VIRTUAL REALITY IN ELEMENTARY SCIENCE CLASS: THE CASE OF A GREEK PRIMARY SCHOOL

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Abstract

The aim of this case study is to investigate any benefits of introducing virtual reality software in science projects that can support the actual goal of science teaching. The project takes place during science classes in a primary school in Greece. After examining whether (a) virtual reality helps achieving the teaching goals set, (b) has positive responses by the learners, (c) is supported by the school context and (d) is convenient cost-wise, it was concluded that virtual reality can have benefits when implemented. However, there are issues to be considered in what concerns responses, the school context and cost.

Science Education Nowadays

According to the OECD (2007, p. 698), scientific literacy, which is described as 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.

Recent research in science education, suggests that the constructivist approach is perhaps the most appropriate model to be implemented in classroom. According to Driver, Leach, Millar and Scott (2000), this approach promotes the construction of the knowledge, which is accepted by the wider, established scientific community to be correct. The construction takes place on the foundations of the previous ideas that learners have developed about science and scientific phenomena, mostly from their every-day life.

These ideas might be incompatible to the knowledge accepted as correct. Examples of such ideas are the notion that the sun moves around the earth and the movement of planets generally. Another example is the micro world, the molecule and atom structure and function. Relevant is the difficulty to distinguish the dissolution of substances, such as salt and sugar, which young learners might claim to disappear or melt, when poured in water. Learners adopt such ideas, mostly because it is very convenient for them to use them to explain the natural world. A simple explanation and presentation of the accepted scientific knowledge is inadequate for learners to reject them. These misconceptions have to be identified and negotiated during class, so that the learners themselves will find them invalid and adopt the correct ones (Driver et al., 2000; Linn, 2003). Such an approach requires and promotes not only science content knowledge but learner interaction, skills such as observation, analysis and critical thought, and methodological abilities, as well as attitudes towards science and scientific issues (Harlen, 2000; Driver et al., 2000).

Virtual Reality in Science Classes

The implementation of virtual reality applications in education generally and even more specifically in science classes is a topic that has attracted attention over the last years. Research has justified that can have both advantages and disadvantages (Zachert, 1975; Cook, 2006; Pantelidis, 2009).

Virtual reality, which includes the use of interactive and computer-based multimedia for participants to act in a computer-oriented world, gains increasing interest as a means to assist education in various subjects including science. The reason for that is that virtual reality provides opportunities for interaction and experimenting opportunities for the learner, helping this way all different kinds of learners, including the visually oriented ones. This is particularly interesting, especially for units that involve concepts, phenomena and measurements that are hard to manage and investigate in real life. Such units are astronomy, earth science, or the structure of the item. Thanks to virtual reality, the learners can observe these contexts, understand phenomena related to them, hypothesize, experiment, draw conclusions, construct knowledge, apply this new knowledge and understand the education benefits of the web and simulations technology.

Thanks to these advantages, using virtual reality in science classrooms has been supported by research to have several benefits. The main benefits are the promotion and development of characteristics that are compatible to the requirements of current pedagogies such as: (a) learner-centered activities, (b) active, inquiry based-learning, (c) collaborative work among teachers and learners, and (d) development and improvement of skills such as creativity, analysis, critical thought and decision-making. The reasons why these requirements are considered important is that research considers them as fundamental virtues for the future citizens, in order to be able to learn by themselves, along with to keep up with the developments in the fields of modern technology (Zachert, 1975; Cook, 2006; Pantelidis, 2009).

According to Pantelidis (1997, 2009), teachers should consider using virtual reality in science and other classes, in cases where: (a) it is easy to use a simulation, (b) teaching with the help of real objects or in real contexts is difficult, inconvenient or expensive, (c) interaction with the help of the virtual reality simulator is equally motivating to the interaction with the real objects or real contexts, (d) it is necessary to visualize, manipulate, calculate factors or information using graphics or other symbols, or (e) the experience of using or creating a visual or simulated environment is important.

However, virtual reality is no certain recipe for success. There are cases where teachers are recommended to consider avoiding using virtual reality, such as when: (a) simulations cannot provide adequate substitution for the real objects or contexts, (b) it is necessary to interact with real people, teachers, learners or real contexts, (c) using a virtual environment may hide risks or dangers for learners, (d) learners may confuse the virtual with the real environment and draw false conclusions or construct false knowledge, and (e) there is cost to be considered. In short, before a teacher decides to use virtual environments in science classes, the overall context and session aims have to be taken into consideration.

