ICT AND DEVELOPING LITERACIES IN THE SCIENCE CLASSROOM: THE ROLE OF VIRTUAL EXPERIMENTS AND SIMULATIONS IN A GREEK PRIMARY SCHOOL

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Abstract

This project examines the benefits of using simulations and virtual experiments in a science classroom by comparing two elementary 5th grade groups, of the same school, in Greece. In the first, simulations and virtual experiments were used, whereas in the second not. Through action research, the study investigates whether the use of simulations and virtual experiments could support the development of scientific literacy, digital literacy and new attitudes towards learning, which are goals set by the National Curriculum. Conclusions show that simulations can help learners become scientifically literate. However, with regards to digital literacy and learning attitudes, the wider context seems to prevail.

Introduction

This paper investigates the educational benefits of the use of virtual experiments and simulations in science sessions in developing scientific literacy, digital literacy and new learning attitudes, by comparing two different contexts, in the first of which these applications are used, while in the second not.

Modern technologies have expanded drastically the access to communication and information. Over the last decades, the idea that the Internet, multimedia and digital technologies can promote education effectiveness and improvement, has been gaining wide acceptance. This happens mainly thanks to the impressive images, sound effects and animation, combined with the opportunities to learn and investigate fields, within or outside teachers' or learners' experience (Cook, 2006).

Ridgway (1997) predicted a continuous effort in developed countries to engage ICT in school curricula. Recent trends in education justify that. schools are expected to qualify learners with appropriate knowledge and skills around computers, multimedia and other means of modern technology. This demand for digitally literate learners is a result of the present technologically oriented society and economic trends.

The introduction of ICT in education and more specifically, in school curricula has two aspects. The first presents ICT as a subject itself. The second presents ICT as a means to assist teaching other subjects (Tondeur, Van Braak, & Valcke, 2007). Nicholson (1995) indicated that the lesson should be planned in such way, so that learners, by using the computer, should get used to gather and analyze data, in order to construct knowledge by themselves and adopt more positive attitudes towards learning and knowledge.

With regards to the latter, there is a wide variety of means, software, hardware that can be implemented in teaching particular subjects. There are also many activities or scenarios on how they can be used to achieve effective teaching. For example, in science subject, teaching can be assisted by spreadsheets, web-pages, data loggers, simulations and virtual experiments. Depending on the learning objectives, such means can act as medium or tool through which a significant part of the lesson will be based or delivered (Williams & Easingwood, 2003).

The focus of this project lies in the use of simulations and virtual experiments and the help it provides to teachers.

Science and ICT

Constructing Scientific Knowledge: a Modern Approach to Scientific Literacy

In most countries, science is an important subject and therefore retains a central place in the national curricula. According to the OECD (2007), scientific literacy, the ultimate goal of Science Education, is defined as:

> 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. (p.608)

Recent approaches, especially constructivism, support that science knowledge should not be treated solely as a sum of information for learners to understand and memorize. It should also focus on skills that will help learners solve problems and set and answer questions about the natural world. Furthermore, it is should promote science friendly and research friendly attitudes, through which learners can promote inquiry.

This requires appropriate lesson planning. Specifically, the teacher should begin by orientating the learners' interest on the topic of the lesson. Then learners' ideas and misconceptions around this 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 apply new knowledge in various contexts. The final stage includes a post-cognitive process of reviewing how learners' ideas and attitudes have been altered throughout the lesson. As result, learners are expected to develop 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).

Therefore, there are several skills that are expected to be developed or be apparent in any lesson, such as observing, exchanging ideas, testing, explaining. These are developed gradually and cumulatively, through questions, as "What is going on?" "Why do you think this is happening?" "What factors are affecting this phenomenon?"

These questions normally bring answers, hypotheses or data that need to be analyzed, by learners under teachers' guidance, in order to construct the desired knowledge. ICT can help a lot in that respect by promoting enquiry and enhancing interaction among teachers and learners, and by recording learners' words, impressions, comments, and replies so that they can be investigated. All experimental, reconstruction activities, along with analysis or discussion skills, are fields where ICT can assist (Williams & Easingwood, 2003).

