Handbook of Research on Technology-Centric Strategies for Higher Education Administration

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Chapter 11
Teaching Basic Astronomy Concepts to Pre-Service Teachers Using 3D Virtual Environments:
Results of a Study in Greece

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ABSTRACT

The study examines the use of two 3D virtual environments for teaching basic Astronomy concepts, to pre-service teachers. The motivation was the fact that pre-service teachers know very little about Astronomy and that the virtual environments can be used as tools for successfully teaching concepts related to this scientific field. Two online courses were also developed, in order to compare the learning outcomes. A hundred and twenty randomly selected students from the Department of Primary School Education, University of the Aegean participated in the study, divided into six groups. Two groups used the virtual environments, two groups used the online courses, while the last two were the control groups. Data was collected using evaluation sheets, questionnaires, and log files. Data analyses indicate that even though all groups that used an application showed significant progress regarding knowledge acquisition, the groups that used the virtual environments had better results. Implications are also discussed.

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INTRODUCTION

A common finding in several studies among students and adults is the broad range of problems, difficulties, and misconceptions they have, even for basic astronomical phenomena (e.g., Duit 2006; Bailey & Slater, 2003; Gazit, Yair, & Chen, 2005; Barnett, Keating, Barab, & Hay, 2000). For example, young students believe that the Earth is flat (Vosniadou, 2012). Older students cannot grasp the rotation of the Earth and of the other planets (Ozsoy, 2012). Astronomical distances are also a problem; the vastness of the universe (distances and sizes) is beyond the comprehension and the perceptual experience of most people (Miller & Brewer, 2010). Research has also shown that these misconceptions are persistent (Clark, Kirschner, & Sweller, 2012). For example, mistakes regarding lunar phases are, more or less, the same in many countries, in all ages, over many decades (e.g., Kuethe, 1963; Ault, 1984; Sadler, 1998; Trumper, 2003) and teaching does not always succeed in correcting these mistakes (Schoon, 1995; Stears, James, & Good, 2011).

Abstract and multi-dimensional phenomena are challenging in their comprehension and application. In order to understand astronomical phenomena, as well as other scientific concepts, individuals create mental models (Redish 1993; Barnett et al., 2000). These models are explanations of what we see, in a way that makes sense to us. Students come to school having preconceived notions of scientific concepts not compatible with the scientific thought and conceptual change is difficult (diSessa, 2006; Duit, 2006; Brown & Hammer, 2008). Young children start with the view that the Earth is flat, based on their experience that the ground is flat. Later, when they are taught that the Earth is round, they change their Earth model into a disk-shaped Earth (Vosniadou, 1991). They integrate the new information into the existing model, instead of discarding it. However, once a model takes root, disregarding it, or even changing it, might prove to be a challenging task. Students will often stubbornly maintain these misconceptions, especially in physics (Casperson & Linn, 2006). Teachers have to be aware of their students' mental models, understand the underlying reasons that led to these models and adapt the curriculum so to address these misconceptions.

It seems that students are not the only ones facing problems in understanding concepts related to Astronomy and physics in general. Both pre- and in-service teachers have problems in teaching physics topics (diSessa, 2000). Concepts with complex abstractions and few real-life references, or ones that incorporate invisible factors or forces, are particularly challenging for them (Chi, Feltovich, & Glaser, 1991). Supporting pre-service teachers in learning basic physics concepts has also proven to be a challenging task (Schoon & Boone, 1998; McDermott & Shaffer, 2000). When it comes to Astronomy, the literature suggests that in-service as well as pre-service teachers, experience difficulties in apprehending even very basic knowledge related to this science (e.g., Kanli, 2015, 2014; Trumper, 2006a). It is also noted that their misconceptions are very similar to the ones that younger students have (e.g., Frede, 2006; Trumper, 2003).

Pre-service teachers' difficulties in subjects related to Astronomy may also imply difficulties in other scientific fields, such as mathematics, physics, and chemistry. It is a paradox to expect teachers to be potent in their job while at the same time they lack understanding of major scientific subjects. Therefore, an intervention to rectify the problem is quite important. In line with the above, the main objective of the present study is to present the results of a project designed for teaching basic Astronomy concepts to pre-service teachers. For that matter, a 3D virtual environment was developed and its results were compared with the results of other, more conventional, teaching methods, as presented in the coming sections.

