs to operate both on an actual and on a symbolic level and in fact in many symbolic ones. This representation-reality binary which originates from Piaget's cognitive shape and has been enriched and updated [13], further supports those learning theories according to which nowadays the student needs multiple symbolic systems to construct knowledge. This way already coded knowledge is enhanced and the subsystems of memory function more effectively because links are created through information and through these movements in order for the student to achieve knowledge. Contrary to this, if we isolate the cognitive load processed during these educational activities from other subsystems (visual, sensorimotor skills etc.) we are lead to negative learning outcomes because only one subsystem is reinforced while all others become weakened [14].
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. Using the body is substantial in concept representation and communication while this is also confirmed by the stress other fields and cognitive objects put in a particular position the body as a learning tool, such as dance theatre, kinesiology, athletics even Mathematics and Physics. All these cognitive objects have student collaboration, embodied interaction, communication and the process of cognitive development as a common denominator.
The body can be defined based on two aspects. There is the embodied or sensual way of being, but at the same time there is also the sociocultural or interactive way in which skills are developed. The notion of body in Embodied Learning, it includes the senses, the mind, and the brain, that is the whole of the student's personality. The body works or operates in a proper or particular way as a natural source of meaning generation, since it helps students to express themselves in a natural way. The body is stated or described exactly as the human corporal experience and the posterior psychological consequences, while others declare that the unconscious aspects of corporal experience compose the basis of cognitive activity and verbal expression [15]. We agree with the view of [16] Lindgren and Johnson-Glenberg (2013) about the primary characteristics of embodied learning:

a) sensorimotor activity
b) relevance of gestures to the theme that is to be reproduced
c) emotional involvement

Both the sensorimotor system and body movements are involved in the process of Embodied Learning and the perceived stimuli can be transformed into a more stable memory and cognitive representations [17]. As [18] Segal (2011) mentions 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.

The procedure that is followed during Embodied Learning is gradually escalating. During the first stage, the student may not proceed to a movement related to the representation of concepts. However, students understand that they are going to be exposed to scientific concepts and they are concerned about the way of representing them. During the second stage, movements are produced sometimes unconsciously or even as the result of imitation while during the third stage the students are asked to think of ways of representing the suggested content.

During the final stage which is also the most important one, students apply the newly acquired knowledge to new environments, through dramatization (image/interactive theatre) or role play, where they represent the scientific concept not only verbally or by using body movements, but also by participating both mentally and emotionally to the extent of embodying this new knowledge. It becomes evident that Embodied Learning is a procedure during which the student employs mental processes expressed through coordinated body movements which are linked to the represented content, through his/her emotional involvement and verbal communication skills.

It is worth stating that at each moment the student acts in a coordinated way and even though he/she is lead to random, unconscious movements, they are most of the times compatible with the content. This way the level of understanding and embodiment of new knowledge to the student's cognitive repertoire is verified. Everything that happens at each moment is of importance since the body is always active and becomes the sender and receiver of messages. The network of all momentary actions is thus gradually constructed which leads as a whole to Embodied Learning. Research results 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 regarding the way knowledge is approached may promote reflection and a reconsideration of that learning is to each person, of what the role of the instructor and of the student is in all subjects.

The principles of Embodied Learning have been examined in various studies and they have often been combined with other learning theories with the aim of reaching the greatest learning results for the student. According to [19] Yandel (2008), Embodied Learning is linked to situated learning, as we can understand how people learn and acquire skills in a situated environment where their participation may lead to a community of practice, while [20] Chu Hung (2015) highlights the fact that knowledge should not be viewed under the spectrum of a simple transmission of information between people regardless of its context but as a social procedure during which knowledge is constructed in a particular spatio-temporal framework where the physical presence of the student and his/her social interaction with the rest of the members is required. For this reason, the student is greatly influenced by the learning content, the activities and culture.

