The use of 3D virtual learning environments in the learning process

Χρήση τρισδιάστατων περιβαλλόντων μάθησης στη μαθησιακή διαδικασία

Nikolaos Konstantinou Secondary School of Kanalaki, Preveza, Greece MSc in Virtual Communities, Panteion University, Dept. of Psychology Email: nikoskon@sch.gr	Iraklis Varlamis Harokopio University of Athens Dept. of Informatics & Telematics Email: varlamis@hua.gr	Andreas P. Giannakoulopoulos Ionian University Dept. of Audio & Visual Arts Email: agiannak@ionio.gr

Περίληψη

Στη σύγχρονη βιβλιογραφία συχνά γίνεται αναφορά στην αξιοποίηση των τρισδιάστατων εικονικών περιβαλλόντων στην εξ αποστάσεως μάθηση. Ερευνητές, εκπαιδευτικά ιδρύματα, αλλά και οργανισμοί συχνά επιβεβαιώνουν την εκπαιδευτική χρησιμότητα ενός τέτοιου περιβάλλοντος, είτε υλοποιώντας εξ αρχής τρισδιάστατα περιβάλλοντα προσαρμοσμένα στις ανάγκες τους, είτε αξιοποιώντας υπάρχουσες υποδομές και πλατφόρμες. Η συγκεκριμένη έρευνα, επιχειρεί μια καταγραφή των πλέον σύγχρονων τρισδιάστατων πλατφορμών και μελετά αν και σε πιο βαθμό μπορούν να ενισχύσουν τη μαθησιακή διαδικασία στην Δευτεροβάθμια Εκπαίδευση. Για την καλύτερη κατανόηση των δυνατοτήτων που προσφέρουν τα περιβάλλοντα αυτά αλλά και των δυσκολιών που πρέπει να αντιμετωπιστούν ώστε να ενσωματωθούν επιτυχώς στην εκπαιδευτική διαδικασία, η παρούσα εργασία εστίασε σε μια πλατφόρμα ανοιχτού κώδικα η οποία μπορεί να χρησιμοποιηθεί ως ένα βιωματικό-συνεργατικό, εξ αποστάσεως, εκπαιδευτικό περιβάλλον. Στο πλαίσιο της εργασίας σχεδιάστηκε ένα μάθημα σε δύο εκδοχές: μία που κάνει χρήση του περιβάλλοντος και μια δεύτερη που χρησιμοποιεί παραδοσιακές εκπαιδευτικές μεθόδους αλλά και σύγχρονες ΤΠΕ. Δύο ομάδες μαθητών με παρόμοια μαθησιακά προφίλ αξιολόγησαν τις δύο εκδοχές και αξιολογήθηκαν ως προς τις επιδόσεις τους.

Abstract

Several research works in literature refer to the use of 3-D virtual environments in distant learning (Kirriemuir, 2008; Kahiigi et Al., 2008; de Freitas, 2006; de Freitas, 2008) .Researchers, educational institutes and organizations confirm the usefulness of such an educational environment, either by developing 3-D environments tailored to their needs, or by exploiting existing infrastructure and platforms. This paper presents an overview of modern 3-D platforms and examines whether and to what extent they can enhance the learning process in secondary education. Moreover, in order to achieve a better understanding of the possibilities offered by these environments and of the difficulties hidden in the successful integration into the educational process, we run a course using an open source 3-D platform as the main collaborative distant educational environment. More specifically, we design two versions of the same course: one that takes advantage of the new environment in order to attract students' attention and increase their collaboration and one that combines traditional teaching methods with modern ICT. The courses are evaluated by separate groups of students, with similar learning profiles. Finally, we assess the students' performance after the course and compare results.

1 INTRODUCTION

Recent improvements in ICT, such as broadband connections and powerful processors, which are nowadays available in most secondary schools, have created new opportunities for educational software. High quality multimedia applications, that utilize 3D graphics and real-time simulation, are useful tools in teachers' hands. The 3D virtual environments (3DVEs) are not a new invention. The 3-D technology has matured and gained attention, since IT companies instead of spending their efforts in designing hi-tech controllers (e.g. gloves, glasses etc), have capitalized on simple interfaces that allow multiple users to interact, to easily build custom worlds and publish their informational content.

