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# A Fifteen-Year R&D Project in the Transdisciplinary Context of "Theatre & Science in Education"

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**Abstract:** The article seeks to present a brief theoretical foundation, a description of the methodology and an overview of the results of a fifteen-year long educational project, which started in 2004 and continues to the present in the Department of Early Childhood Education (DECE) National & Kapodistrian University of Athens (NKUA). The project comprises a series of consecutive and interconnected experimental teaching interventions, in which early childhood student teachers attempt to cross the boundaries between two different cultural traditions and present theoretical scientific ideas using the techniques of Puppet Theatre and/or Installations.

The results of over twenty successive interventions illustrate, among others, that the comprehension and occasional management of scientific and epistemological ideas can be achieved by non-experts through transformations that act as bridges between the sciences and the humanities. The learners' aesthetic values, skills and capacity of artistic expression improved dramatically. The techniques of installations boosted the descriptive level of the demonstration experiments, while the joint presence of teachers with different specialisations and the constant renewal of the topics put to the students contributed to the project's success.

**Key words:** science education, art education, transdisciplinary teaching-learning approaches, early childhood teachers education.

## 1. Introduction

As we enter the third decade of the 21st century, the worldwide upheavals in the field of general education caused by the end of the cold war era (Tselfes & Paroussi 2015, pp. 10–13; Papasotiriou & Tselfes, 2009) tend to be reflected in educational proposals that are increasingly in line with our postmodern era (Hardy, 2006). Disciplines of all kinds started presenting the construction of their theory through short narratives (Bruner, 1996; Fuchs, 2015; Davies et al., 2019) and, thus, began to introduce figures and practices of the Arts into the scientifically rational "fortresses" that educational institutions had been building till at least 1990 (Elfand, 1990). These institutions now agree to observe the evolution of this invasion with a critical eye, legitimising its actions as being inter/trans-disciplinary. Furthermore, they accept the nonconformist interventions of, thanks to the Internet, widespread alternative principles and values of other cultures, balancing them with social, aesthetic and political criteria. Thus, they end up retrospectively seeking the meaning of the discourse produced by the deconstruction of sections of the major theoretical scientific narratives, by the adoption of multiple representations (transformations)

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of the theoretical schemas and the influences of the aesthetics that run through the modern constructions of the Arts and Sciences (Tselfes & Paroussi, 2015, pp. 47–68).

This trend continued and was reinforced by the educational policies that emerged post-2009 as cures to the economic crisis and thus allowed a project bringing together Theatre and Science, such as the one presented below, to seem not only normal in the field of education but also innovative. All the more so, in fact, given that the academic freedom that Greek universities still provide generously offered a realistic framework to develop it in.

The reason behind this project was, of course, personal: it is based on the interest of a puppet theatre director in the role played in theatrical expression by light and shadow through shadow theatre and in a physicist's persistence regarding the attraction of the scientific content of optics. Thus, the launch of an interdisciplinary course titled "Theatrical applications and the teaching of physics"[1] was decided without the two collaborators, as it later turned out, understanding each other from the beginning. The only thing they possibly believed, because of their appreciation of each other's work, was that the two of them together probably knew everything that there was to know about light and its shadows. Something that, *ex post* again, proved to be inaccurate (Paroussi & Tselfes, 2006, 2007).

The dynamics of this collaboration can be understood based on the assumption that, like most human-social and personal practices, its actions were constrained by three categories of factors: *material*, *normative* and *human* (Pickering, 1995). Admittedly, the material and normative factors did not significantly limit the action. The material aspects were adequately covered by the small funding of the NKUA's Special Account for Research Grants (SARG) and the infrastructure of the Department of Early Childhood Education, while, in the context of academic freedom, the normative factors (the *musts* and *must nots*) corresponded to the interests of the teachers/researchers: the corpus of schemas being taught and the methods of research. Only the human factors set a severe constraint. As it turned out, two people with totally different cultures would have to coexist for a long time, would disagree radically on substantive issues (most often publicly) but, ultimately, would weather the storm as work partners. And if this venture turned out at least to be a teaching success, this seems to be due to conforming to the human factors' pressures which, in practice, led to accepting the process of *trial and error* as legitimate, both in teaching and in learning; for both the learners and the teachers.