Moreover, it has been supported that Embodied Learning enhances declarative and procedural knowledge. Students first learn declarative knowledge (know-about), that is the terminology and the nature of all things. They then acquire procedural knowledge so as to fulfill a series of activities using logical thinking and their experiences in practical applications. This means that the student needs to accomplish a series of structured activities, procedures and methods to solve a problem, to fulfill a task etc. After acquiring procedural knowledge, students are able to accomplish various activities without memorizing them and are able to apply preexisting knowledge to other activities.

Educational activities created based on the principles of Embodied Learning, need to be holistically planned in order to address the student's body, mind and emotions and to meet the learning goals. Several studies [21], [22], [23] show the results of student interaction through body movements and student discussion and seem to agree that students understand and reproduce abstract concepts more successfully, through embodiment rather than repetition.

According to [24] Lea (2014) Embodied Learning is linked to the Action- Based Language Theory [25] which examines the ways language symbols acquire meaning when they are based on perception, action and emotion systems. Moreover, various studies [26], [27], [28], [29], [30] highlight the importance of movements, pictures and verbal communication in achieving the desirable learning outcome.

Thus, several studies have concluded that Embodied Learning combines cognition, socioemotional development, the students' sensorimotor skills, their cognitive and social skills [31], [32], [33], [34], [35]. Embodied cognition is based on the principle that cognitive processes are developed through direct, defined and very particular interactions between people and their environment [25], [36], [37], [38], [39]. This way, cognitive processes are linked to the sensorimotor ones. When visual and motivational processes in the brain are activated through cognitive activities such as reading or problem solving activities at the same time semantic codes are also activated during the execution of those activities.

Despite the fact that Embodied Learning has been supported by the results of many studies, there is little research on the field of Embodied Learning and the several forms of Art such as theatre, and the theatrical representation. 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: We agree with theories of embodied learning state that cognitive processes are based on perception and on mental and body action [39] and cognitive approaches that students handle abstract symbols, process information, embody elements from their experiences and from the real world and are able to represent scientific concepts by reinforcing their conscious movements with their emotional involvement. Studies have claimed that mental action and reflection is of vital importance in Embodied Learning [40]. Mental action means at the same time raising awareness of the topic, involvement movement and emotion in the representation of the scientific content. Through Embodied Learning and through theatre students develop their critical thinking [41] and learn ways of representing concepts and their own thoughts using their bodies, they create images and representations to solve problems and explore new ways or approaching knowledge.

b) student's sensorimotor involvement using their bodies or gestures: We support that two types of knowledge are needed in Embodied Learning and in performing a theatrical play. These are the biological primary knowledge and the biological secondary knowledge. The first one includes the knowledge and information that the student obtains during the course of his/her life without clear instructions, guidance or teaching. Biological primary knowledge includes random, unconscious movements that the student may perform during the learning process, like those performed in a theatrical play, since the student is driven by inner motives, having embodied concepts dressed with the appropriate emotional involvement. Biological secondary knowledge includes knowledge which is useful in the sociocultural environment, and this is the reason why the students learn them through guidance and conscious effort. The student needs instructions in this type of knowledge in order to be able to represent the scientific content of a notion, since representing it is a complex process. It is worth mentioning that in order for the representation of a scientific concept to be accurate and successful both kinds of movements need to coexist. The student's conscious movements mean that he/she has understood the scientific concept through cognitive processes and at the same time he/she is able to represent it using the appropriate emotion. At the same time the student needs to be able to perform random, unconscious movements which indicate the student's character and the degree of embodiment of knowledge.

c) emotional involvement: We claim that apart from the process during which the student learns to represent scientific concepts [42], this learning process needs to be accompanied by appropriate emotions on the part of the student. In theatrical performances, the student needs to experience, to feel the represented concept. For this reason, the embodied emotion plays a significant role in the theatrical performance. According to the embodied emotion the students gradually learn to recognize feelings, to experience them, to represent them and finally to describe them and categorize them.

d) social interaction and communication between the students: We believe that through theatre that students inside and outside of the classroom experience a social momentum as they form their ideological beliefs while being in communication with their students [43]). This way, they start cooperating and communicating with each other and being concerned about the final cooperative and team outcome.