Promotion of Digital literacy

Shapiro and Hughes (1996) along with Gagel (1997) have defined ***digital literacy***, as a combination of four abilities: (1) catching up with the rapid and continuous technological progress, (2) solving problems of technological nature, (3) using means of modern technology effectively, and (4) assessing the philosophy and theory of technological development as well as the benefits of technology in peoples' lives.

The Association of College and Research Libraries (2004) has set six standards, which reflected these ideas. According to those, a digitally literate person, when negotiating a particular subject should: (1) determine the extent of information needed, (2) access this information effectively and efficiently, (3) evaluate critically any information and resources, (4) engage this information in a wide knowledge base, (5) use this information and data effectively to achieve a purpose, and (6) understand ethical and legal issues about accessing information and appreciate other aspects of the wider subject investigated, as economic or social.

Schrimsaw (2003) mentioned numerous factors which make this process challenging. Such factors are the wide range of ICT means, the difference 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 benefits, as well as the risks that may arise during its use in the classroom (Karagiorgi, 2011).

ICT in a Science Class- Interactive Simulations and Virtual Experiments

ICT can help the teacher present states and phenomena from the outside world, which learners can observe, discuss, question, analyze and in doing so, construct knowledge. Computers and applications help learners exchange ideas or data through video-conferencing or email. They also help thanks to sites of relevant institutes and organizations, such as aquaria or natural history museums, or sites containing other virtual tools such as simulations or virtual experiments (Harlen, 2001).

Interactive simulations of phenomena and experimentation are software projecting the natural phenomena, facts digitally on a computer screen. They give learners the opportunity to test, interact or incorporate data on outside world facts. They enable learners analyze links between real-life phenomena that they may see or not see in their everyday experience and the scientific theories or laws abiding them. To help learners, they usually include activities such as graphics or game-alike tasks in which the learner can participate in, interact with objects and phenomena. An example is the virtual representation of the electrical circuit, which may contain activities that show learner how to construct a simple circuit, how to expand it or even ruin it. Learners can manipulate interactive tools and observe what happens on screen. The software gives immediate animated responses that help them understand cause-and-effect relationships and multiple linked representations (PhET, n.d.).

Hence ICT can enhance science teaching. However, this is not always the case. The progress and outcome of any session does not cease to depend on the teacher. Any means used in class, should be used appropriately, according to plan, otherwise it may be no helpful. The teacher should evaluate if there is benefit from using any technological applications. Williams and Easingwood (2003) mention three points that teachers should have in mind, during this evaluation. The first is the compatibility between the application used and the session objectives. The second is the degree of ease or difficulty of using this application in classroom. Finally, the third is learners' skills and their adequacy to use the computer and any application.

When it comes to digital literacy, the issue gets more complicated. Joint (2003) states that using ICT applications as means to other subjects is not sufficient to make learners more qualified computer users. The reason is probably the fact it has to be clarified to learners that the focus of the session includes promotion of ICT skills too.

Within a broader context, there is debate on whether using such means can promote adoption of learning-friendly attitudes by learners. This issue is approached through four characteristics from the side of the learners: motivation, self-confidence and self-belief about learning, emotional factors, and learners' personal learning strategies.

To sum up, literature shows that using simulations in a science class have positive results but can also have challenges. This idea triggered this research project.

Science Education in the Greek Primary School

Science is a core subject in the Greek primary education, as in almost every country in the developed world. It is an independent subject the fifth and sixth grade, the final ones of primary school. In previous grades, science topics are included in a cross-disciplinary subject of social and environmental study.

