THE VIRTUAL EXPERIMENT IN THE SCIENCE CLASSROOM

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Abstract

This paper presents findings from a study about the potential of enhancing science classrooms with virtual experiments. Considering the widely claimed benefits of using information technologies and multimedia, along with the importance of experimental tasks in a science class, this action research process took place in a Greek primary school science class. The focus was on the following questions:

1. Which units or concepts of science curriculum can be assisted by the use of virtual experiments?
2. How can the use of virtual experiments enhance pupils' skills both for the subject of science as well as Information and Communication Technologies?
3. What barriers can be surpassed by these experiments?
4. What challenges arise?

The data were gathered through documents such as the official curriculum, observations, pupils' notes or work, as well as personal or group interviews with the pupils, parents and teachers. Findings show that there can be both benefits and risks with using the virtual experiment. The role of the teacher or mediator, along with appropriate lesson planning should not be neglected.

Introduction

This paper aims to examine the potential of using virtual experiments in primary science classrooms. Modern technologies are well known, nowadays, to bring on new possibilities in peoples' lives, in obtaining access to communication and information. The World Wide Web, multimedia as well as digital technologies have gained much attention and respect over the last decades, due to the widespread belief that they can expand the effectiveness of education and school processes. Several factors, such as the impressive images, sound effects and animation, in combination with the opportunity to learn and investigate areas from various fields, within or outside the teachers' experience, by stimulating numerous senses, are the main reason why a lot of discussion takes place about the necessity to introduce information and communication technologies (ICT) in schools and the teaching process (Cook, 2006; Karagiorgi, 2011).

Ridgways (1997) predicted that developed countries would enter a continuous process in an effort to engage ICT in the school curricula. Recent trends in education have well justified this prediction. Scrimshaw (2003) has pointed out a number of factors which make this process challenging. Such factors include the wide range of ICT means and the differences among teachers, duties, pupils and activities that are involved in many ways in the education process. Indeed, the multi-dimensional nature of ICT generates thought about the ways in which computers or the Internet can actually and practically assist the teachers in their work. Each technological application, calls for individual study in order to identify the benefits, as well as the risks that may arise during its use in the classroom (Karagiorgi, 2011).

Tondeur, van Braak, and Valcke (2007), have pointed out two main interlinked axes of the introduction of ICT in education and more specifically, in school curricula. The first identifies ICT as a subject to be taught. Schools are expected to prepare and qualify learners with the appropriate knowledge skills around computer, multimedia and other means of modern technology. This demand for technologically literate learners comes as a result of the technologically-oriented present society and economic trends. The second axis identifies ICT as a means to promote teaching and learning in other subjects. In other words, when the educator engages the computer, the web and other means of technology in the education process, more successful results are thought to be able to be achieved. In explaining this further, Nicholson (1995) proscribes that the teaching process should be planned in such a way that the learners, by using the computer, should be able to gather and analyse data, so that they can construct knowledge by themselves.

With regards to the latter dimension, there is a wide variety of means, software, and hardware that can be applied in the teaching process of particular subjects. Additionally, there is a wide range of activities or scenarios on how exactly they can be used to achieve the desired results. For example, in the subject of science, teaching is claimed to be assisted with the help of spreadsheets, web pages, data loggers, simulators and virtual experiments. Depending on the decided learning objectives, such means can act as the medium or tool through which a significant part of the lesson will be based or delivered (Williams & Easingwood, 2003).

Science and ICT

Science, in most countries is a core subject and therefore retains a significant place in the national curricula. According to the OECD (2007, p. 698), *scientific literacy,* the ultimate goal of science education, is, “the capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.”

Constructing Scientific Knowledge: A Modern Approach to Scientific Literacy

Recent approaches in science education, especially the constructivist approach, claim that the subject of science should not be dealt with solely as a volume of information that the learner needs to understand and memorize. It should also focus on the development of skills. To do this, the lesson needs to be planned in an appropriate way. Specifically, the teacher should begin by orientating learners' interest on the topic of the lesson. Then learners' ideas and misconceptions around the particular topic should be elicited and reconstructed towards the knowledge accepted as correct by the present scientific community. This reconstruction can be carried out through different activities such as experiments. Afterward, learners will try to apply the new knowledge in various contexts. The final stage of the class includes a post-cognitive process of reviewing how the learners' ideas and attitudes have been altered throughout the lesson. Along with that, learners are expected to develop a deep understanding of the nature of scientific knowledge, as well as the way scientists and groups of people approach and work towards it (Driver, Leach, Millar, & Scott, 2000).