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 emotions is of great importance since it may affect the degree of embodiment of new scientific concepts [40] and that the body does not only affect the way students learn and how they represent concepts in a play, but it also affects the way they perceive the topic, the action, the space, the concepts and the way they experience the later in order to render them in the best way possible. Students' past experiences are linked to their mental representations, are embodied and expressed through cognitive action, helping the students to better understand the scientific concepts and their feelings and the way the body can code and establish social norms as students find themselves in a verbal exchange.

f) brain-body-emotion coordination, holistic use of the student's personality: We agree with the perspective which is based on a holistic way of constructing knowledge and on contextualization [44] as all aforementioned parameters are required in order for the learning outcome to be achieved.

g) motivation: We argue that Students would not have been able to perform tasks related to body movements to represent a scientific concept in a given, known and situated environment had they not been motivated to participate in a theatrical representation.

2.1 Arts and Science: Combining two different subjects

Arts which allow creativity and representation such as theatre, provide fertile ground for the expansion of Science Education [45], [46], [47]. Knowledge of scientific concepts and the ability to represent them is possible through the combination of gestures, body movements, metaphors, expression of emotions so that the student acquires knowledge of the concept and semantic flexibility in representing it. [48] Cook et al. (2008) suggest that students who either consciously or not make specific gestures acquire new knowledge faster and better compared to those who are only limited to verbal instructions.

In fact, the combination of verbal expression, body movements and emotional involvement helps in the creation of cognitive shapes important for the representation of knowledge. In a study conducted by [49] Thomas & Lleras (2009) it was suggested that body movements or movements of parts of the body help students to represent scientific content, even if these movements are not performed at the moment of the learning process while it might be that the students may not have thought that the learning content could be associated to body movements. The subject area of science affects the writing of script, the integration of related scientific concepts in the form of conceptual field [13] 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.

The idea transcending the Scientific Theatrical Performances has been to put into practice these theoretical frameworks and principles, presented in the previous sections, 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. In the remaining sections of this paper we describe the rational and study that we carried out 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.

2.2 Analogical reasoning

Another key of a successful meaning generation in theatrical performances is the analogical reasoning. Analogies are parts of human thought. From them, we can acquire new knowledge or change that which already exists in our cognitive structure. In this sense, understanding the analogical reasoning process becomes an essential condition to understand how we learn [50]. 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 analogy is not simply a comparison between different areas: it is a special type of comparison which is determined by the order in which serving and on the type of information that connects. Analogy according to [12] Gentner (1989) "is the mapping of knowledge from one sector (the base) to another (the target), which indicates that a system of relations in which exists between objects of the database, is also among the target objects "(s.201). The aim of the analogy is the transfer of a relational structure of a known or familiar area to a less known [51]. It follows that the power or the success of an analogy does not depend on the number of features that have common areas of the base and the target, but far more than the coincidence of relational structures between the two sectors and the related information system it transmits [12].

In many cases in the literature the term "analogy" is used synonymously of the term "metaphor" while some authors distinguish between the two terms.

Specifically, it is found (Aubusson 2006) that there is a need of a coherent use of the terms metaphor and analogy. They conclude that through the use of the term metaphor all comparisons can be attributed in which there is some kind of recognized similarity between two concepts or things while when the comparison is extended to a wider range of similarities and differences, then the term analogy is used. As a result, all the analogies are metaphors but all metaphors cannot be considered analogies.