## 2. An Initial Teaching Methodology

When we started out, we had two teaching methodologies at our disposal. Broadly speaking, one comprised the basic characteristics adopted by the Arts and the other those adopted by the Sciences. Thinking along the lines of the two-pronged representation-intervention (Hacking, 1995) in parallel to that of educational production-reproduction (Sewell, 1992), we could say that, during the teaching of the Arts, the learners evolve in response to goals relating to the *production* of representational artefacts under the evaluative pressure of aesthetic values and, during this effort, are obliged to *intervene* on their material by *reproducing* artistic practices. Similarly, during the teaching of the Natural Sciences, the learners attempt to meet goals relating to the *reproduction* of conceptual scientific schemas under the evaluative pressure of *reason* and, during this effort, are obliged to *intervene* mainly in texts, also *reproducing* scientific practices.

Given that students become more easily involved and end up being more effective in processes of *intervention* and *production* through trial and error rather than by *conforming* to rigid instructions and in the

[1] https://opencourses.uoa.gr/courses/ECD6/.

*production* processes of material artefacts rather than the *reproduction* processes of conceptual schemas, the initial choice of teaching methodology leaned in favour of the Arts.

Our choice was validated *a posteriori* by strong theoretical support (see for example Dragonas et al., 2015), when texts supporting this very same teaching proposal as being suitable for promoting creativity, innovation and inclusion in education emerged in the literature.

## 3. A Theory About Learning

Specifically, and based on the widespread acceptance of content transformation by pedagogical and contextual factors, as well as the fact that *learning* is an interaction between subject and object but is also ascertained by the subject's local actions and productions, we finally opined that: learning is ascertained and therefore can be examined as the subject's ability to transform a content with a view to producing successfully in a variety of contexts.

This formulation may seem a bit convoluted, but we have worded it in this way because we would like it to be as general as possible. Because we can no longer bear to think that, as a human or social function, learning can signify something different in theatre compared to science. But this is certainly not a novel finding. For instance, in the current educational reality of Science Education we say that a student has mastered a scientific schema if, through their local action and production, we are convinced that they transformed some pre-existing idea of theirs (in all likelihood functional in an empirical, everyday context) in a direction that is effective in the context of school science. In other words, learning is associated with the transformation of conceptual schemas and practices or of the content and methodology, because it is a transformation that is carried out by the learner in order to produce something, a statement that certainly applies to the field of the Arts.

Yet at the same time, a transformation is operated before that by the teacher, in their effort to persuade the learner to reproduce it. This, in our opinion, is a crucial point, which we will return to when we attempt to answer a final question related to whether what we have done is useful. For we will probably not disagree about whether learning is the transformation that the learner or the teacher effect. But the transformation carried out by the teacher beforehand is clearly different to the transformation carried out *in vivo* by the learner. The former goes from artistic or scientific knowledge to school knowledge thanks to pedagogical tools, while the latter moves from empirical to school knowledge using largely undefined and rather personal means. And the question is one of education policy: which of the two transformations should contribute to the creation of educational content?

## 4. A Final Teaching Proposal

Based on the above, we decided that the central theoretical hypothesis of the project's organisation would be based on the pragmatist view of J. Dewey (Dewey, 1913; Stoller, 2018; Garrison, 1995, 2007), according to which we expected that, where our case was concerned, the knowledge, skills and competencies would emerge as transformations of the embodied experience (Whitehead, 1929) of agents who attempt to project the content of a scientific subject by following artistic disciplines, i.e., using and transforming practices, of an artistic subject (theatre, puppet theatre or installation).