Thus, using virtual reality in a science class is claimed to have both benefits as well as risks, both of which can be identified, negotiated and analysed in relation to the context, aims and characteristics of the individual teaching intervention (Cook, 2006; Pantelidis, 2009).

The Research Project

In order to carry out a project of evaluating the effectiveness of virtual reality in a science class, it is important initially to describe it by presenting the main points of it, which are: the science subject in the implementation context, which in this case is Greek Elementary School; the plan of the project; the project's evaluation criteria, or factors that will show whether implementation of virtual reality was successful; and finally, the research questions as they emerge from the above.

Science in the Greek Elementary School

In the Greek elementary school, science exists as an independent subject in the last two grades, the firth and sixth. Up until the fourth grade, science topics are negotiated in a cross-disciplinary subject, called environmental study, which also includes topics from other subjects, such as sociology and geography. In the last two grades however, all these subjects become separated. So does science. As with every subject in the Greek public school, the teacher has to follow a packet distributed from the Ministry of Education, which includes the learners' book, workbook, and teachers' book. During the last years, electronic material is distributed too.

Following the instructions of the curriculum, the topics included in the science subjects are states of matter, mechanics, energy, heat, electro-magnetism, light, sound, living beings, ecology and anatomy of the human body.
Any activities involving materials, such as software, which are not distributed by the ministry and not proposed by the curriculum, should be examined and have their implementation formally justified. This justification should explain the reasons these applications are important to use and prove they are friendly, not risky for learners (YPEPTH, 2000; Law 3966, 2011; Karagiorgi, 2013).

The Plan of the Project

For the purpose of this project, learners took part in tasks, which involved applications of virtual reality, during science classes. A variety of software was used, in different units and different projects. The topics were planned according to the learners' interest background as well as the goals.

The software selected were mostly distributed to schools, or downloaded free of charge from the web. Attention was paid so that these pieces of software were easy-to-run and use in the school computers. Significant effort was done to find applications in the Greek language, the learners' primary language. As these were rather limited though, the majority of applications used were in

English. These visualizations might represent the micro world, energy plants, energy transformations, environmental phenomena and issues, and outer space. The applications were: (a) *Sketchup*, a software to design, draw, and organize, with already installed three-dimensional models (Sketchup, 2014); (b) *Biodigital Human*, which helped with sessions of the human body and several conditions (Biodigital Human, 2014); (c) *Celestia*, a simulation for outer space (Grigorio, 2014); and (e) simulations of the University of Colorado, which address a wide range of science topics (Phet, 2014).

Learners were presented three-dimensional visualizations and were asked to experiment with different factors, in order to observe the reactions, analyze, draw conclusions and construct knowledge. Other projects included designing and virtual constructions. Topics could be, for example, to design a virtual school science laboratory, with emphasis given on designing the appropriate space for experimentation and understanding the necessity of materials and equipment. Another topic would be to design a school, house or building that would be autonomous energy-wise.

Identifying Indicators

As Kozma and Wanger (2005) claimed, in order to monitor and evaluate accurately the impact of implementing virtual reality or any other application of Information and Communication Technologies in education, it is important to identify the appropriate indicators. Indicators are pieces of information that can describe a specific state, trend, warning or progress and help identifying inputs, outputs and generally the effectiveness of a program or project, that might otherwise be difficult to observe.

There is a wide variety of indicators to use in research projects. Selecting the appropriate ones is a crucial task. Selection has to be based on certain criteria. Basically the indicators have to be relevant to the context and the aims of the project. Moreover, using many indicators instead of few can strengthen the accuracy of the conclusions drawn. Furthermore, flexibility is necessary because, as the program goes on, many factors or goals might change or be reviewed. This might call for review of the indicators used (Wieman, Gast, Hagen & Van der Krogt, 2001). Indicators proposed for projects evaluating the effectiveness of ICT in education can be grouped in four categories:

1) Input indicators, such as school resources, teacher training, curriculum guidelines, pedagogical trends and attitudes.
2) Output indicators, such as learning outcomes, learners' attitudes, attitudes or skills, teachers' attitudes or long-term outcomes.
3) National indicators such as national test standards, national social or economic context.
4) Cost indicators in terms of establishing the appropriate equipment, internet service, maintenance (Kozma & Wagner, 2005).