BACKGROUND

3D virtual environments (VEs) simulate real or imaginary environments that give users the sense of "being there" (Hew & Cheung, 2008). From a technical perspective, they use a set of hardware and software with which people are able to visualize and interact with highly complex data in three dimensions (Aukstakalnis & Blatner, 1992). Their three main features are immersion, interaction, and imagination (Burdea & Coiffet, 2003).

- **Immersion:** The illusion of being "present" the simulation. It largely depends on the type of the simulation.
- **Interaction:** User's actions result in reactions from the simulation and vice versa.
- **Imagination:** Any kind of an environment, real or imaginary, can be realized in a VE.

VEs' significance in education lies in the fact that they enable learners to explore the virtual environment, use and manipulate virtual objects, and so they encourage them to express their personal thoughts and to construct their knowledge (Pan, Cheok, Yang, Zhu, & Shi, 2006). Also, the interactions with the virtual objects or with other users, enable students to become active learners (Mikropoulos & Natsis, 2011). VEs attract the interest of students and, in combination with the sense of presence and the in-world activities, the educational process becomes more effective (Mikropoulos, 2006; Martin et al., 2011). Teachers are capable of customizing the teaching material to the needs and learning styles of each student so that they can learn at their own pace (Lee & Wong, 2008).

With regard to Astronomy teaching, conventional teaching methods are not adequate to address the difficulties that students as well as in- and pre-teachers have. The effectiveness of textbooks, charts, slides and illustrations is questionable because it is difficult to conceptualize 3D objects using 2D depictions (Nussbaum, 1979; Baxter, 1989). Experiments, demonstrations, and visualizations can help students to grasp physical phenomena (diSessa, 2000; Hewitt, 2002). Through visualizations, simulations, and interactive learning experiences, students can make connections between the learning material and the real world (diSessa, 2000; Linn & Eylon, 2006). In this context, VEs can become an essential tool since they are simulations that give students the chance to come in contact with environments that resemble real ones, thus having the ability to discover and use knowledge in its actual context (Barnett, Yamagata-Lynch, Keating, Barab, & Hay, 2005).

Literature suggests that 3D models, simulations, and VEs are important tools for teaching concepts related to Astronomy, but also for addressing related misconceptions (Barnett et al., 2005; Bakas & Mikropoulos, 2003). A 3D simulation can encompass both small and large scales. This can prove helpful in understanding astronomical distances (Schneps, Ruel, Sonnert, Dussault, Griffin, & Sadler, 2014). Side-by-side comparisons of a rocky planet and a gas giant would be difficult with physical models, but can be performed easily in a 3D simulation (Chen, Yang, Shen, & Jeng, 2007). A VE does not only incorporate astronomical phenomena, but it can also reflect the rules of physics if programmed accordingly (Dede, Salzman, Loftin, & Sprague, 1999). This, together with the representation of the content in a non-textually-mediated way, allows students to understand complex concepts and, later on, use this knowledge to interpret real scientific problems (Squire, Barnett, Grant, & Higginbotham, 2004). Finally, an important aspect of such applications is the ability to manipulate time and space. Most astronomical phenomena are time-dependent. Although a multimedia application or an animation could present an astronomical phenomenon at different times, the viewpoint is fixed (Pasachoff, 1996). In a 3D simulation, the user has the freedom of moving to multiple perspectives in time as well as in space (Mintz, Litvak, & Yair, 2001).

MAIN FOCUS OF THE CHAPTER

As it was already mentioned, pre- and in-service teachers experience difficulties in apprehending even very basic astronomical knowledge. In addition, their misconceptions are persistent (Korur, 2015), as in younger students. Other researchers have pointed out that pre-service teachers acquire very little scientific knowledge during their studies (e.g., Frede, 2006). For pre-service teachers to become able to teach Astronomy concepts properly, significant effort must be made in order to help them correct their misconceptions and to develop their understanding in this field (Trumper, 2003).