The project's steps were articulated around assessed, consecutive, semester-long (78 teaching hours) teaching activities, each of which requested that the groups of students attending them produce a theatrically, semantically and aesthetically complete study presenting a scientific or an epistemological idea from the field of Physics. The

results of the assessment of each teaching intervention modified the structure and content of the following one.

Therefore, expecting that the learning would be realised by the learner through their effort to achieve a goal, we always began the course after agreeing with the students, who worked in groups, on a clear end goal, which we did not allow them to ever forget: the production of a theatrical or artistic study that promotes a scientific idea.

In order to achieve this goal, we followed the steps dictated by the theatrical/artistic discipline:

1st step: the in-depth study of the idea in scientific, school or other sources and the public presentation and discussion of the study's outcomes,

2nd step: the construction of a script that transforms and promotes the idea,

3rd step: the construction of a *visible* script, a story board as it is called in the performative arts,

4th step: an initial selection of appropriate techniques,

5th step: the realisation of trials and corrections,

6th step: public rehearsals and appraisal,

7th step: public presentation to an audience,

8th step: the final evaluation meeting of the productions.

This schematic process, in the end, is dominated by *trial and error*, which on the whole does not allow the steps to evolve as sequenced above. An impressive technique can change the script and transform the idea in a different direction. A failure during the trials can modify the technique, delete scenes from the story board, and so on. This fact is the *strong card* of this particular teaching approach, because the failures, the repetitions and the modifications improve the act of learning more theatrical expression practices and more characteristics of the scientific idea. Its difficult part mainly concerns teachers, who are constantly faced with new and unexpected ideas, differentiated individual preferences on behalf of the learners and different learning practices that gradually and in varied ways develop within the groups.

## 5. Methodologies for Recording and Analysing the Learning Outcomes

### 5.1 From the Final Productions

In a teaching-learning process such as the one above, what the teacher can identify, from the perspective of science, are the scientific and epistemological schemas that the students produce by transforming the corresponding schemas they have drawn from sources, which can be empirical, school-related, scientific, but also historical, epistemological or philosophical. These new schemas, as well as the manners of their transformation, constitute the learning outcomes of our case study. They can be assessed according to the facts of each group's final theatre study or installation, but cannot be safely individualised nor can they be identified in their entirety. There is usually evidence that the students have learnt something (or far) more than what appears in the final performance. This *extra something* is lost in the end inventory, as it is produced in the places and times where each group works without supervision, trying out, adding, removing. But obviously, the course's logic does not allow these productive working hours to be destroyed through supervision, that is to say to be ruined by the assessing gazes of the teachers, which in all probability would force the learners to shift their interest from achieving their productive goal to satisfying the occasional goals of gaining the teachers' approval.

The data of a final theatrical study can be analysed in three different ways (Paroussi & Tselfes, 2008): a) Dramaturgically: which elements of the narrative structure involve scientific schemas and how are they formalised? Do we encounter them in the hero, in the good, in the antagonist or in the solution? b) Semiotically (Peirce, 1964):

how do the scientific schemas and their transformations function in the performative signs' global referent? For the great problem of introducing the declarative scientific discourse into the narrative-performative one resides in the if and how one will construct a global referent framework of signs, which the spectator will perceive in the way intended by the creator; and, c) Aesthetically (Tillis, 1992): what is the role of the motion-design-sound relationship in the composition of the schemas in the signs? In other words, how do the scientific schemas enter the signs most easily: through the movement, the image or the sound? And how are they transformed? Does their presence or their transformation destroy the aesthetics of the whole, which exists only through the harmonious coexistence of the three elements (motion-image-sound)?