The physical presence of participants and the sense of a shared experience inside the classroom is an integral part of the educational process. The distant learning that uses educational software, usually fails to meet these criteria, since students have a sense of isolation in their own computer systems. As a consequence, the cooperative relation between the teacher and the students is absent during the educational process. On the other hand, the 3DVEs offer new opportunities in combining the training capabilities of distant and synchronous communication with the common sense of presence and active participation. They extend single-user 3-D applications and 3-D item representations to a virtual environment, where participants are free to act, to interact with objects, to collaborate and live a shared experience. Several research works have shown that the feeling of presence in a 3DVE, for students and teachers results in a positive effect on the learning process (Russo and Benson, 2005; Selverian and Hwang, 2003). The virtual presence in a 3DVE is being built by representing individuals with virtual personas, called avatars. Avatars are able to interact with their environment and other avatars, as in real life. In a 3DVE for education, students create their virtual personas, join the virtual world and carry out educational tasks, or simply communicate with each other. As a result learning in classroom may be replaced or supplemented by learning in the virtual world, by student oriented and collaborative activities.

The aim of this research is to study whether distant and blended learning can be efficiently supported by 3D virtual interactive and multi-user environments. Since learning in the secondary education is based on sharing of experiences, interaction and constructivism, it is necessary to find a 3DVE that allows students to interact with their environment, communicate with their fellows and their teachers, act in a creative manner and feel members of a group while being inside the virtual world. For this reason, we perform a comparative analysis of state of the art 3D virtual environments and choose the one that best fits our needs.

In order to evaluate the contribution of the 3DVE in the educational process in comparison to classroom-based or blended solutions, we divide students into two groups, teach them using both methods and perform an assessment using the same set of questions. In addition, we collect students' feedback using a questionnaire that captures their level of satisfaction from each course and each teaching method, their familiarity with 3DVEs and computers in general and their experience overall.

In the following section, we present an overview of state of the art 3D platforms. In sections 3 and 4 we provide details on the design and implementation of the two courses, with emphasis to the 3DVE version. Section 5, contains the details and results of the evaluation, while section 6 summarizes our conclusions from this work and our next steps in the same direction.

2   RELATED WORK

Research in learning environments verifies the claim that 3DVE support constructivist learning tasks and that they allow participants to interact directly with the learning object/information, which is usually represented as a 3D object (Bricken & Byrnes, 1993; Dede, 1995; Winn, 1997). According to Winn (1993), traditional teaching is perceived as a "third person" experience, since tutor intervenes between student and knowledge. On the contrary, inside the virtual world, students are able to access information directly, to decide whether and where it should appear. Moreover, students are usually asked to construct part of the target information by composing existing knowledge thus moving a step towards constructivism.

The ones being skeptical about 3DVEs claim that the absence of physical contact cannot be easily replaced and needs further research. The restricted capability to convey non verbal messages is one of the disadvantages compared to traditional classroom based learning. It is our belief that 3DVEs cannot replace physical contact and real life experiences; however, they can be low cost yet valuable solutions for teachers, since they allow simulation of real objects and events. Additionally, they can be used as a basis for building persistent learning spaces, where students may interact without the presence of their teachers, as suggested by Dawley (2007). An interesting research work in this direction is Sloodle that attempts to migrate a traditional LMS (Moodle) into Second Life[1] platform (Kemp & Livingstone, 2006), thus creating richer forms of interaction for students.

The primary aim of our work is to study the efficiency of 3DVE as an educational tool, through an online course. At the same time, we intended to create a robust yet flexible implementation that can be utilized for more courses in the future and that allows fast course deployment and re-usability of sources. Finally, we aim at a free and open source solution that can operate over the existing school network and allow educators and students to interact in a common environment. In order to find the best possible solution, we study state of the art platforms and evaluate them according to our requirements. When choosing the appropriate 3DVE we bear in mind Scott's (2001) recommendation on the use of a new technology: "can be a mistake if it does not add perceived relevance and effectiveness to the course or solve a key problem" (quoted in Bonk et al, 2002).