In accordance with the curriculum, the subject is taught for three 45-minute sessions per week. As with all subjects in Greek compulsory education, there is a teaching packet of a learner's' textbook, workbook, teacher's book. Recently a set of CDs with activities relevant to the subject, such as virtual experiments, structured according to the curriculum, has also been distributed (YPEPTH, 2000).

There is debate concerning the exact role of science education in schools. All agree that it is through science that learners will get the necessary qualification to resolve everyday problem situations, understand the evolution and progress in science and technology, and understand relevant risks and issues. The subject topics are mostly mechanics, motion, animals and plants, energy, electricity, human anatomy (YPEPTH, 2000).

The Research Questions

The project's broad context is the investigation of benefits of using ICT in the Greek primary school. To do this, it is necessary to investigate ICT in all aspects, including as a tool to promote scientific literacy, in other words, in a science class. The virtual experiments are an interesting aspect, unique for the science subject and compatible to recent pedagogical approaches (Harlen, 2000; Cook, 2006).

As mentioned, ICT give opportunities for inquiry, observation, analysis, discussion, investigation and knowledge construction. Such knowledge may apply not only to ICT, but also to other subjects such as science. This may also address general learning attitudes of pupils. However, the use of ICT cannot always guarantee successful results of teaching (Linn, 2003; Williams & Easingwood, 2003).

Promotion of scientific literacy, digital literacy and new learning attitudes, coincide with the wider goals of the Greek Curriculum (YPEPTH, 2000). Bearing all that in mind, the questions of the study are formed as following: (1) Does the use of virtual experiments and simulations in the classroom assist in approaching scientific literacy? (2) Does the use of virtual experiments and simulations in science classroom assist in approaching digital literacy? (3) Does the use of simulations in the classroom encourage learners to adopt new attitudes towards learning?

Methodology

Insights to the Appropriate Data Collection Process

The particular project focuses more on investigating human behaviours and response in a specific context, rather than using statistical data to test a hypothesis. It is more of a qualitative rather than quantitative nature. Action research was more suitable for the project, since it involved the teachers' personal involvement in problem solving process, reflection, collaboration and dialogue, as elements of empirical research. Evaluation of classroom learning practices is an appropriate case for action research. A comparative study seems more suitable to identify actual positive results from using of simulations and virtual experiments as opposed to not using (Cohen, Manion, & Morrison, 2000).

The most appropriate data collection techniques for the study were concluded to be document analysis, observation and semi-structured group interviews (Bell, 2001). The documents used were mostly the subject curriculum, lesson plans, as well as notes on the multimedia or simulation software used, tests and projects of the learners.

The main topics on which the interviews and observations took place focused on three topics of the learners' behavior and responses.

The first topic emphasized learners' interest, their desire to participate in activities and their responses on science concepts and natural phenomena. These responses would address their skills in: concept understanding; describing and explaining applications of phenomena on every-day life or real situations; and reviewing how their ideas changed during the session. These topics would reflect the level of scientific literacy reached by learners (Driver et al, 2000).

The second topic emphasised learners' responses and behavior towards ICT. They were asked about the way and the reasons they use computers and the Web. They were also observed using them. There also was focus: (i) on the way they identified information needed in activities, (ii) on the way they collected it, (iii) on how they evaluated its meaning, relevance, accuracy, (iv) on the way it was used, and (v) what was learnt from the information and the process generally. Attention was paid on the progress of responses throughout the year and if this was linked to the use of virtual experiments. Digital literacy is reflected this way (Martin & Grudziecki, 2006).

The third topic emphasised the four characteristics of learning attitudes. With regards to motivation, there were questions, on interest in learning, reward or penalty and general ideas about schooling. With regards to self-confidence and belief, there were questions about how learners evaluate themselves and what they expected to learn from the session. With regards to emotional factors, there were questions about anxiety and assurance issues. Finally, with regards to personal learning strategies, there were questions about memorisation, understanding, elaboration and self-examination. Again, these topics were linked to the use of virtual experiments and if it can be a motivation to develop new ideas and attitudes about learning (OECD, 2007).

