THE ROLE OF REAL AND VIRTUAL EXPERIMENTS IN SCIENCE LEARNING

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ABSTRACT
Learning science requires understanding of concepts and formal relationships, a process that has often proved difficult for students. Numerous experiments for use in physics instruction are provided using different pedagogical tools. The paradigm described here adopts a socio-constructivist approach, where the student takes an active role in the construction of his knowledge, and it exploits three different media: a video in order to motivate students' interest; objects from everyday life for the experiments; the technology-based learning environment "ModellingSpace", which emphasize qualitative understanding, semi-quantitative understanding, requiring written explanations and cooperative learning. Results shows that the use of three media is essential in order to advance the reasoning of students in greater depth and pass to formal thought. The realisation of experiments in computer is not contrary to reality, but can supplement it.

KEYWORDS
Experimentation, learning, physical sciences, modelling, video, technology-based learning environment.

INTRODUCTION

Learning science requires understanding of concepts and formal relationships, a process that has proved to be a difficult task for students. Numerous experiments for use in physics instruction are provided by books, Internet sites using different pedagogical tools as video, technology-based learning environments and real objects. How can a professor decide what experiments to use? How can a professor decide what pedagogical tools to use: real or virtual? How can she/he move away from traditional "book" experiments in labs and from lecture demonstrations that have been reported to achieve little? What do the students learn? In which conditions do the students learn better? It is a pedagogic delusion to think that the work of students in groups automatically involved their collaboration.. The interaction between students depends from many agents such as their personality. Many times, their oppositions lead them to conflicts that prevent the problem's solution or a student with an error representation accomplishes to convince the other. The teacher's role could be described as changing from that of 'sage on the stage' to 'guide on the side'. The teacher's role as tutor is very important (Dumas-Carré & Weil-Barais, 1998). Teachers are already beginning to develop and trial new strategies which both positively exploit the new opportunities arising, and focus attention away from the distracting nature of sophisticated features of the technology itself, and onto intended science learning objectives. The creation of groups is not a simple case. In addition the interactions between students and between professor and students are very significant and influence the construction of the models. The use of ICT in school science, on the whole, has yet to establish its transformative role. Teachers are motivated and committed to using ICT in the classroom. The research literature converges on the conclusion that teachers tend to use ICT largely to support, enhance and complement existing classroom practice rather than actually re-shaping subject content, goals, activities and pedagogies.

This paper describes an approach to classroom experiments designed within a socio-constructivist approach, where students take an active role on the construction of their knowledge, and it exploits three different media: a video in order to motivate students' interest; objects from everyday life for the experiments; the technology-based learning environments "ModellingSpace".

THEORETICAL FRAMEWORK

Experiments in science

Experiments in traditional physics instruction are used as lecture demonstrations, high-school classroom demonstrations, and as laboratory experiments. There are two pedagogical techniques used for lecture demonstrations. In a traditional course, students observe an experiment and then the instructor explains what happened and why. In reformed instruction, students predict what is going to happen before the experiment, and then reconcile their predictions with the observations that follow.

We suggest an innovative approach, where the student acts and creates models in Science via the use of three different media. Modelling activities have been a substantive feature of the work of the science education research community for the past 20–30 years. This approach is much closer to the practice of real science. Many researchers agree that modelling should be in the centre of teaching of sciences (Martinand 1992, 1994; Lemeignan & Weil-Barais, 1993 ; Bliss, 1994; Mellar et al., 1994; Tiberghien, 1994, etc.).

For science education, it is especially important that students learn to develop models and explanations of natural phenomena (Coleman, 1998; Coleman, Brown, & Rivkin, 1997). Currently, various software tools support students' construction of models (Jackson, Stratford, Krajcik, & Soloway,1996; Komis et al., 2001; Dimitracopoulou et al., 2004), explanations (Sandoval & Reiser, 1997), and arguments (Linn, Bell, & Hsi, 1998) for natural phenomena.

We suggest that this method can be taken further. We suggest that essentially the realization of experiments with the computer after conducting real experiments that will advance the reasoning of students in greater depth and facilitate formal thinking. The symbolic experiments are not contrary to reality but can supplement it.