2.1   Active worlds

Active Worlds[2] is a general purpose 3DVE, which, however, offers a specialized educational community, called AWEDU. Guests or "Tourists" can use the free AW browser in order to connect to the official AW servers and access the public areas. Subscribed members or "Citizens" have a unique user name and avatar and are allowed to browse all parts of the world for a small fee. Finally, one can be "World owner" by downloading and installing the free AW server. The platform offers many capabilities, such as object creation and composition, file exchange, synchronous and asynchronous text and voice based communication. Dickey (2005) in his work presents two case studies, where Active Worlds was used to support synchronous and asynchronous online learning in his "Business Computing Skills" course as well as provide a friendly virtual campus for the University of Colorado. The conclusion of

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[1] www.secondlife.com
[2] www.activeworlds.com

Dickey's work is that the 3DVE supported the collaborative and cooperative learning. Although the server version is free, connecting to the official servers requires a fee, and the user interface is a bit outdated.

2.2 Second Life

Second Life[3] is the most popular 3DVE. It is mainly a consumer application but has been used extensively by universities (e.g. MIT, Harvard, Edinburgh University etc.). It offers distant learning capabilities that allow teachers to design, implement and support online courses easily. Although registration is free for visitors, ownership of digital land comes at a cost. Second Life allows public access and thus follows a restrictive policy for non-adult members. It also offers distant learning capabilities that allow teachers to easily design, implement and support online courses. Participants can upload multimedia content, create or reassemble 3D content using SL's scripting language and basic shapes, without having advanced programming skills. Finally, all communications can be synchronous or asynchronous, using either audio or text. Although, Second Life was our choice on a previous attempt to create an online course for university students, we decided not to use it this time, for the following reasons:

- Having all computers in the lab to concurrently access the SL servers is infeasible over the existing 2Mbit connection.
- SL is a public space and as a result, it has a restricting policy for non-adult members. On the other side, the TeenSecondLife solution offered from Linden Labs requires a costly and complex registration process for teachers and students.

2.3 Open Simulator

OpenSimulator (or OpenSim) is open source software which allows the construction of a bespoke 3D VLE. One can build a virtual world in which many computers can get connected with multiple communication protocols. The main programme is a copy of SecondLife, therefore the way its virtual environment is depicted is identical to the one in SecondLife. Its use is free and it runs under the BSD licence. Although OpenSim is considered to be software in the alpha testing phase, it is already used formally by educational organisations and companies such as IBM, Microsoft, Nokia and Intel. It has two modes: a standalone for VPNs or LANs and a grid mode that uses multiple servers and supports many users. Most of the functionality of the OpenSimulator's server is based on the use of independently developed modules, which can be plugged in, thus adding functionality to the platform. The OpenSimulator project hosts a collection of these pluggable modules on OpenSimulator GForge[4].

2.4 Project Wonderland

Wonderland is open source software based on the client server architecture and it supports the development of applications of virtual and mixed reality. The Wonderland project is based on many technologies among which is the Looking Glass programme for the creation of scenes and jVoiceBridge6 which enables the reproduction of real sound. Accordingly, the main technology for the production of 3D graphics is Java3D, whilst it cooperates with well known programmes for building 3D graphic objects such as Blender and Maya. Finally, the same company who builds

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[3] www.secondlife.com
[4] http://forge.opensimulator.org

this software is also using it for synchronous virtual meetings of its employees at the MPK20 space [Burns, 2007]

2.5 *Croquet*

Croquet is an open-source solution for creating collaborative and application sharing environments, used for simulations, problem solving, even for multiplayer online role-playing games. It is built to support a small data transfer between the multiplayer- interconnected environments without using a central server. It runs in its on virtual machine thus it can be easily transferred to any common operating system. A number of VLEs have already been built in Croquet, e.g. by the University of Minnesota, the University of British Columbia, etc. [Smith and Kay, 2003]

2.6 *Comparison of the 3-D platforms*

Table 1 summarizes the platforms we studied and their features concerning openness and availability, re-usability of objects and portability. Based on these characteristics we decide to deploy our course in Open Simulator, which is free and open source, and at the same time resembles the popular 3DVE Second Life. The ability to import objects from Second Life and the user friendly interface allow us to adapt it to our needs.