For the specific project, in light of its aim as well as the time and place it was carried out, perhaps the most appropriate indicators have to be from the categories of input, output and cost. The lack of national indicators and formal national tests in Greece makes this indicator rather hard to use (YPEPTH, 2000).

In fact, output indicators are very useful for such a project. Analyzing and focusing on learners' responses, attitudes and skills can provide essential evidence whether virtual reality or any ICT application can be beneficial or risky to use when teaching any subject including classes such as science (Kozma & Wagner, 2005).

In order to get more accurate results though, it is necessary to triangulate any findings with other indicators (Cohen, Manion & Morrison, 2011). Therefore, input indicators can be useful too. School resources and curriculum guidelines can reflect the school context, in which the teacher works. It is this context in which virtual reality is being implemented. Neglecting the characteristics of this context cannot give credibility about the implementation.

Cost should also be examined. Even the most pedagogically useful ICT application might be difficult to include in teaching, if the cost is high (Kozma & Wagner, 2005).

Research Questions

Virtual Reality has been described by research to have significant benefits when used during science classes. However, research has also pointed out a number of risks that might emerge during this use. Most of these risks are linked to the school working conditions and the overall context, where the class takes place (Pantelidis, 2009).

It is necessary to evaluate and monitor the effectiveness of using virtual reality in science lesson, in relation to the context of implementation. This requires selecting the appropriate indicators, from the wide variety of those suggested. For the purpose of the Greek Elementary school context, the most appropriate are found to be input indicators, output indicators and cost (YPEPTH, 2000; Kozma & Wagner, 2005).

There are four research questions that are formed for the specific study.

The first question is "Did the use of virtual reality assist the goals of science classes?" This question is linked to output indicators focused on the learning outcomes.

The second question is "Did the learners respond positively?" This question is linked to the output indicators focused on the learners' attitudes.

The third question is "Was the school context appropriate?" This question is linked to the input indicator of the school and its' conditions, in which teaching takes place.

Finally, the forth question is "Was the cost manageable?" and is linked to the cost indicator.

Methodology

Selecting the appropriate methodology and data collection techniques is largely based on the aim of the study and the research questions. The aim of this research has to do with examining the linkage among contexts, means and human behaviors. The approach used, which is based on the analysis of learning outcomes, attitudes, working conditions and cost management, orients it more to the qualitative paradigm (Bell, 2001; Cohen et al., 2011).

In this research, 80 pupils of the fifth and sixth grade of an elementary school in Greece were involved. The action research approach was applied, as the study was designed and implemented by the teachers of those pupils. The implementation of virtual reality in the class was designed, based on the aims of each unit. The data were collected through observation of 122 sessions of both classes, 209 semi-structured group interviews with the learners and notes from learners' work samples or projects.

The data that referred to the first research question came from the learners' responses, notes, tests that reflected their understanding of the science subject knowledge and skills implementation. Learners were asked questions such as, "What did we learn today?" "What did we do in class to learn?" "Are there any things you did not understand?" "Can you explain what you've learnt to your classmates who haven't?"

The data that referred to the second research question came again from learners' responses and notes, which this time reflected their aspirations and impressions of the virtual reality implementations in class. Learners were asked questions such as "Did you like the program we used in the computer?" "Do you remember what we did with it in class?" "Did it help you understand?" and "Is there something you did not like about it?"

The data that referred to the third research question came from observing the implementation of virtual reality in class and identifying what was easy or not for the teacher to do with it.

Finally, the data that referred to the fourth research question came from estimating the cost for the school for implementation and maintenance of the software of equipment.

Findings

The findings of the study, which were in some cases positive and in others negative, can be categorized and presented in accordance to the four research questions of the project.

1st Research Question: "Did the use of virtual reality assist the goals of science classes?"

With regards to the first research question, it was found out that the use of virtual reality applications helped achieving teaching goals. Pupils understood concepts of science that were negotiated through these applications, such as energy, energy forms and transformations, molecules, atoms and their structure, and systems of the human body and their functions. Constructing this knowledge was facilitated a lot, thanks to the learners' opportunity to experiment through these applications, repeat the experiment many times when needed and finally draw conclusions. Many learners explained expressed statements such as "the computer program showed me what exactly was happening … so I know that this [the electric circuit] is not how I thought it was," which imply that the applications helped rejecting misconceptions too. This was done by learners working alone, or in groups, or under the teachers' guidance.