Modelling as a cognitive activity

Research in the field of cognitive psychology has shown that the process of translation among the various symbolic systems is essential for science learning (Vergnaud, 1987). Gerard Vergnaud (1987) has proposed a general theoretical framework (schema) which emphasises the relationships that students have to construct in order to be able to understand and interpret situations, to communicate their purpose and to make predictions, inferences, etc. He emphasises the role of the student's actions and cognitive resources in the elaboration of knowledge, within a constructivist approach. He distinguishes three functioning registers: a) the register of actions on real objects (each student's knowledge is dependent upon the reality: the student acts, manipulates and thus provokes changes and transformations in the world of objects); the register of mental representations (presented in Vergnaud's theory by the «invariants operators», or the "constant organisation of the activity associated to classes of problems"); the register of symbolic representations (maths, language, etc.).

In parallel, it has been proposed that the use of technology-based learning environments can facilitate the connection between the three registers: aspects of reality, their conceptualisation and their symbolic representations (Smyrnaiou & Weil-Barais, 2003; 2004) while students' understanding was better. However, students' understanding was significantly better, when students carried out real experiments before using the software (Smyrnaiou, 2003).

We think if the advantages of these three pedagogic tools can contribute in the learning of concepts in physics taking into consideration the cognitive processes that are involved in the modelling.

DESCRIPTION OF THE STUDY

Hypothesis

We start from the hypothesis that the models created by the students depends on the way that they work: (1) if they work individually and they interact only with the technology-based learning environment (2) if they work in groups (3) if they work in groups and their teacher helps them.

The teaching paradigm

Based on the presented theoretical framework, we discuss an innovative approach in Science teaching. Specifically, it concerns Hooke's Law using springs. The physical system we study has certain advantages: it is simple enough and represents a wide spectrum of real systems in order to make it as reusable as possible. The paradigm is designed within a socio-constructivist approach, where the student takes an active role on the construction of his/her knowledge, and it exploits three different media: a video in order to motivate students' interest; objects from everyday life for the experiments; the software "ModellingSpace".

First, students look at a video. A spring that is neither compressed nor extended is in its equilibrium position. The length is perturbed slightly and the spring tends to come back to the equilibrium position. As long as the deformation is elastic, the force exerted by the spring will be proportional to the amount of the stretch from equilibrium. Now, a mass is hung from the spring, it is displaced from the equilibrium position and it oscillates. They describe and explain the video, expressing their first representations. Next, they carry-out the experiment using different springs. Finally, they design and virtually run the experiment using "ModellingSpace" (Dimitracopoulou et al., 1999; Komis et al., 2001; Dimitracopoulou et al., 2004) which is an open-ended learning environment that allows students to create models, work and reflect on entities (representing objects) and their properties (representing concepts), while they construct the model of the situation using the entities (concrete or abstract), the properties and their relations.

Material

ModellingSpace is a technology-based learning environment, currently functioning only as a prototype (Komis et al., 2001; Dimitracopoulou et al., 2004), designed to familiarize pupils with the steps of modelling. Using this learning environment, the pupils can build models of the evolution of physical, biological, systems, etc. Concretely, users of the learning environment determine the constitutive entities of the system in which they are interested and the descriptors of these entities. Users then propose relations between these possible descriptors to account for the evolution of the system.

The interest of this technology-based learning environment is that it makes possible for pupils to handle various semiotic systems, making possible to express the entities and their relations. By comparing the transformations of the entities (represented in a figurative way by dynamic images) associated with various expressions of the relations, it is possible to comprehend the compatibility or the incompatibility of the relational expressions. It is thus possible to exploit the possible mapping between various manners of representing the relations: graphic coding with arrows of variable size (↑↑ which means the covariation of two descriptors), logical, mathematical expression, a graph, and a table of measurements. ModellingSpace (Komis et al., 2001; Politis et al., 2001) thus make it possible for students to connect various symbolic notations of relations between variables and thus encourage various processes of translation between the various semiotic systems (language, semi-quantitative relations, etc).

Method

We compared the models created by the students using the ModellingSpace in the three phases. When they:

1. work individually
2. work in groups and each group functioned independently of the others

3. work in groups which was functioned independently of the others and their teacher participated also to the process.

Students attended first grade of higher-secondary school (15-16 years old). Each group consisted of three students. The teaching strategy was implemented with 15 students in the first phase, 5 groups (or 15 students) in the second phase and 5 groups (or 15 students) and their teachers in the third phase. The duration of the implementation was 20-30 minutes for each individual while the duration of the implementation was 30 - 40 minutes for each group. The students had volunteered to participate. The implementation of the experiment was video-recorded, while some of the participants were also interviewed afterwards.