	Active Worlds[1]	Wonderland[2]	Croquet[3] Cobalt[4]	Second Life[5]	Open Sim[6]
Open source	No	Yes	Yes	No	Yes
Free Client/Server	As guest/Yes	Yes/Yes	Free peer	As guest/No	Yes/Yes
Objects' Library	RenderWare TrueSpace script		Google 3D	Proprietary	OpenSim forge, Google 3D ,SL
Language	C	Java	Smalltalk	C++	C#
Focus	Education (AWEDU)	Any	Any	Business	Any
Capabilities	web browsing, voice chat, basic instant messaging				
	-	application sharing		easy content creation, uses scripts	

[1]http://www.activeworlds.com	[4]http://www.duke.edu/~julian/Cobalt/Home.html
[2]https://lg3d-wonderland.dev.java.net	[5]http://www.secondlife.com
[3]http://www.croquetconsortium.org	[6]http://opensimulator.org

Table 1. Characteristics of the 3-D platforms

The following section provides details on the in-class and online versions of the course, as well as on the infrastructure supporting the online course.

3   COURSE DESIGN

In order to perform a comparative study of the 3DVE, we decided to deliver the same lesson, more specifically an introduction to computer architecture, using: a) classroom teaching supported by a multimedia presentation (in-class session) and b) educational activities and informational content inside the 3DVE (online session).

The multimedia presentation comprises slides referring to the VonNeuman architecture and a brief overview of the basic components of a computer system: the motherboard, the microprocessor, the main memory, the storage devices, the input and output devices and other peripherals. All objects have been created as 3D items in the virtual environment so that the students can interact with them. Moreover, we

developed a set of assessment questions that helped us evaluate students' performance. Finally, we developed a questionnaire for the students who attended the online course in order to collect their feedback on the 3DVE and the educational process.

3.1 Lesson planning

The planning of the online and in-class lessons is based on the ARCS model of Motivational Design of Instruction (Keller, 1983), which argues that successful activities should motivate students, draw their attention, be relevant, and exert their confidence and satisfaction. We decided not to employ the more recent ADDIE instructional model (Dick and Carey, 1996) (Analysis- Design-Development-Implementation-Evaluation), which mostly refers to systematic instructional designs and would have proven too prescriptive for the nature of a 3DVE.

In accordance with the above, during the designing phase of both sessions, it was important to define the target audience and adjust any tools to the needs and preferences of the student body. These secondary school students share many characteristics with the so called 'Net Generation' (Oblinger and Oblinger, 2005), 'internet generation' or 'Millenials'. Even though they do not own a personal computer at home, their interaction with new technologies on a daily basis allows them to act confidently when dealing with ICT.

Based on the key characteristics of our Net Generation learners (connected with technology, experiential, multitasking and social), we designed the two versions of the course with the following objectives in mind:

- Enable students to interact cooperatively online with each other and their tutor in such a way so that they can feel as acting on a network.
- Give to the students the opportunity to seek and find information on demand, thus allowing them to learn constructively by doing rather than by being told what to do.
- Offer various activities for different difficulty levels and learning styles, as well as coordinate and support the multitasking action of students in the 3DVE.

Figure 1. Students completing their tasks in OpenSim

In the in-class session, we used a rich media presentation in order to attract students' attention. We used photos of computer parts and animations in order to achieve a vivid result. We provided students with details and asked several questions in order to get their feedback. However, in the absence of real computer parts we didn't perform any group tasks.

Figure 2. Displaying the presentation in OpenSim

In order to evoke students' motivation for using the 3DVE, we instructed them to create their own avatars and form groups based on the colours of their virtual clothing. After that, they were asked to collect as many computer components as possible to a predefined gathering point (Figure 1). All items were hidden inside the virtual world and students were asked to find and identify them. Later, they had to describe the items to the other members of the group and finally to work as a team and put the components in the appropriate place on a virtual motherboard. When a user clicked on an item, useful information concerning the item's role and operation was presented. The interactive part of online experience was accompanied by an online presentation (Figure 2), which was projected on a virtual wall inside the 3DVE.

3.2 The role of the teacher

The in-class experience was more teacher-centred than learner-centred since the teacher provided the students with the needed information at his presentation. The in-class lesson became more interactive afterwards, when the question-answer section was introduced.

During the online lesson, the role of the teacher was predominantly facilitative and assistive as far as the technical requirements of the 3DVE were concerned. The purpose of the collaborative activity was to motivate students to acquire computer parts and construct a working computer with the help of their classmates. The teacher was there, first in order to provide clear instructions on how to complete the activities and consequently in order to support students and solve any technical difficulties. Consequently, the online lesson was more learner-centred, active and collaborative than the real-class lesson.