Consequently, there are a number of particular skills that are expected to be developed or be apparent in any lesson, such as raising questions like: "What do we see here?" and, "What is happening here?" These questions normally lead to answers, hypotheses or data that need to be analyzed by the learners, under the teachers' guidance, in order to construct the desired knowledge. The importance of computers in the science classrooms is also focused on promoting enquiry and enhancing the interaction among teachers and learners. This includes recording learners' statements, impressions, comments and replies so that they can be investigated and understood.

All the experimental and reconstruction activities, in combination with the analysis or discussion skills, are fields where information and communication technologies can mediate to assist the learning process (Williams & Easingwood, 2003).

Using ICT in a Science Class

Computers are extremely useful, as they can present to the learners information and facts from the outside world, that they can observe, discuss, question, analyze and, in doing so, construct knowledge. For example, the computers also help learners exchange ideas or information through video-conferencing or email. However, this may also happen by visiting websites of institutes and organizations of interest, such as aquaria or natural history museums, or sites containing other kinds of virtual tools such as simulations or virtual experiments (Harlen, 2001).

Interactive simulation of phenomena and experimentation on them is an opportunity for learners to test and interact with or incorporate data on outside world facts. It enables learners to analyse the links between real-life phenomena that they may see or not see in their everyday experience and the scientific theories or laws regarding them. To help learners these simulating software usually include activities such as graphics or game-like tasks in which the learner can participate in and interact with objects and phenomena by using the mouse or the computer. A characteristic example of that may be a virtual representation of the electrical circuit, which may contain activities that will show the learner how to construct the simple circuit, how it can be expanded or even ruined. The learner can manipulate interactive tools and observe what happens on the screen. The software then gives immediate animated responses that help the learner understand cause and effect relationships and multiple linked representations (PhET, 2011).

It is therefore often stated that ICT, the web and relevant software may contribute a lot to effective science teaching. This however, should not be considered a panacea. The teacher's role should never be ignored or neglected. As already described, any kind of material used during the teaching process, should be used appropriately and according to plan. Otherwise there will be no benefit for the learners. It is therefore, up to the teacher to decide, after consideration if any means of technology can actually help the learning process.

This decision, indeed, needs to be made after evaluating three dimensions. The first dimension has to do with the identity of the item. Initially, it is important to see what kind of technological means or electronic material is available that is relevant to the objectives and goals that the teacher has set. Finding out, whether these means are easy to find is also necessary. Moreover, the software should be tested to see if it is easy to use in the classroom, if it needs time to load, and if it is compatible to any computer or equipment existing in the classroom.

The second dimension has to do with lesson planning. The teacher has to ensure that the use of software or tool does not happen at the expense of other activities that the lesson plan includes. For instance, if the lesson involves writing activity, the teacher has to make sure that there is enough time for learners to use the computer, observe, discuss, analyze and then start writing or vice versa. If learners have to move before or after using the computer, this should not cause any trouble.

Finally, the third dimension is relevant to the learners' skills with ICT. If learners are expected to type or surf on the net to collect information, it should be ensured that learners develop those skills. Otherwise the activity will fail (Williams & Easingwood, 2003).

Science Education in the Greek Primary School

Science is a subject with a significant place in the Greek primary education curriculum, reflecting the necessity attributed to the specific field of study. As an independent, autonomous subject it exists only in the fifth and the sixth grade, the final ones of the primary school. In the previous years, scientific topics are taught within a cross-disciplinary subject of environmental study.

The curriculum defines that the subject will be taught for three 45-minute sessions per week. As with all subjects in the Greek compulsory education system, there is a teaching packet of a learner's textbook, workbook, and teacher's book. Recently a set of CDs relevant to the subject, structured according to the curriculum, has also been distributed. These CDs contain activities, such as virtual experiments (YPEPTH, 2000). The topics are primarily about mechanics, motion, animals and plants, energy, electricity, and anatomy of the human body.

There is wide discussion concerning the exact role of science education in schools. The common ground where all opinions agree is that through science, learners will get the necessary qualification to resolve everyday problem situations, understand the evolution and progress in the fields of science and technology, and understand risks and social issues relevant to science and scientific development. Cross-curricular approaches, which involve the combination of units from science with other fields and everyday life contexts, are strongly encouraged.