A very common distinction between the two terms is that in the metaphor A is B (eg, the immune response is war) while using analogy we mean that A is like B (eg the person is like the solar system). Another distinction is that the comparisons made in the analogy is expressed with a very detailed manner, indicating that at least four terms have to be existed (two in each of the base areas and target) and the relationships between them, as well. In this difference also mainly supported the view that the analogies are more useful to science by metaphors [12]. Accordingly, the example of "the person is like a solar system" may be considered as an analogy if we consider that it implies the relation pairs (sun-core) and (planets- electrons). In other words a more clear formulation of the analogy would be: "The person is like the solar system: the individual core is in the center as the sun is in the center of the solar system and the electrons move around in orbits around it like planets around the sun.

Analogies have played an important role in scientific discoveries and many support that they are central to creative thinking. They are not only the pillar of creative thinking mechanism but also the base, of problem- solving.

The inference using analogical comparisons is flexible and robust and thus plays an important role in creativity both in science and in other fields. [52] Dunbar and Blanchette (2001) found that the analogies are used extensively by scientists as they worked on a daily basis to draw conclusions, playing an important role in the justification and making assumptions. These analogies compare the base with the objective problem and reveal some invisible similarities between them. A creative analogy uses a new base to bring new and creative possibilities to light (D.P. O'Donoghue).

3 Problem Solution

3.1 Participants, Sampling

The program "Learning Science through theatre" (LSST- http://lstt2.weebly.com/) attended thirteen (13) secondary schools from Attica. The thirteenth theatrical students (500 subjects) Secondary school (high school) dramatize scientific concepts and knowledge from the subjects taught, through a non-binding scenario titled "Parallel Worlds, which consists of five modules / instruments and concerns the disciplines of biology, astronomy and physics. Schools were asked to choose at least one section which dealt.

At least one teacher per school was responsible for coordinating the work. 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 program is based on the pedagogical framework developed by the European CREAT-IT program (www.creatit-project.eu), and to the authorities of the exploratory methods of science learning (Inquiry Based Science Education).

3.2 Method

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 the report. 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 methodology employed to analyze scientific data gathered from the theatrical performances constitutes a merging of qualitative and quantitative analysis [53]. 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 programme. 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/ 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, they are further divided into subcategories for clarification reasons and are driven by the same data [54].

The data were categorized and these categories were analytic, as they apart from different elements. They were, also, valid, as they are totally combined to the theoretical framework. Their properties emerge from the data analysis [54].

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:

I. whole body movements
II. isolated gestures
III. facial expressions and
IV. emotional involvement

These subcategories were based in 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.

Multiple representational systems include:

i. verbal communication
ii. non- verbal communication (Emdodied Learning)/ kinesthetic representation
iii. digital representation
iv. Art

Each of these categories describe what is examined in each area and where the research focus lies. The relations between these different levels are distinct.

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 [55], which map the relations between a familiar field (base) to an unknown one (target). The FAR model [56], [57] is used to represent the categories of Analogical Reasoning. The steps that this model follows are the following [56]:

F (Focus): Focus on the concept which is being taught and on the analogy used. Is the concept difficult to comprehend, unfamiliar to students or is it an abstract one? What do students already know about the concept? Are they familiar with the analogy used?

A (Action): Explanation of the similarities which connect the base to the target and discussion of the analogy

R (Reflection): Assessment of students to determine whether they understood the analogy; making all necessary corrections

These 3 stages (Focus, Action, Reflection) could be labeled as

i. Familiarization with the base
ii. Finding common characteristics between the base and the target concept
iii. Underlining the parts where the analogy collapses

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

It is worth noticing that students discussed similar Science concepts in all 5 theatrical plays while the gravitational waves and the gravitational field were central concepts. For this reason it is useful to comparatively study these concepts using the cross analysis method and to examine:

a) how the concept was represented by the majority of students in all 5 plays
b) how many different ways of representation were used
c) which representational systems lead to the most efficient and faithful representation of the scientific concept. However, the rest of the scientific concepts are studied too, since they contribute to the central research question.

3.3 Results

Students employed scientific concepts in all of the theatrical 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. For example, the students tried to explain Fred Hoyle's scientific theory for the explosion of the universe or creation of bosons in the Higgs field.