Nevertheless, some students were not familiar with any form of 3D virtual environments and as a result they faced some difficulties while navigating and

interacting with the 3D objects. Consequently, it would be wise to mention that teachers who would choose to deliver their lesson in a similar online environment while being themselves away, they will definitely need to have a facilitator in the computer lab, who would intervene and assist the students, if the users are not technically experienced in using a 3D environment.

3.3 Student assessment

A performance assessment answer sheet was distributed to students. It contained 23 closed questions (fill in the gap, match, true-false, etc.) and aimed to measure the levels of remembering and comprehending the concepts that the students learned from their experiences. The same assessment quiz was given to three different student groups:

The *baseline* group (A - 16 students), was not taught any of the learning material and was asked to complete the sheet based on their previous general knowledge on computers' architecture.

The *in-class* group (B - 22 students), was taught the specific thematic unit with the typical teaching methods used in a class, such as presentation, questioning and explaining. Right after the lesson, the students were given the assessment quiz.

The *online* group (C - 18 students), participated in the online lesson. The students watched an online slides presentation in the virtual environment and completed a learning activity the aim of which was to engage them in a more active-experiential and collaborative approach to the learning material. At the end students were given the assessment quiz as well as an evaluation questionnaire.

3.4 Questionnaire

The questionnaire was distributed to group C who participated in the 3DVE. 27 evaluation questions were divided into four main categories: a) demographics; general information about the user sample (gender, technical skills, etc.), b) pedagogical evaluation, c) technical and functional evaluation of the virtual environment and d) psychosocial evaluation of the virtual environment.

Details on the results of the evaluation are provided in section 5.

4   IMPLEMENTATION

4.1 Technical specifications

The number of terminals and the size of the world set the requirements for the OpenSim server. For a virtual area of 10000 objects, of similar numbers of images and scripts, accessed by 10-15 clients, we need 5-10 GB of hard disk space at least 512MB of RAM (the more the better) and a dual core processor for the server. The installation of the OpenSim server was performed on the lab's server, which had an AMD x2 2,3 Ghz processor, 2 GB RAM, 500 GB Hard disc space, onboard graphics card and was running Windows XP SP3. The Hippo OpenSim client software was installed on every terminal in the computer lab, which had an AMD x2 processor, 1GB RAM and an Nvidia onboard graphics card each. A MySQL database on the lab's server was used to store the world's 3D objects and the objects (and avatars) created by the students. The prototype configuration faced no performance problems even when all nine terminals accessed the server concurrently.

When the requirements from the server increase, OpenSim enables to interconnect more than one server to a collaborative grid. Servers can be located on distant places, thus allowing more than one classes or schools to connect to the same 3DVE.

4.2 Content and activities design

The next step is the design of the 3D world, which can be significantly accelerated by the use of open source 3D templates for buildings and auxiliary spaces. Objects from previous courses in SL have been imported and re-used in the prototype course. Additional 3D objects, required for our activities, were created by combining basic shapes (such as squares, balls or pyramids) and formatting their properties (i.e. size, appearance, material, object's attributes, etc.). Finally, existing content, such as text, images and multimedia presentations have been embedded in the 3DVE. In order for the 3D objects to be interactive, they had to be scripted. The well-known scripting programming language LSL (Linden Scripting Language) from Second Life, was implemented in our case successfully. This scripting language is easy while there exists detailed documentation and functions ready to use[5]. Consequently, the students had the ability to interact with the 3D objects and read information about their role and function by clicking with their mouse on each object. The design and implementation of the whole project lasted seven days, working 2-3 hours per day. Accordingly, the option to store the whole environment, including the 3D objects, ensured any future use without such time requirements.

As Bonk et al (2002) point out it is important to ensure the infrastructure prior to the start of the online course. Even though the students' experience in the 3D world in this study is not an integral part of their studies, it is still very important to secure that all participants have a computer and an internet connection of reasonable capacity both at home and at school. Consequently, the lack of computers and the need to use the school computer lab in order to complete this study set the practical boundaries in experimental settings like the one under discussion.

In accordance to the suggestions made in literature review (Garrison and Anderson 2003, Salmon 2004, Bonk et al 2002), part of the learning activity was an introductory session, which took place a couple of days prior to the online experience. The purpose of this introductory session was to familiarize the students with the technology used whilst addressing any questions and technical difficulties.