As far as the units of the subject are concerned, it is well recognized that they are many and spread. The strict limitations of time and place do not permit all the important units that concern science education to be included and negotiated within the national curriculum. It is therefore necessary to prioritize the aims and goals of the subject. The challenge rising is to select the fundamental units and include a critical approach to them. This way the learners will have understood the basic concepts and phenomena of the topic, the necessity of studying them, and the skills required. The selection process should take into consideration different aspects of school and everyday life, if the overall aim of the school is to prepare learners to become fully developed cognitively and socially aware people that will be able to understand, cooperate and contribute to society (YPEPTH, 2000).

The Topic of the Study

As a conclusion, drawn from the previous discussion, it can be found that it is worth investigating the potential of using the modern technologies in the context of the Greek primary school. To do this, it is necessary to investigate the modern technologies in all aspects, including as a tool to promote scientific literacy, or, in other words, within the subject of science (YPEPTH, 2000; Karagiorgi, 2011). The virtual experiment, software providing interactive stimulation of phenomena and experimentation that can project the to be investigated natural or every day facts and concepts in the classroom, is perhaps an interesting aspect, unique for the science subject and compatible to the recent pedagogical approaches (Harlen, 2000; Cook, 2006).

As mentioned, technologies are expected to give further opportunities for analysis, discussion, investigation and knowledge construction. Such knowledge may well apply not only to ICT, but also to other subjects such as science. This depends on the particular education activity within which software is used. However, the use of modern technology cannot always guarantee the successful result of the teaching intervention. In spite of the fact that research has shown possible benefits, there are numerous factors arising that may challenge the teacher's work. This happens particularly if the teaching activity is not carefully and thoroughly planned (Linn, 2003; Williams & Easingwood, 2003).

It is therefore, interesting to investigate the following questions:

1. Which units or concepts of science curriculum can be assisted by the use of virtual experiments?
2. How can the use of virtual experiments enhance pupils' skills both for the subject of science as well as Information and Communication Technologies?
3. What barriers can be surpassed by these experiments?
4. What challenges arise?

Methodology

Insights to the Appropriate Data Collection Process

To identify the most appropriate methodology that will answer the questions set above, it is important to comprehend present education research methods. Perhaps the greatest decision begins with whether the research analysis will follow a positivistic or a non-positivistic approach. The former tries to investigate human behavior aiming to identify general rules that will help researchers make predictions on it. The latter is more focused on the idea that it is not possible to delineate human behavior with rules.

Relevant to this decision is the one about a qualitative or quantitative research approach. Qualitative or phenomenological enquiry, which is influenced by the non-positivist movement, uses a naturalistic approach that tries to understand phenomena that are context-specific (Patton, 1990). Quantitative or logical enquiry is based on the positivist movement and uses experimental methods and quantitative measures to test hypothetical propositions (Kerlinger, 1970). Qualitative and quantitative paradigms represent a fundamentally different enquiry approach, and supplementary research actions are based on their underlying assumptions (Patton, 1990).

Qualitative research has been defined by Strauss and Corbin (1997, p.17) as, "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification." Whereas quantitative research seeks causal determination, prediction and generalisation of findings, qualitative researchers seek illumination, understanding and extrapolation only to similar situations. Consequently, qualitative analysis results in a different type of knowledge. The aim of the particular study focuses more on the latter. This perhaps is the main reason why the qualitative approach is more appropriate.

Action research is perhaps suitable for the particular project, as it involves the teachers' personal involvement in the problem solving process. Action research involves reflection, collaboration and dialogue as elements of an empirical research study. Learning practices in the classroom and innovation evaluation are generally considered to be appropriate cases for action research (Cohen, Manion, & Morrison, 2000).

For education research, the data collection techniques available are usually interviews, questionnaires, biographical notes, documents, diaries and observation (Bell, 2001). Having in mind the nature of the study and the research questions, the most appropriate techniques were determined to be documents, observation, notes analysis and semi-structured group interviews. The documents used (mostly during session planning) were primarily the subject curriculum, as well as notes on the multimedia and simulation software used.

The main focus of interviews and observations was the learners' behaviour throughout the sessions. More specifically, emphasis was placed on learners' interest and desire to participate in the activities and their responses on the concepts and phenomena being taught. These responses addressed concept understanding, describing and explaining applications of phenomena in every-day life or real world situations and a review of how their ideas changed during the session. It is these topics that can show the level of scientific literacy reached by the learners (Driver et al., 2000).