In relation to that, these applications offered opportunities for learners to develop skills that are also promoted by the Curriculum. Examples of such skills are observation, hypothesizing, exchange of ideas, and testing with different factors to understand patterns between concepts and phenomena. Learners for instance were able to understand the relationship between materials' density and their ability to float by doing relevant tests, where they explained that "we don't just read it, as in [the text-book], we have to think and try." They were also able to express and evaluate their ideas about what a science laboratory at schools should contain or look like.

In short, it was concluded that using virtual reality in a science class could help the successful approach to the goals of the class, such as the construction of scientific knowledge, along with the development of skills and attitudes. This justified the same finding of research and literature (YPEPTH, 2000; OECD, 2007; Pantelidis, 2009).

2nd Research Question: 'Did the learners respond positively?'

In what concerns the second research question, virtual reality was found out to be a significant stimulus of interest. Learners were very enthusiastic to see such applications used during the class, and they were willing to take part in any activity that involved them. Comments such as "these (the applications) help us understand better what we read in the book," show that they considered it a major assistance.

However, there were some rather negative points that emerged. First, not all learners were positive about watching illustrations of the human anatomy. Even though most learners claimed that "this is what our body looks, like, it is natural," there were a number who kept expressing their opinion to avoid those. Nevertheless, this number decreased during the year. Second, learners sometimes focused too much on the attractive illustrations and could not identify the actual point of using them in the classroom. Third, learners had developed an idea of virtual reality as game, such as the games they play at home and were sometimes not happy to see the particular applications used during the lesson. Those findings are compatible to the conclusions drawn by Cook (2006) and Pantelidis (1997; 2009), about risk and confusion for learners.

3rd Research Question: 'Was the school context appropriate?'

The investigation of the school context and its appropriateness showed that on one hand, there was fruitful ground to use virtual reality as means in the science class. At first, the school equipment was existent. Most applications were generally easy to use in the classroom. There was no notified negative reaction from parents and other groups about the use of such applications.
On the other hand, however, implementation involved challenges as well.

First, having only one computer to use the applications in the classroom was not always convenient. Moreover, moving learners to the computer laboratory for such classrooms was time consuming. Second, there was limited time for the teacher to carry out the regular checking before class to make sure the application was loaded and ready to be used. Third, the necessary formal justifications, which had to be done before and after any class using ICT in the classroom, demanded time. Even though this justification task was not difficult itself, it was an extra duty for the teachers, which worked at the expense of other lesson planning duties (Law 3966, 2011).

In other words, the context of the school included some features that facilitated the use of virtual reality. However, it also included others mostly in terms of time and infrastructure, that according to research should create concerns on whether to use it or not, (Kozma & Wagner, 2005; Pantelidis, 2009).

4th Research Question: 'Was the cost manageable?'

Overall, there was no significant cost necessary to implement the specific activities. Certainly, this was because basic conditions for this project had already been met and the plan of the project was based highly on the available equipment of the schools. This approach is found to be cost efficient (Kozma & Wagner, 2005). There was an already established internet service provided along with a computer laboratory in the school and one computer linked to the Internet in every classroom. Additionally, the fact that the applications used were available online free of charge, also helped carrying out these activities with no additional cost.

During the project though, it was apparent that this policy had restricted some of the possibilities for teachers. First, there were a number of software applications that were thought to be of interest and suggested by the learners, which however were not available for free. Second, as mentioned in the findings of the previous question, it was found out that only one computer in the classroom was barely enough for the teacher to work conveniently. Avoiding the options to pay for a greater variety of software applications, and especially for more computers, limited options, but did not prevent the project from being carried out (Kozma & Wagner, 2005; Pantelidis, 2009).

Conclusions

This project investigated the potential benefits from teaching science in a primary school in Greece with the help of applications of virtual reality in tasks of various topics and goals. Virtual reality is claimed through various research projects, to have both advantages and disadvantages when being used in teaching, generally and specifically in science subjects (Harlen, 2000; Linn, 2003; Pantelidis, 2009). Such an evaluation needed the appropriate indicators, which were decided to be teaching outcomes, learners' responses, school context and cost (Kozma & Wagner, 2005).

Table 1 presents a summary of the findings, listing results for each research question.