RESULTS

Results with the video

Modern research has examined the pedagogical value of video in order to support students' learning. The video arose students' interest with its dynamic and rich information that it offers. The quality of picture and the flexibility open new prospects and make it particularly attractive. Its advantages can facilitate teacher's work. The interesting operations that it offers for pedagogical use are the fast and easy reading and implementation of experiment, the saving of time, its repetition, the elimination of errors and damage, as well as the reduction of students' and teacher's stresses. A lot of sources with free videos that can be used in the class exist in various sites. Researches have shown that the professors of secondary education hope they allocate video and use it in their class (Beichner, 1996; Escalada and Zollman, 1997), owing to his advantages that already have been reported and that they make more powerful tool in relation with the picture and oral or written speech.

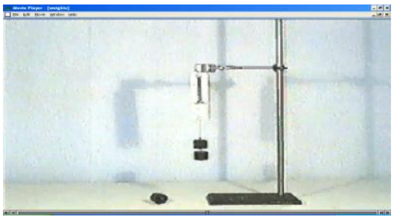

Figure 1. Video: Hooke's Law

In our research, is the question of what happens in the video (figure 1), the answers of students are very rich: they are focused on the objects (eg. *spring*), in the concepts and law of physics (eg. *force, Hooke's Law*), on the process of measurement (eg. *measurement of length*), they describe their actions (eg. *If I hang a mass…*). For example a student answers: "*A spring…two weights are hung and logically we measure the elongation of spring* " *while an other student of same team continues "the law of Hooke … the force exerted by the spring is proportional to the amount of the stretch from equilibrium … f = kx".*

The video mobilised the interest of students that participated in our research. Their expressions were positive when they watched the projection of video more times. Moreover, they evaluated the video positively and they judged it as essential in the teaching when they were asked relatively. We have not observed remarkable differences between students' answers concerning the video in relation to the way they have experimented (individually, in groups of three, in groups of three with the intervention of their teacher). Only in the third case, when in the process participates their professor, prompts them to see more times and "carefully' while certain professors ask them "*do you remind anything… we have taught it in the book… it exists in a frame with the spring and the dynamometer in the chapter 2… I help you*". Or another teacher said "*beautifully! You have met it in the lower secondary school and you have given it also a name*".

Results with the objects

The students realise the experiment using different objects (springs, mass). We remark the most of students have difficulties measuring the spring's elongation. They do not know from which point they must measure the elongation. They forgot the equilibrium position. When they work in groups, most of the time it helps them positively and they agree to measure to elongation of the spring from the correct position. Of course, the interactions between the students as well as the role that each student plays in the team are very interesting. Nevertheless, there exist some teams (minimal) where a student has the role of leader or there are disagreements and they do not arrive at the correct result.

When in the process at their professor interviews, he says "*I imagine that we will make what we see on the video*" or "*remove the weights and hung them again with attention in order to you see the changes and to say us what is observed*". Another teacher asked the "*Is this proportional with the weight; How did you observe it? Did you observe it or will you observe it?*" or "*Are you sure that is the Law of Newton*?"

Another students' difficulty is to measure the force exerted by the spring. Some of the student did not know (especially when they work individually), others propose the law of Hooke and few of them propose the third law of Newton (especially when their teacher participates in the process).

Results with the technology-based learning environment

When they use MODELLINGSPACE we begin in the environment with the open-abstract entities, in order to allow the students to freely express their ideas. They name the objects. They record their attributes and the relations between these attributes.

Even if almost all the teams of students lead to proportional conclusions after the completion of experiments with the objects, nevertheless the models that they built in the technology-based learning environment of modelling are different. The representation of previous conclusions with symbolic form varies and is influenced by the way they have experimented (individually, in groups of three, in groups of three with the intervention of their teacher).

Concretely, the models differ as for the type and the number of entities, of properties and of the relations that they used. In addition the models differ as for the physics law they expressed, for their complexity and if they use the sticky notes where they write their explications.

When students work individually then they creates a) an entity (eg. *spring, dynamometer, elongation*) or b) two entities. Thus other students use open-abstract entities, other entities-text and the two types together as can be seen from the models that we mention. None of the students has created the entity "system spring-mass". Eleven (11) students create two entities when four (4) one entity, especially the entity spring when they experiment individually. However, when they experiment in groups they create two entities. For the attributes, we observe that certain write one or more and sometimes they invent some that does not exist (eg. *mass, elongation, friction of spring, gravity*). Many students do not write the attributes but only the entities. Certain students can not distinguish the attributes from the entities especially when they experiment individually. Seven (7) students, when they work individually, write an attribute that does not exist or exists but it is not suitable for this situation or concerns the entities. Most of the students however are puzzled in how many and which will determine as attributes. When they work in groups, the most of the times it helps them positively, they create two entities and they write the most of the attributes are suitable. When their teacher participates in the process the models arrive to the scientific model. The teacher asks them many questions but also helps them when the students answer by a false response.