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. For example, students who impersonated important scientists of the Faculty of Sciences tried to illustrate their theories. The student - Aristarchus explained why the sun is considered the center of the universe and the student- John Dalton used a cylinder and rotated it with a long drive. That movement demonstrates how chemical reactions work and what are their results. Characteristic example is also that of a student who plays Hubble and declares that the galaxies are moving with speeds that are proportional to their distances from us.

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. For example, a student who embodies the grandmother wonder about the existence of the boson and cannot understand the name. The students were trying to explain the Higgs theory, but the grandmother confuses with "bazonio" (Greek idiom for the word "stupid").

In most cases, they used simple everyday objects, which verifies that they gained, built and appropriated the knowledge. This means that they managed to successfully connect newly gained knowledge with everyday life and to use it in an everyday environment. Students either used special pairs of glasses to indicate the brightness of the sun, or used fans to visualize the rise and fall of temperature or the creation of the universe and the big bang are experienced by opening-closing umbrellas and the expansion / contraction of the universe is expressed through the use of balloons. A student (played Fred Hoyle) broke the balloon with a needle so as to represent the explosion of the universe and a student who played Democritus, broke the chalk it was crumbled into small pieces. Then, the student- the God particle poured lemon on chalk to highlight the creation of bubbles. Some students represented the movements of the planets. The planets are swirled and students represented all the movements of the planets and the Earth around itself and the sun with their hands in a circular motion

Consequently, it becomes obvious that the verbal representation of scientific concepts constitutes a cornerstone in the process of gaining knowledge since it illustrates how students perceive scientific concepts. However, it is not this verbal representation per se that confirms the building and gaining of new knowledge. Being able to explain scientific notions does not necessarily lead to notion understanding. Therefore, what is required is the use of a semantic field and the use of more than one representational system in order for the student to comprehend the scientific content of these notions.

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. This way, students establish better connections between cognitive structures, employing at the same time multiple systems of symbols. This conceptual field takes into consideration all parameters, conditions, concepts and situations which surround and determine knowledge since the entity itself apart from its conceptual field, may acquire different meanings and demonstrates different representations. Therefore, the way several concepts relate to each other in the student's mind with the use of several noting systems becomes apparent.

For this reason, students are asked to approach concepts, properties of concepts or phenomena with the use of Embodied Learning. The majority of students mostly used their whole body, as theatrical plays require that students be physically present and use their bodies to represent concepts. It is then understood that the verbal representation of scientific meanings is a cornerstone of the construction of knowledge, as reflected how students are perceived by the scientific content. However, these verbal representation of concepts does not support itself and conquering and building knowledge. The explanation of scientific concepts are not necessarily always leads to the understanding of the concept. It is, namely, the existence of more than one representational system to conquer the student the scientific content of the concepts. For example, the students attributed with all their body the whole move of a shooting star, the opening of a shooting star, which initially moves with speed detectable and then falls and disappears. The student-Mars illustrated and reflected Mar's god militancy by gymnastic exercises through the body, while Hermes- student, moved around himself, to perform fast rotation (a characteristic of Hermes).

Student's emotional involvement plays a significant role in the use of Embodied Learning. Apart from the process of learning to represent scientific concepts [42], this cognitive process needs to be accompanied by certain emotions from the part of the student. In theatrical plays, the student needs to experience, to feel the represented concept. Therefore, embodied emotion is central to theatrical representation and according to this, students gradually and in an escalating manner learn to recognize emotions, to experience them, to represent them, to describe them and finally to understand their qualities and categorize them. In addition to the process in which the student learns to represent scientific concepts [42], this cognitive process must be accompanied by appropriate feelings of the student. In the theatrical representations of the student must be experienced, to feel the meaning represented. For this, the central point in the theatrical representation is considered the embodied emotion, according to which the students gradually escalating and learn to recognize the feelings, to experience, to depict, to describe and ultimately characterize and categorize. For the analysis of data in focus to the feelings of students and their subsequent performance chosen to focus on expressions through cessations of videotaped plays and then the intersection of expressions of their faces in conjunction with the voice. Despite the fact that the emotional fluctuations of the students are not easily captured, however, there are cases in the sample, where the students' feelings emerge. During the fall of a shooting star, who has lost its brightness and brilliance, a student was spoking with stronger voice, was using her body and she started falling in the scene so as to represent the fall of the star and the loss of her glory. In another example, students who represented prokaryotic and eukaryotic cells laughed, as one of them discovered that he had a cell wall and they started to dance and have fun.