Table 1

Findings by Research Question

Research question 1: *Did the use of virtual reality assist the goals of science classes*?”	Research question 3: *Was the school context appropriate?*
✓ Learners managed to understand concepts. ✓ Learners had opportunities to experiment and draw conclusions. ✓ Learners could test their ideas and reject misconceptions ✓ Learners developed and applied skills.	✓ The equipment was already available. ✓ There were no reactions from other people, as parents. ✓ Equipment was inadequate sometimes. ✓ Preparation time was limited. ✓ There were legal restrictions.
Research question 2: *Did the learners respond positively?*	Research question 4: *Was the cost manageable*?
✓ Learners were enthusiastic generally ✓ Some of them were disturbed by illustrations of the human anatomy. ✓ Some could consider illustration as a tool to learn. ✓ Illustration was dealt with sometimes as a game.	✓ The cost was limited as the software used was available online for free and the equipment was already available. ✓ Maintenance, upgrading and further software or equipment provision opportunities were limited though.

Overall, the conclusions were both positive and negative. Learning outcomes were achieved as intended. Learners were enthusiastic; however, they did object sometimes. The school context was helpful but did have restrictions, mainly in terms of equipment and formalities. Lastly, the cost was managed to be kept low, which of course had restrictions too (Kozma & Wagner, 2005; Cook, 2006; Pantelidis, 2009).

Before generalizing any conclusions through, it is important to have in mind the limitations of the certain project. This research focused on one particular school, with a certain number of learners, in one subject, during one year. It would be interesting to compare it with other similar projects taking place in other education contexts (Bell, 2001; Cohen et al., 2011).

References

Bell, J. (2001). *Doing your research project: A guide for first - time researchers in education and social science* (3rd ed.). Buckingham: Open University.

Biodigital Human. (2014). Retrieved from http://www.biodigitalhuman.com/

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). London: Routledge / Falmer.

Cook, M. P. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education*, *90*, 1073-1091.

Driver, R., Leach, J., Millar, J., & Scott, P. (2000). *Young peoples' images of science*. Philadelphia: Open University Press.

Harlen, W. (2000). *The teaching of science in primary schools* (3rd ed.). London: David Fulton Publishers Ltd.

Grigorio, F. (2014). *Celestias' user guide*. Retrieved from http://www.celestiamotherlode.net/creators/fsgregs/CelestiaUsersGuide1-5-1.pdf

Karagiorgi, Y. (2013). Locating ICT in primary science education in a reformed Greek –Cypriot National Curriculum. *Education and Information Technologies*, *18*(1), 47-68.

Kozma, R.B., & Wagner, D.A. (2005). Core indicators for monitoring and evaluation studies for ICT in education. In D.A. Wagner, B. Day, T. James, R.B. Kozma, J. Miller, & T. Unwin (Eds.), *Monitoring and evaluation of ICT in Education Projects* (pp. 21-32). Washington DC: InfoDev.

Law No. 3966. (2011). *Institutional framework of experimental schools*. Foundation Institute for Educational Policy, Organization of the Institute of Computer Technology and Office "DIOFANTOS" and other provisions.

Linn, M. (2003). Technology and science education: Starting points, research programs and trends. *International Journal of Science Education*, *25*(6), 727– 758.

Organisation for Economic Cooperation and Development (OECD). (2007). *Education at a glance – Glossary*. Paris: OECD Publications.

Pantelidis, V. S. (1997). *Virtual reality in education and Gardner's Theory of Multiple Intelligences*. Retrieved from http://vr.coe.ecu.edu/gardner1.htm

Pantelidis, V. (2009). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education Special Issue* (pp. 59-70). *Klidarithmos computer books*. Retrieved from http://earthlab.uoi.gr/theste/index.php/

Phet. (2014). *Phet Interactive Simulations, University of Colorado*. Retrieved from http://phet.colorado.edu/

Sketchup. (2014). Retrieved from http://www.sketchup.com/

Wieman, A., Gast, L., Hagen, I., & Van der Krogt, S. (2001). *Monitoring and evaluation at IICD: An instrument to assess development impact and effectiveness* (Research report, No. 5). Hague: International Development Research Center.

YPEPTH: GREEK MINISTRY OF EDUCATION AND RELIGIOUS AFFAIRS, (2000). *Mathematics and science curriculum for primary and secondary education*. Athens: Pedagogical Institute.

Zachert, M. J. K. (1975). *Simulation teaching of library administration*. New York: R. R. Bowker Company.

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