The Research Sample

Sample selecting is an important part of a research project. It is important to have a representative sample that will lead to accurate conclusions (Cohen et al., 2000). Two groups of pupils participated in this study. The first included 14 fifth grade pupils of the age of 10-11. The second included 16 sixth year pupils of the age of 11-12. There were no reported cases of learning difficulties among pupils. There were a number of culturally diverse, or bilingual pupils. However their fluency on the mainstream language, which was Greek, was not lacking in comparison to their mainstream fellow pupils.

The particular sample was selected, as it was easy-to-access. The characteristics of the sample set it as appropriate to carry out the study. The ratio of male to female pupils was almost one-to-one, the average in Greek primary schools (EL. STAT, 2011). These data were collected during the years 2010-11 and 2011-12.

As far as the teaching approach used, according to both the curriculum and recent research in applied science education, the teacher is expected to decide which approach better suits the learners, depending on their background, time and place restrictions, resources available and the lesson context. For the purpose of the chapters taught during the research, lessons were carried out in a constructivist approach (YPEPTH, 2000).

Findings

Research results for each question are discussed below and summarized in Table 1.

Question one.
Which units or concepts of science curriculum can be assisted by the use of virtual experiments?

It was concluded that virtual experiments were necessary when the topic of the session had to do with concepts and contexts outside the everyday experience of the pupils. Chapters related to the microworld, may involve phenomena about molecules and atoms. Computer illustrations can help pupils better understand the concepts. Examples of such cases may be the teaching of mixtures and dissolutions. When the dissolving of sodium chloride in water is illustrated, pupils can see what the behaviour of molecules actually is. Another example is also the presentation of the electrical circuit, which may present the electric current and the movement of electrons in the cables. Chapters related to the macroworld can also be helped. With lessons on the solar system, these illustrations can show clearly the interaction between gravity, mass and other fundamental concepts on earth as well as other units.

Virtual experiment is a tool that can help the teacher attract the interest of the pupils for the topic of the session. It can also help the learners observe the concept or phenomena of the topic that are not easy or even possible to be observed within the learners' routine. By helping learners understand the topic's context, the approach to the new knowledge is being helped too (Harlen, 2001).

Question two.
How can the use of virtual experiments enhance pupils' skills both for the subject of science as well as ICT?

The illustrations assist in two ways. The first, which is relevant to the findings mentioned above, is linked to the enhancement of learners' experience of fields unknown to them. The second is relevant to the learners' opportunity to experiment on these contexts and fields. For example, instead of solely watching the electrons moving through the circuit, the learners can test composing a circuit by themselves with the necessary items such as batteries, cables, switches and light bulbs. The software always helps them evaluate the results of their actions through immediate specially illustrated feedback. Something similar happens with the illustration of the atom nucleus and the conditions under which it is bombed to release energy. Illustrations can also provide activities in the form of games that will help learners understand the conditions interfering with the phenomena.

In short, the illustrations can be very helpful, as a supplement to the ordinary experiment, providing the learners with the opportunity to experiment and come in touch with contexts they may not know in depth (Harlen, 2001; Driver et al., 2000). Additionally, the learners familiarize themselves with the use of software, simple or complicated, that can involve several IT skills such as typing, processing, searching, evaluating, understanding formats (Harlen, 2001; Williams & Easingwood, 2003).

Question three.
What barriers can be surpassed by these experiments?

Barriers to be surpassed exceed those already mentioned about the learners' experience and experimentation. The virtual experiment can also facilitate testing with mathematical calculations and representations, along with different techniques of data handing and knowledge constructing. This is a set of skills that has to be taught too (YPEPTH, 2000; Harlen, 2001).

For example, the representations provided could help learners organise or have the data they need organised in order to construct knowledge. When, for example, watching an experiment illustrated, they can also watch graphs or tables with all the measurements that the experiment involved stored and presented. This helps learners get an idea on how to manage the amounts of data before drawing conclusions. Without the software these tasks would need much more time to be carried out.

This importance of this advantage lies in the fact that it can help learners develop the learning skills they need in order to be able to construct knowledge. Learners can also acquire a deeper understanding of the nature of scientific work and knowledge. These two are factors that modern pedagogy supports as a main goals, instead of simply having the knowledge transmitted by a teacher, as it was previously expected (Driver et al., 2000; Williams & Easingwood, 2003).