An example: A study was titled "The Earth revolves and it is round". It was performed using the Shadow Theatre technique on three screens that were illuminated consecutively. On the right-hand screen, the first to be lit up, there appears a coloured figure of a circular Earth with a large mountain dominating on her. The figure of the Earth revolves slowly, at the same time as the figure of a person climbs the mountain. Due to the movement, in a short while the person appears to be walking on the flat and then to be descending while in fact moving towards the mountain's peak (as narrated by Salviati in Galileo's *Dialogue Concerning the Two Chief World Systems*); then, as the volume of the music playing in the background increases, the person falls from the Earth into nothingness and a heartrending scream accompanies this spectacular fall, which fills up the entire screen. After this, the screen on the left lights up, where a ship travels on a round and immobile Earth with the person who fell off the previous Earth as its passenger. As the ship moves from the upper part of the circular Earth towards its side, the fall is repeated, with the music and the scream, which are repeated, signifying the same impasse as before. The finale is presented on the central screen where, using a projection system with a concave mirror, a spherical Earth now appears revolving slowly, while the music is that of a typical "gloria" of classical music.

This study, without any trace of oral speech, dramaturgically unfolds a narrative where the hero (an everyday person) experiences, in the form of an imaginary adventure, the contradictions created by scientific schemas about the Earth's shape and movement (as transformed by everyday culture) and the corresponding empirical ones. Obviously, the transformed schemas that the creators-learners use with ease constitute the *antagonist*, composed by the contradiction between the naive scientific schemas of "the Earth revolves and it is round" and the experiences of a flat Earth.

Is there a solution? Yes, and it is rather ironic and ambiguous. The final glorification of the spherical Earth, along with the hero's suffering because of it, seem to point to an impasse in the Aristotelian principle of *identity*. An impasse in the principle that something either *is* or *is not* and that any third possibility is ruled out. An ironic evasion that seems to prevail in the ontology of the learners, who tend to deny rather than resolve the dilemmas posed to them by constructivist-type conflicts. An ironic evasion that reminded the teacher of Physical Sciences that, in official scientific activities, too, the Earth both moves and does not move (relativity of motion) and is flat and spherical and neither of the two, since it is determined each time by the issue/relationship that we have before us.

The development of the signs is complete, although some scientific schemas are sacrificed in its name. For instance, in order to organise the sign *and the revolving and the spherical Earth* they rid themselves of the person, in the second act, but the moving ship does not share the fate of its passenger. The aesthetics is also adequate, possibly with some difficulties in the coordination of the movement.

**5.2 From Case Studies of the Productions' Evolution**

Here, the data are collected at the end of each discernible, as far as possible, step of the groups' action (successive trials) and the analysis is carried out on the basis of the previous process, but whose facts we attempt to interpret each time based on Pickering's model of practices (1995). According to this model, and as already mentioned, the choices of introducing scientific schemas, as well as of their transformation, in the groups' successive creation phases are influenced by the context's local material, normative or human agencies. Agencies which, ultimately, also shape the learning trajectory within the artistic context, if not also the particular profile of the group.

An example: During the creation of a theatrical study with a theme drawn, once again, from texts in Galileo's *Dialogue*, the group of students began with a shadow theatre improvisation, in which a figure of Galileo, using an archaic-style form of speech, gave a glowing self-presentation of the scientist. A study that was obviously pressured by the educational and social stereotypes that are activated upon hearing the name "Galileo". After studying aspects of the era when Galileo wrote the *Dialogue*, as well as elements of his biography, the group presented a study with shadows of human bodies, in which he recounted his trial in a dramatic style. Here again, the group appeared to plunge into the conflicts between the Church and Astronomy as presented in History, focusing on the conflict's most dramatic moment. Following the study of texts from the *Dialogue* the group seemed surprised by the multitude of disagreements observed between empirical phenomena and scientific theory and decided to present, for its final study, what in essence was its personal cognitive upset. In three consecutive scenes and using mixed techniques (from shadow theatre to black theatre), it presented God creating the world with His commands, science changing this image and, finally, the form of the Universe as represented by scientific theory. A determining role was played in this creation by the tenaciousness of the group's members to use the impressive techniques of black theatre. Thus, we can say that the learning process was basically cognitive, i.e., it was guided by the normative factors imposed by the teachers, but at its critical endpoint it was influenced by the human factor of producing a spectacular finale. This allowed the students in the group to embrace and transform additional scientific schemas of contemporary astronomy and therefore present a universe where Earth is nowhere to be seen.