The Research Sample

Data were collected during the academic year 2012-13. The sample was selected, as it was easy-to-access. It was composed of two groups of 5th graders of a Greek Primary School. Both groups had 22 pupils. No cases of learning difficulties were reported. There were few bilingual pupils, but their fluency in Greek, the mainstream language, was not lacking compared to their mainstream fellow-pupils. These sample characteristics make it appropriate for the study. The ratio of male to female pupils was almost one-to-one, as is the average in Greek primary schools (EL. STAT, 2011).

Each group had a different main teacher for Greek, Mathematics and most subjects. However, science was taught in both groups by the same teacher, who was also the main responsible teacher for the first group. In the second, however, he was only teaching science. The crucial difference between the two groups was that in the first, ICT use was frequently used, whereas in the second it wasn’t, as its main teacher was reluctant to use ICT in her class. This assisted further the comparative approach in this project. The constructivist approach was used in the chapters taught (YPEPTH, 2000).

Findings

Table 1

Study Findings

Research Question 1: Does the use of virtual experiments and simulations in the classroom assist in approaching scientific literacy?	✓ To a large extent. ✓ Learners of the first group (where simulations were used) showed better understanding of micro-world concepts and phenomena: Molecules, atoms, electrons. ✓ Learners of the first group showed better understanding of macro-world concepts and phenomena: Planets. ✓ Learners of the first group were more stimulated.
Research Question 2: Does the use of virtual experiments and simulations in science classroom assist in approaching digital literacy?	✓ To a limited extent. ✓ Few learners from both groups got motivated and learnt new things about ICT and used them. ✓ Most learners from both groups kept on using ICT only for games and basic skills of networking sites.
Research Question 3: Does the use of simulations in the classroom encourage learners to adopt new attitudes towards learning?	✓ To a limited extent. ✓ Few learners from both groups were motivated and adopted new learning strategies. ✓ Most learners from both groups showed no difference in that aspect.

Research Question 1:
Does the use of virtual experiments and simulations in the classroom assist in approaching scientific literacy?

With regards to the first question, it was concluded that the pupils of the first group showed deeper and more thorough understanding of scientific concepts, skills and overall better performance in the science subject in comparison to the second.

At first, first group learners seemed more stimulated. These applications helped the teacher attract their interest. They also helped the learners watch concepts or phenomena of the topic that are not easy or even possible to be watched otherwise. By helping them understand the topic context, approach to the new knowledge was largely helped too (Harlen, 2001). Attracting the interest of second group learners had to be done with other means, as text-book photographs, which were not as helpful.

Second, topics related to the micro-world, were understood better by first group learners. Phenomena relevant to molecules and atoms were easily demonstrated to them. An example was the illustrations of mixtures and dissolutions, when pupils can see the behavior of molecules. Another example is the presentation of the electrical circuit, which showed the electric current, the flow of electrons across the cables. Second group learners had a difficulty understanding these issues deeply and demonstrated common misconceptions when asked or when applying new knowledge.

Third, first group learners better understood topics of the macro-world too. When teaching about the solar system, these illustrations helped, showing clearly the interaction between gravity, mass and other basic concepts, on earth and other planets. In the second group, the use of a textbook and images was not equally effective.

Overall, it was concluded that the assistance of the illustration comes in two dimensions. The first, which is relevant to the mentioned above, is linked to the enhancement of learners' experience with fields unknown to them. The second one 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 illustration of atom nucleus and the conditions under which it is bombed to release energy. Illustrations can provide activities under the form of games that will help learners understand the conditions interfering with the phenomena.

In short, the illustrations can help, as a supplement to the ordinary experiment, providing the learners with the opportunity to experiment and come in touch with contexts they are may not know in depth (Harlen, 2001; Driver et al, 2000).

Research Question 2:
Does the use of virtual experiments and simulations in science classroom assist in approaching digital literacy?