The problem appears to be more intense in Greece. The vast majority of students studying at the departments of primary education in Greece have a theoretical background; in high school they studied, in-depth, literature, language, and history, but science lessons played an unsubstantial role in their education. As a result, when studying at the university, their failure rates in mathematics and science courses are very high (Stamelos & Emvalotis, 2001).

While extensive research has been conducted regarding the use of VEs in all levels of education, disproportionally less research targeted pre-service educators (primary and secondary education) in relation to Astronomy. From the review of the relevant literature, the authors found that in a number of studies researchers used just 3D models (e.g., Küçüközer, 2013; Barnett et al., 2005) and in some cases, no conceptual change was noted (Trundle, Atwood, & Christopher, 2002). When more comprehensive applications, like VEs were used, the results were considered satisfactory (e.g., Keating, Barnett, Barab & Hay, 2002; Trumper 2006b; Shin, Kim & Kim, 2006).

SOLUTION

Having in mind the relative lack of research in using VEs to address pre-service teachers' problems regarding the understanding of Astronomy related subjects, the authors decided to use a VE for teaching basic Astronomy concepts to them. The target group was students studying at the Department of Primary School Education, University of the Aegean. Since the learning content in many of the studies mentioned in the previous section focused on planets and the solar system in general, a portion of the application would also be dedicated to presenting our solar system. For that matter, a VE that was previously developed by the authors was used, as an initial basis. This VE was tested in a pilot project and it was addressed to pre-service teachers (Mastrokoukou & Fokides, 2015). Furthermore, the authors decided to include space exploration too, because no previous research has been conducted on pre-service teachers regarding this subject. This part of the application was also based on a previously developed VE that was used by high-school students (Fokides & Atsikpasi, 2016). Both of the aforementioned VEs were extensively restructured and updated; more 3D objects and more learning material was added. Moreover, on the basis of the feedback from the participants, in both of the previous studies, the authors decided to add more interactions with the 3D objects, because this was considered as the applications' most significant disadvantage. Therefore, a substantial effort was put into adding scripts (small programs) that allowed interactions to take place.

For the re-development/re-design of both virtual worlds, OpenSimulator was used (http://opensimulator.org/). OpenSimulator is an open source multi-platform, multi-user 3D application server. Virtual worlds can be accessed through a variety of clients and across the web. OpenSimulator allows virtual world developers to customize their worlds using a variety of technologies and the framework is extensible. Both applications were to be hosted on the Department's Opensimulator server.

During the course of the development, the authors decided to split the application into two separate applications; one for teaching facts and concepts regarding space exploration (VE1) and one for teaching facts and concepts regarding solar system (VE2). This was done because of:

- **Technical Limitations:** The total virtual space of the application was 2048X2048 meters. Although this is not a problem for servers running Opensimulator, only high-end client computers can handle such an oversized VE, without significant lagging (unsatisfactory application's display speed).
- **The Cognitive Load:** In view of the amount of the learning material which was added to the already existing one, it became clear that it would be very difficult for an individual to handle all of it at once.

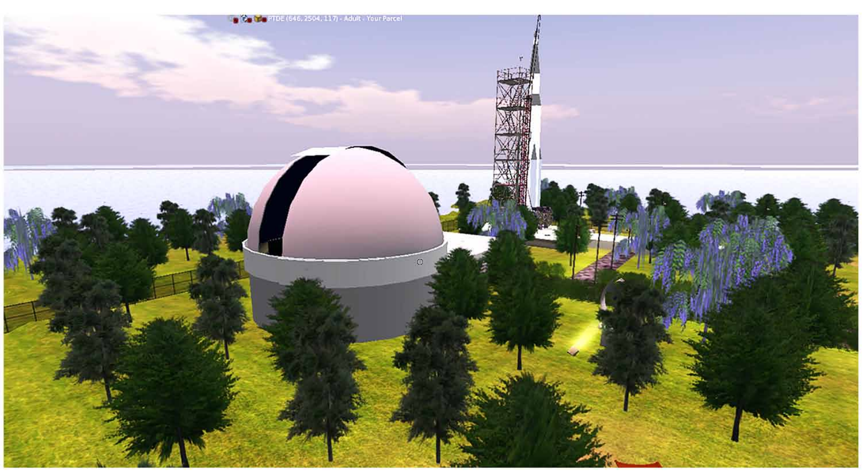
VE1 had two levels. On the ground level, the technology behind space exploration was presented. A wealth of highly detailed 3D models was included; from the first rockets to the space shuttle, space suits, rocket engines, a rocket launch pad, moon vehicles, the Mars Rover, to name but a few (Figures 1-2). Scripts were added that allowed interactions to take place; the user could launch the Apollo 11, ignite rocket engines, disassemble a multistage rocket and see its stages, put rockets side by side and compare them, teleport from one place to another, to name a few. Videos and slide presentations were also included, providing more detailed information on all objects. The second level, which was placed high in the sky, presented man-made satellites. Gravity was set to zero so that users could float in space. Once again, the user could interact with objects (e.g., put satellites side by side and compare them or disassemble them and get information on each of their main parts). The learning objectives of the application were not just to provide detailed information on rockets and satellites, but to allow users to understand how they function and to make comparisons.