Another difference is presented for the semi-quantitative relations that they use in order to connect the entities. Thus some students, when they work individually, use two mathematical relations together, the one above in the other or a false relation, while most students when they work in groups use the suitable semi-quantitative relation which is compatible with the linguistic expression that they use in their conclusion. When they work individually they use a semi-quantitative relation of covariation (↑↑) between the entities in order to express "as long as the deformation is elastic, the force exerted by the spring will be proportional to the amount of the stretch from equilibrium". When they work in groups and especially when the teacher participates in the experiment they use the semi-quantitative relation (↑-) between the "constant of the spring" and the "amount of the stretch from equilibrium".

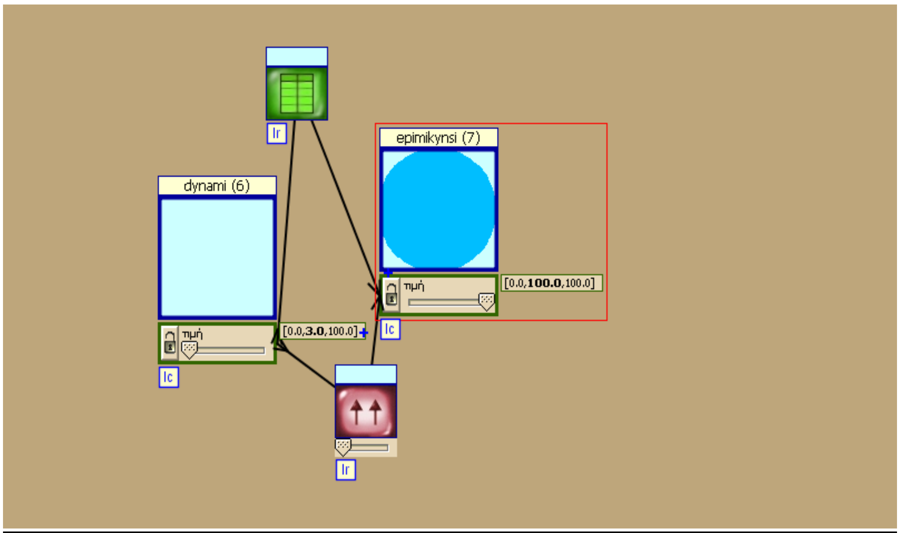

Figure 2. A model created by a group of three students

With regard to the laws of science the majority of students create models that express the Hooke's law. Only when they work in groups of three and their teacher participates, they create models that express Newton's law (2 groups the third law of Newton and 1 group the second law of Newton).

The models are more complicated when the teacher participates because she/he proposes them to express in the same model the relation of covariation (between "force exerted by the spring" and "amount of the stretch from equilibrium"), the relation (↑-) between the "constant of the spring" and the "amount of the stretch from equilibrium". In addition, she/he proposes to express in their models not only the Hooke's law but also Newton's law and to use sticky notes to explain the symbols, the formulas and the laws. For example a teacher proposes "*you can use a sticky note and write by a linguistic expression the law*". Some other students use the sticky notes when they work in groups but they write their actions or some verbs or words without scientific meaning.