### 5.3 From Studies of the Performative Characteristics Behind Established Science Education Teaching Practices

Here, the most interesting course concerned demonstration experiments whose theatrical representation using Object Theatre led to the production of studies where the global referent of the natural world ultimately seemed to be traversed by human passions. An alchemy-style approach and scientific schemas with imprecise characteristics, since at this level the empirical world is more complex than its description in school science, and not only there. The analysis of the studies, in this case, was mainly semiotic and sought to reveal the place and transformations of the scientific schemas, given the attempt to integrate them into a global referent intelligible to a non-scientific spectator.

Overall, the studies that were carried out and subsequently analysed showed that the scientific content of the effects of an experiment is only revealed in the context of a global referent that is based on scientific theory. From the teaching point of view, this would point to the fact that we should not expect demonstration experiments to be, of themselves, able to teach theory, as knowledge of the theory constitutes a prerequisite for constructing and understanding the experiments. Thus, from the perspective of our project's interdisciplinary approach, we consider as successful those studies that, within an anthropomorphic referent, managed to create a puzzlement regarding

the phenomena, which could potentially also function outside the theatrical performance itself and trigger learning events relating to the Natural Sciences.

An example: In a black theatre (object theatre) study, a pointy skewer chases a balloon. When it catches up to it, it hits the balloon and bursts it, the background music successfully signifying the process of anxiety and the catastrophic ending. The scene is repeated and, during the third iteration, as the skewer prepares to strike, the balloon turns its back part (where the latex still remains thick) towards the skewer. The balloon does not burst when the skewer pierces it in this position. Instead, the skewer gets trapped. In the final scene, a multitude of blown-up balloons with trapped skewers dance triumphantly on the stage. As expected, after the applause at the end, the question on the lips of all the spectators was to know how it was possible for the balloon not to burst.

A second example (Giannoulatou et al., 2019): In the context of an art installation, it was confirmed that a scientific demonstration experiment can work in the way that science suggests. This particular installation took the form of an art event comprised of a series of artefacts (smaller installations) that presented ideas about light (indiscriminately taken from tradition, philosophy, science, or even religion). In this context, we expected that the students, but also the visitors, would be able to approach the scientific ideas as alternatives to other ideas displayed in the same space, without the awe that accompanies school science. Here, two groups of students organised a part of the installation under the title: what is light when all is said and done? A shower of particles or a wave? In this part of the installation, Newton's ideas were projected first: light as a set of rectilinear moving particles, from which visitors could protect themselves with an umbrella (use of a video and shadows) and also take a souvenir snapshot. Next to this, Huygens's ideas were projected: light is a wave and is therefore deflected at the edges of the obstacles it encounters, it traverses where we believe there is shadow and no umbrella can fully protect from it (posters and a video). Visitors were called to attempt solving this controversy when they entered a darkened space and performed Fresnel's critical experiment: they created the shadow of an opaque circular disk (a suitably shaped CD) and were requested to observe and explain a speck of light that persistently appeared in the centre of the round shadow. Even in the cases of visitors who had not grasped Huygens's ideas, the critical experiment served to highlight doubt as a scientific virtue. Those visitors who accepted to be interviewed after exiting the installation at least doubted the particle theory, while simultaneously accepting that it was in line with their personal experiences.