With regards to the second research question, though, results were different. There were learners in the first group, who explained that they were using the simulations, when studying, or even in order to accomplish several projects either at school or at home. There were few learners who were inspired by simulators and prepared various projects linked to science topics as renewable energy resources, economical electricity use or greenhouse effect. Learners engaged themselves in gathering evaluating, using and applying information in a wider context, with the help of ICT becoming this way more familiar with them (Harlen, 2001; Williams & Easingwood, 2003).

However, this was not only the case in the first group. A similar number of learners in the second group were found to be using ICT when studying science at home and engaged in similar projects.

The vast majority of learners in both groups reported that their use in the computer was restricted to online games, or even networking sites. This was reported in the beginning, throughout the year as well as in the end, showing no major difference.

So, in both groups only few learners were inspired to seek and learn something new or deeper about ICT. It is therefore unclear whether the initiative of the first group learners to become more digitally literate was the use of simulators or a wider preexistent interest in that area (Cohen et al, 2000; Linn, 2003).

Research Question 3:
Does the use of simulations in the classroom encourage learners to adopt new attitudes towards learning?
Results were similar in the third research question. There was no significant difference observed, in what comprised learners' ideas about learning generally.

In the first group, for instance, few pupils were found to be changing their ideas about learning and how ICT can help them learn more effectively and efficiently. These learners, for example, mentioned that, inspired from these applications they tended to use the computer to understand new concepts and do their homework, regardless of the subject or assignment duties. They also kept asking if there were similar applications on other subjects, so that they would use them to learn better. In fact, it was interesting to see two learners, who in the middle of the year started using drawing and personal illustrations in order to explain and understand new concepts, as "these drawings help, showing better just as the virtual experiment helps." It is worth mentioning that they were using these illustrations in other subjects. These examples show that virtual experiments can lead to new learning strategies.

However, there were similarly few learners in the second group, who were found to develop new methods and ideas about learning. These learners, specifically, mentioned that their techniques in understanding and memorising at the end of the year were different than the beginning. They attributed that partly to the use of computer at home or to advice given to them by others. They explained that this way they were more 'certain' and confident about what they learn in class and how to prepare for the next session.

Of course, as mentioned, only a few learners used virtual experiments while studying. Thus, it is not sure that any difference noticed in their attitudes is attributed surely to the use of virtual experiments and simulators (Cohen et al, 2000; OECD, 2007).

Conclusions

This study examines comparatively if using virtual experiments in science teaching, can promote scientific literacy, digital literacy and wider learning attitudes. With regards to the first, virtual experiments offered significant assistance. Phenomena happening outside the pupils' experience were effectively presented, negotiated or analyzed with them, helping science knowledge construction this way (Driver et al, 2000; Williams & Easingwood, 2003). Digital literacy could have also been promoted as pupils were expected to become more familiar with ICT and its' educational role. However, the results do not support that assertion adequately. The same applies to the shift in learning attitudes. Simply using one application of modern technologies in a specific subject did not seem to suffice. Perhaps digital literacy and development of new learning attitudes demand deeper, wider and longer efforts (Tondeur et al, 2007).

To sum up, using virtual experiments was found to significantly promote scientific literacy, but it is dubious if it can promote digital literacy or new learning attitudes.

Before generalizing about these conclusions, it is essential to point out the limitations of this study. Its sample includes participants from two typical Greek primary school classrooms. It was perhaps the most appropriate considering the goals, time and place restrictions. It is not large enough to make the findings able to serve as grounds for accurate generalizations or definite future predictions though. Additionally, the study evaluates only one aspect of ICT in only one subject of the Greek primary school curriculum. However, it can justify that using virtual experiments in a science classroom, has both pros and cons, depending maybe on teachers' attitudes and actions (Cohen et al, 2000).

Perhaps the major issue concerning whether or not to use virtual experiment in classroom has to do with the particular teacher's working style and the role that the teacher attributes to the computer (Williams & Easingwood, 2003; 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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