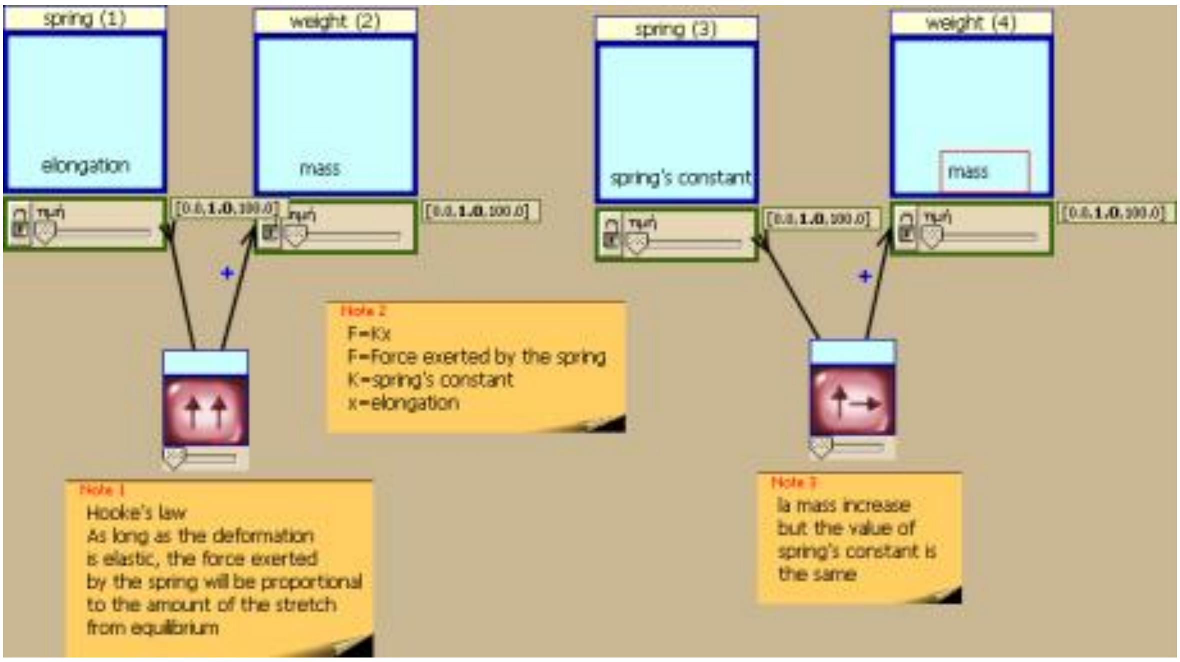

Figure 3. A model created by a group of three students when their teacher participates in the experiment

EVALUATION OF PROCESS

All the students evaluate positively all the phases of the process. They believe that the use of three media helps them to understand better the physical phenomenon. They do not want to remove from the process one of the three media (video, objects and software of modelling). But their answers differ in the order of video's use.

Their professor also evaluates positively the use of video, objects and software of modelling. Concretely, a professor says that "*it appears from the way that children functioned that the software is attractive and functional because in very short time they have accomplished to attribute something that they had acquired as knowledge through the experiments they realised* ". Another says that she would use with the same way "*because the particular thematic unit becomes very easily in the laboratory with materials of daily use, thing that a teacher is obliged, to direct his students to say that …. the software then it is a good way, through the representation, to see what the students have understood …and in a next phase to become the reverse* ".

The data that we have collected from the answers of students and professors allow us to consider that the combination of the advantages of each medium leads the students to understand and learn better the physical phenomenon.

CONCLUSION AND PROSPECT

Preliminary results show that students develop rich representations through their exposure to the three media: video, real objects and software.

The video motivated the interest of students that participated in our research. Their expressions were positive when they watched the projection of video more times. Moreover, they evaluated the video positively and they judged it as essential in the teaching when they were asked relatively. It has not been observed remarkable differences between students' answers concerning the video in relation to the way they have experimented (individually, in groups of three, in groups of three with the intervention of their teacher).

When students experiment by the objects, the majority of them have a difficulty with the measurement of elongation of spring. They do not know from which point they must measure the elongation. They forgot the equilibrium position. When they work in groups, most of the time it helps them positively; they compound and measure the elongation from the correct position. Of course, the interactions between the students as well as the role that each student plays in the team are very interesting. Nevertheless, there are some teams (minimal) where a student has the role of leader or there are disagreements and they do not arrive in the correct result.

Even if almost all the teams of students reach the same results after the experiment with the materials and formulate their conclusions with the use of almost the same linguistic expressions, nevertheless the representation of these conclusions with symbolic form via the software of modelling leads to very different results. The representation of previous conclusions with symbolic form varies and is influenced by the way they have experimented (individually, in groups of three, in groups of three with the intervention of their teacher). Concretely, the models differ as for the type and the number of entities, of properties and of the relations that they used. In addition the models differ as for the physics law they expressed, for their complexity and if they use the sticky notes where they write their explications. When they work in groups, the most of the times it helps them positively, they create two entities and they write the most of the attributes are suitable. When their teacher participates in the process the models arrive to the scientific model. The teacher asks them many questions but also helps them when the students answer by a false response and the models are more complicated.

Thus we can formulate in this point the proposal, that is essential the realisation of experiments in computer (students work in groups and teacher participates in the process) after the realisation of real experiments, in order to advance the reasoning of students in greater depth and pass to formal thought.

The symbolic experiments are not contrary to reality, but can supplement it. This proposal can be verified or denied with the continuity of experiments in the second phase of program as well as from the reverse process.

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