## 6. Some Successes — Some Failures

The most important finding, possibly, is that the students find it difficult to be part of, but eventually integrate, the trial-and-error teaching context when this is also applied to scientific topics (Paroussi & Tselfes, 2018). This means that only after great effort done they manage to accept that they are allowed to test/transform scientific ideas in order to perform their artistic work instead of presenting them in the *correct* way to their teacher. And of course, when they achieve this, they resent remarks such as "Galileo says no such thing...".

As for the learning outcomes, the students were able to:

a) achieve an understanding and local artistic management of scientific, as well as epistemological, ideas in a narrative theatrical context, transforming the ideas' content in directions that are also clearly functional for the more general goal of scientific literacy (Tselfes & Paroussi, 2009);

b) dramatically improve their aesthetic values, as well as their theatrical expression skills and abilities, as the objective of representing scientific ideas prompts looking for novel narrative structures and sparks creativity

(Paroussi & Tselfes, 2019);

c) enhance the communication level of the scientific demonstration experiments, not only theatrically but also using artistic installation techniques (Giannoulatou et al., 2019); and,

d) create bridges between the Natural Sciences and the Humanities as, on the whole, theatrical representation moves according to referents concerning issues examined by the latter (see also Tselfes & Paroussi, 2019).

These successes can also be attributed to the fact that the student groups worked towards achieving their goals in a space that is professionally-equipped for the production of theatrical studies, featuring light systems, multiple stages, decent sound systems and machining tools. This space created the atmosphere and conditions of a genuine apprenticeship in theatre/puppet theatre. It was a real production space, which also improved the study of the scientific topics that were part of it. This, in our opinion, is something that is lacking in educational scientific laboratories, which at a first glance appear as being places where one can reproduce important ideas and facts, but which are in fact produced elsewhere and by other people.

## 7. Discussion

A first question worth asking is whether we are still interested in inter/trans-disciplinary educational approaches. These approaches came into being in the literacy era (see, for instance, the OECD's PISA programme, http://www.oecd.org/pisa/) and were linked to educational goals concerning the acquisition of skills and competencies, which are far removed from understanding the content to successfully participate in all types of quantitative examinations/evaluations (Paroussi & Tselfes, 2018). Today, in a time of crisis, we are traversing a period of educational goals targeted at developing skills (and not competencies) in innovation (and not creativity), work and entrepreneurship. These limit educational interdisciplinarity to related sciences (such as Science, Technology, Engineering and Mathematics, or STEM). Have we then ceased being interested in the unity of knowledge and practice? In teaching methods that include aesthetics? In the creative handling of scientific ideas? In attenuating, or doing away with, the ring-fencing of academic cognitive objects?

The economic and pandemic crisis restricts the possibilities of increasing the funds available for education, at least in Greece. Are we interested in courses that cannot be held without the participation of at least two teachers? Because inter/trans-disciplinary approaches cannot be implemented otherwise. A heavy academic tradition has ensured that each subject has its own disciplines. And it is extremely naive to believe that one can teach them without at least having experienced them correctly.

Are we interested in courses whose objectives are ill defined in terms of content? Classes whose teaching will produce local Pedagogical Content Knowledge (PCK), which cannot aspire to generalisation? For if the PCK is produced by the transformations that the learners achieve when trying to attain various goals and not by those that the teachers presume when trying to assess what the learners can produce (Park & Oliver, 2008), then the PCK is probably neither finite, nor can it be generalised, nor yet be evaluated quantitatively. Therefore, are we interested in courses where the assessment of students/learners is directly linked to (and partly determined by) the assessment of the courses themselves? In other words, by the local/ad hoc assessment of the production of both teachers and learners, but also the dynamics of their relationships?

Our answers to these questions are most emphatically affirmative. The fact that these affirmative answers do not lead to viable applications within the current education system is of little importance. For the idea that will shape the inevitably new educational system, adopted by the new social structures that emerge at the end of the

crisis, may not yet have seen the light. But there is probably also no one, educator, student, parent or ruler, who can claim that the current educational system is viable.

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