As far as student assessment is concerned, we created a set of multiple choice questions in hardcopy, and evaluated the participants of each session on an individual basis. Also students who participated in the online course were given a paper questionnaire, which they used for the evaluation of the 3DVE. The overall evaluation of students and the evaluation of the 3DVE from the students are discussed in the following section.

5 EVALUATION

5.1 The evaluation of the 3DVE

The aim of the platform evaluation questions (listed in Appendix) was to depict the interest of users for the online course, collect their complaints and uncover their difficulties in using the platform. As a consequence, the questionnaire was filled by students from group C only (online group) and comprised questions that cover the pedagogical, technical and psychosocial aspects of the course.

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[5] *http://www.lslwiki.net/lslwiki/wakka.php?wakka=HomePage*

5.1.1. Pedagogical evaluation

According to the results in Figure 3, students showed clearly their satisfaction and excitement when asked about their use of the 3DVE. They preferred participating in this creative way of learning over attending a typical in-class lesson, because they had an active role to play for the completion of the lesson.
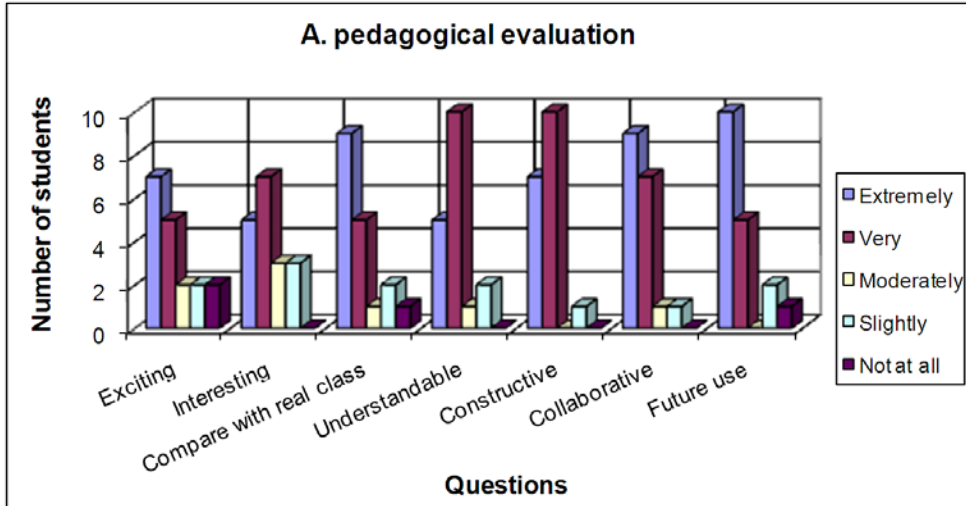

Figure 3. Results of the pedagogical questions

They perceived the lesson to be very understandable due to the various activities they were engaged in. They enjoyed the collaborative activity of collecting computer parts and the constructive task of assembling them after further reading about their function. Only 2 students faced difficulties in working with their fellow students. Finally, almost all students showed a clear interest in further using 3DVEs for learning other subject areas in the future.

5.2 Technical-functional evaluation

In the technical and functional evaluation of the environment, only 4 (out of 18) students reported that they faced some difficulties. Accordingly, the majority of students found the environment easy to navigate and thought that the avatars were lifelike enough, although they expressed the desire to have the graphics and figurativeness of the environment improved.
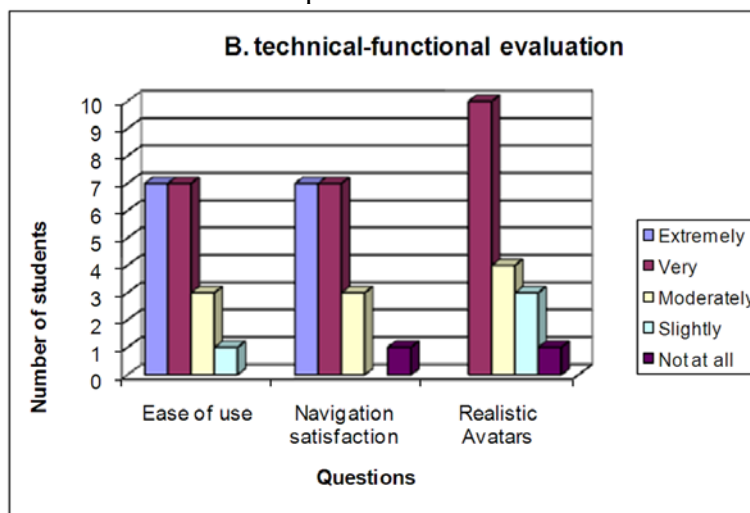