Fig. 1

Sometimes students only used isolated gestures. In this case it was observed that a single representational system (only nonverbal communication, or 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, for example both verbal description and nonverbal communication. This connection of two or more representational systems leads to the creation of deeper meanings. While the Pluto-student could easily perform the position of the planet with individual moves (as the student arrived last, just to emphasize that it is the last planet in our solar system), it is not the same in the case of quarks, where scientific concept and terminology is difficult. At this time the student was using an orange to indicate the size of the universe and explains the usefulness of quarks, but also the students danced so to fully clarify the movements of the structural Earth stones, quarks. We realize then, that the coexistence and interaction of two representational systems, both verbally and nonverbally, fully convey the meaning and content and lead to the conquest of knowledge.

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- language (verbal communication), which is used to present, analyze and explain a scientific approach, Art (dancing, music, and painting) and Embodied Learning- which offer 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.

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. The scientific concept / domain object is mapped, identified common elements with the most simplistic sense / base section after the necessary mappings, joined the relevant parts of each sector. The assignments made are structural, to successfully model the scientific knowledge and not only simple comparisons, metaphors or similes. For example, the opening and the sudden closing of the umbrella reflects the expansion and contraction of the universe, and suggests similarities between the two sectors as for the structure and the way of functioning. Additionally, the rotary motion of Mercury around himself was reflected in the same way by the students through a rotary motion around their bodies, while the movement of electrons, protons, and neutrons was represented by the students, as they were sitting next to each other and a student revolved around them.

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.

Summarizing, the data analysis shows that the representation of scientific concepts is accomplished in multiple ways. 11/22 concepts (50%) were represented by students only with verbal description, explaining and analyzing every sense, while 4 / 22 concepts (percentage 18.18%) was represented by students with different forms of art (painting, music representation). It also mentioned that 21/22 (95%) concepts were represented by the students using Embodied Learning and therefore Embodied Learning can contribute to the scientific generation of meaning and the acquisition of knowledge, passing from the traditional knowledge conquest model to more constructivist standards. The use of analogies in percentage 45.45% (10/22 concepts) or even the use of metaphors in an amount 13.63% (3/22 concepts) confirms our hypothesis, according to which the generation of a scientific meaning directly links to the development of analogical reasoning and enhance students' creativity. As a result, the combination between Art and Science can lead to higher learning outcomes. The acquisition of senior learning processes from the students is best achieved by using two (7/22 concepts (or percentage 31.81%) used two representational systems simultaneously) or more representational systems (3/22 to concepts (or 13, 63%) were observed three representational systems), as one feeds the other.

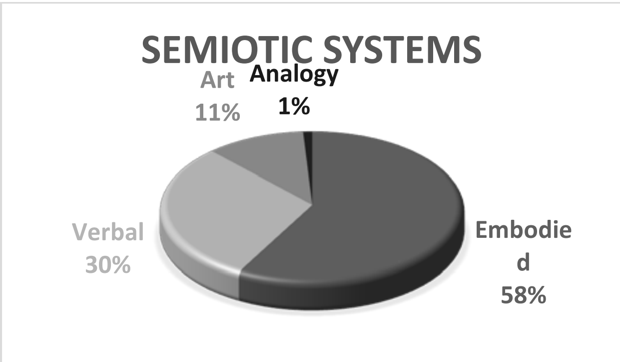

Table 1

4 Conclusion

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.

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