Question four.
What challenges arise?

There are indeed several points to consider when using software, such as virtual experiments in a science class. This finding underlines the necessity of the teacher and lesson-planning factor (Harlen, 2001).

First, it is easy for learners to focus their attention on the fascinating illustrations and game-like experimental activities and not pay attention to the ultimate role of the activity, which is knowledge construction. The software is treated as a means for entertainment in total and very little for learning.

Second, it is not always easy to set up and prepare the software for the classroom to use it as soon as the session begins. Having in mind several factors such as learners' motivation and time restrictions, it is expected that there will be enough time and the appropriate equipment.

Third, in relation to the previous point there is the obstacle of electricity cuts, which happened a few times during the period of the study and as a result the activities based on the virtual experiment had to be abandoned.

Fourth, there was a language issue too, as the vast majority of the virtual experiments found and used were designed in the English language (YPEPTH, 2000; PhET, 2011). For pupils whose first language is not English, such as the Greek pupils, this may bring on challenges.

The findings about the barriers show that without proper lesson design and consideration for learners' general attitudes and the working conditions of the school, visual representations may actually be an impediment rather than a means of learning (Linn, 2003; Cook, 2006). The computer and software have many assets that make it useful in a science classroom. However, without careful and proper planning, the lesson can easily loose its focus and the learning goals set by the teacher can be missed (Williams & Easingwood, 2003; Karagiorgi, 2011).

Before making any generalizations, from the above conclusions, it is essential to point out several limitations of the particular study. The sample of the population includes male and female participants from a typical Greek primary school classroom. It was perhaps the most appropriate in consideration of the goals and time and place restrictions. However, it is not large enough to make the research findings able to serve as grounds for accurate generalizations or definite future predictions.

In addition, it is important to mention that the study evaluates only one aspect of ICT in only one subject of the Greek primary school curriculum. However, it could be just enough to justify that using virtual experiments in a science classroom, has both pros and cons, depending on the teachers' attitudes and actions (Cohen et al., 2000).

Table 1

The Main Findings on Each Research Question Briefly Described

Research Question 1: Which units or concepts of science curriculum can be assisted by the use of virtual experiments? • Effective illustration of micro world: molecules, atoms, electrons. • Effective illustration of macro world: planets. • Interest stimulation.	Research Question 2: How can the use of virtual experiments enhance pupils' skills both for the subject of science as well as ICT? • Pupils' experience with natural phenomena is enhanced. • Pupils' experiment. • Pupils become more familiar with software.
Research Question 3: What barriers can be surpassed by these experiments? • Pupils learn how to collect data by experimentation. • Pupils practice handling data and constructing knowledge. • Pupils get a deeper knowledge of the nature of scientific work.	Research Question 4: What challenges arise? • Pupils get distracted by the illustration and don't focus on the process-subject. • Equipment set-up takes time. • There are problems when there is electricity cut • Language issues

Conclusions

This study supports the claim that virtual experiment software can offer significant assistance in a science classroom. Phenomena that happen outside the pupils' everyday world experience can be presented, discussed or analysed with them. This helps learners in their task to construct scientific knowledge and attain scientific literacy (Driver et al., 2000; Williams & Easingwood, 2003). Technological literacy can also be promoted as pupils become more familiar with the computer and its educational role. Despite that thought, any teacher deciding to use virtual experiment, as with any other means of ICT, has to be concerned about risks and challenges that may arise.

Perhaps the major issue concerning whether or not to use virtual experiment in the classroom has to do with the particular teacher's working style and the role that the teacher attributes to the computer. Usually, the virtual experiment is preferred in cases where it is required to engage the learners in problem solving situations, where they participate actively in a set of learning activities (Williams & Easingwood, 2003; Cook, 2006).

In any occasion, the lesson should never neglect the essential tasks and skills that science classrooms should involve, such as observation, experimentation, discussion and self-reflection on misconceptions about concepts and phenomena (Driver et al., 2000). Any teaching intervention, using any means of ICT should always be planned to involve or develop these elements of the science classroom and, of course, be focused on particular goals (Cook, 2006).

These conclusions along with the limitations could serve as guidelines for further studies with similar topics and interests. If there is knowledge without certainty, then that knowledge must always be open to criticism (Cohen et al., 2000).

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