Figure 4. Results of the technical-functional questions

5.3 *Psychosocial evaluation*

The sense of being present in the 3DVE proved to be extremely high among students. More than half of the students (11 out of 18) would prefer to name their avatar after their real name, thus identifying their real self with the virtual self. The rest replied that they wouldn't, which is also understandable as they created their avatars in a short 2 hour familiarity session.
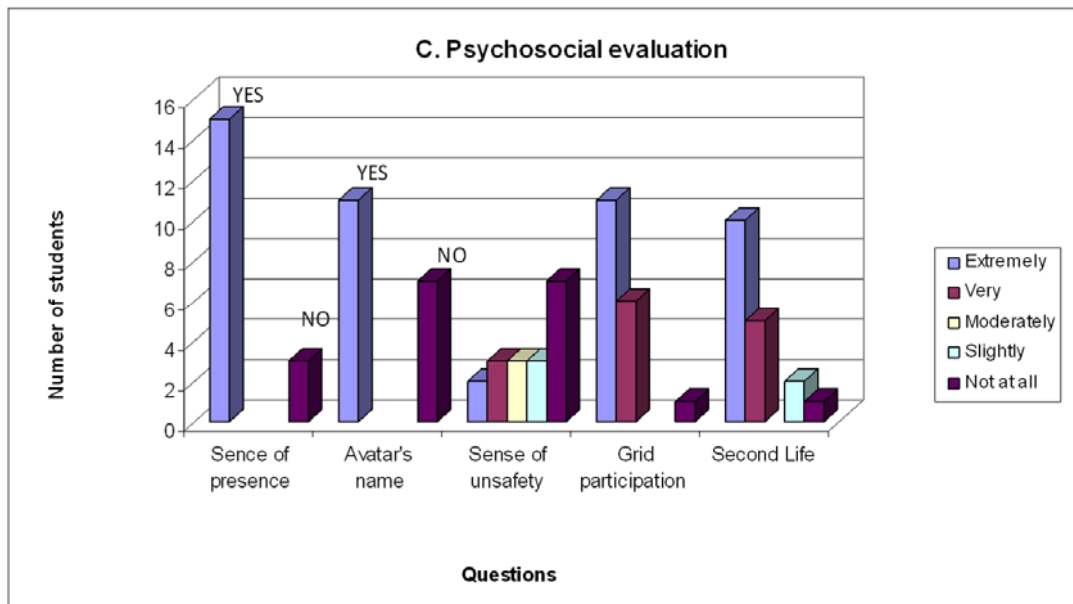

Figure 5. Results of the psychosocial questions

Some students (7 out of 18) answered that they would not feel unsafe at all to collaborate with strangers in other online virtual worlds. The other 11 students showed from moderate to high anxiety as far as safety was concerned. In general though, they were extremely interested in connecting the environment with other online worlds for meeting other students and for collaborating with them. Likewise, there was extreme interest in using SecondLife, which has many interconnected users who socialize and network freely.

5.4 **Students' assessment**

Kay and Knaack (2007) use an assessment tool to evaluate the use of web based learning tools, such as the 3D world used for this study, and found that overall usefulness, clear instructions, organized layout and good theme/motivation are very important to students.

Apart from the above, it is necessary to provide evidence, which can support the usefulness and pedagogic impact of the 3D world. It is important to highlight the effect of the online learning experience to the student performance and estimate its pedagogic value. In order to evaluate how effective this learning activity was, a test was distributed to the three groups of students who participated in this study. As it was mentioned above -in the 'Design of the online and in-class sessions' section- the first group of students was not given any material to study prior to the test. The second group participated in the course which was delivered in the classroom by the teacher with the use of a projected presentation. Finally, the third group of students participated virtually in the 3D world by interacting online with each other and the teacher, viewing an online presentation, getting instant information about the parts of the computer used and collaboratively completing the online exercise.

The results of the test, which are depicted in Figure 6, showed that the first group answered correctly to the 35% of the questions in average (8 correct answers out of 23 questions), the second group answered correctly to the 56.5% of them (13 out of 23) and finally the third group achieved a 74% of correct answers (17 out of 23).
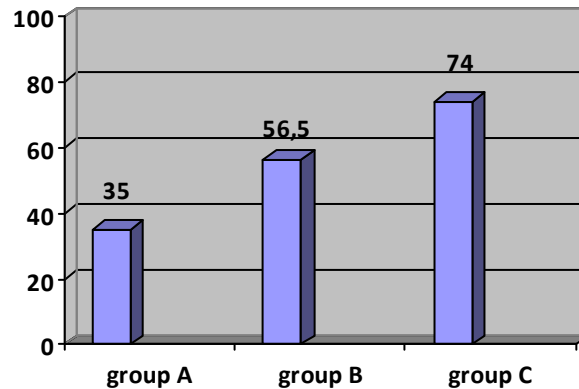
Figure 6. Results of the student assessment tests

In comparison to the students of the baseline group (A), the students of the in-class group (B) showed an increase in performance by 21,5% whereas, students of the online group (C) almost doubled the correct answers (an increase in performance of 39% in comparison to the baseline). Apparently, this significant gap resulted from the further learning activities through which the students in group C had the opportunity to interact with the lesson's concepts and comprehend them better. An equivalent learning activity in the classroom with real computer parts would potentially have similar results. Its materialization though depends on spatial and hardware constraints which make it extremely difficult as a teaching method. At this point, it is important to pinpoint that the use of a 3DVE does not aim to replace the lesson in the classroom, but to offer solutions to specific problems and to enhance the learning process by enriching it with constructive, collaborative and experiential activities.

6   CONCLUSIONS

This paper dealt with the application of the 3DVE OpenSim at the computer lab in Kanalaki's High School. Our goal was to explore the virtual environment's effect on the learning process on a local level, as well as to test the specific environment as a distance learning environment. It is more apparent now that -as the hardware and software construction technologies have matured- the possibility to apply these methods is feasible as it is cost effective and requires no special knowledge apart from some experience in finding tutorials online.

The OpenSim 3DVE has certain advantages over other 3D worlds, such as the relatively easy design and materialisation of learning activities which can have a positive impact on students' performance. If the possibility to apply these methods in distance learning is also taken into consideration, then it becomes apparent that this is a beneficial and productive learning tool in the current educational reality.

Students' comments suggest that they found the 3D environment interesting and amusing. It improves the ability of students to construct objects, to learn and share their knowledge. It allows collaborative tasks to be assigned to student groups and educators to co-ordinate and support students' activities. The ability to interconnect virtual worlds in OpenSim offers the opportunity to create a wider grid for communication among distant school units of the Greek

school network which could become a virtual educational community for both students and teachers. The next steps of our work is to attempt to deploy the same course across more than one schools thus allowing students from different backgrounds to interact in the same virtual environment.

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APPENDIX - Evaluation questions

Pedagogical
Exciting: 'How exciting was the virtual environment you used for the needs of the lesson?'

Interesting: 'How interesting did you find the lesson than was delivered completely online in the 3D environment?'

Compare with in-class: in comparison with the equivalent lesson delivered in class, did you find the 3DVE experience better or worse?'

Understandable: 'How understandable was the delivery of the lesson with the use of slides and other media in the 3DVE?'

Constructive: 'Do you agree with the following sentence?- 'Assembling the virtual computer parts helped me understand their function".

Collaborative: 'Did you collaborate with your fellow students in order to complete the virtual activities?'

Future use: 'Would you use in the future a similar virtual environment for learning other subject areas?'

Technical – Functional
Ease of use: 'Was the use of the virtual environment easy enough?'

Navigation satisfaction: 'Were you satisfied with the navigation around the virtual environment?'

Realistic avatars: 'Do you think that the avatars were realistic?'

Psychosocial
Sense of presence: 'Did you have the sense of being present when interacting in the 3D virtual world?'

Avatar's name: 'Would you like your avatar to have your real name?'

Sense of safety: 'Would you feel unsafe to meet other students you don't know in an online 3DVE?'

Grid participation: 'Would you like our 3DVE to be connected with similar 3DVEs (OpenSim grids) in order to meet and collaborate with other students from all over the world?'

SecondLife: 'Would you like to use SecondLife, a readymade virtual world, with thousands of residents connected simultaneously?'