Figure 1. The first level of VE1

Figure 2. 3D models on the first level of VE1

VE2 had three levels. On the ground level, an observatory was placed where the users could get the first piece of information about the solar system through images and videos (Figure 3). The second level, which was placed high in the sky as in VE1, was the first depiction of the solar system, including the Sun and the eight planets. High-resolution photos were used for texturing the planets. Users could observe the planets' rotation on their axis, as well as their revolution around the Sun. Satellites were also revolving around their respective planets. All celestial bodies were designed on a scale, however, due to the actual size of the solar system in comparison to the limited size of the virtual world, the distances of the planets from the Sun remained relevant but not scaled. Revolving speed around the Sun of all planets was adjusted accordingly so that Neptune could complete one revolution in one hour. Planets' orbits and axial tilts were accurately presented.

Figure 3. The first level of VE2



The third level was the second illustration of the solar system. At this level, students were informed about the solar system, by observing the planets, seeing slides and watching related videos. Scripts allowed the users to stop, restart, change the planets' revolving and rotation speed, but also to move the planets and to compare their sizes, rotation, and gravity. This was a crucial part of this VE, because users could automatically get the results of the comparisons they choose to make. The same could be done with the satellites that were included in this level. The amount of information to be presented to the users was kept minimal. As in VE1, the learning objectives of the application were not to "teach" in depth about each and every planet but to allow users to understand the rotation of the planets, their relative sizes, and distances from the Sun and to make comparisons. For instance, the focus was not on the exact diameter of a planet (although the figure was presented), but on how many times it is smaller or bigger than the Earth. Finally, instructions on how to use the application were added. At their final stages, both applications were given to a small group of users to test their integrity and minor changes were made.

The most laborious procedure -besides the actual re-design of the virtual worlds- was the addition of the interactions with the virtual objects, although in some cases ready-made scripts were used. The collection of the learning material, and later adding it to the applications, was also a time-consuming process. In general, the development of a virtual environment is quite a lengthy procedure. One might claim that the cost of developing such applications (in terms of hours spent) is high, compared to other types of computer applications (e.g., multimedia). On the other hand, others might argue that the learning results such applications might yield are worth the labor.

A fact that has to be stressed out is that both applications did not include any kind of exercises or guidance. Users could freely explore the virtual worlds, interact with whatever objects drew their attention, and study whatever learning material they were interested in.

In parallel with the development of the virtual worlds, two complete online courses were developed (LMS1 and LMS2), having the same learning material (images, videos, and texts) the virtual worlds had. Each course was divided into subsections, depending on the subject they were discussing. The courses were then uploaded to the Department's learning management system (LMS) so that they could be accessed by the students. Once again, users would be free to study whatever subsection they were interested in and with no particular order. The reason for developing these online courses was because the literature suggests that their learning outcomes are comparable to conventional teaching (e.g., Neuhauser, 2010). Consequently, two online teaching methods were devised; one using the virtual worlds and one using the online courses. In late February 2016, after having finished both the VEs and the online courses, an invitation was issued by the authors, addressed to students studying at the Department of Primary School Education, University of the Aegean, to participate in the study. Indeed, a number of them responded affirmatively, as it is presented in the following section.

RESEARCH DESIGN AND PROCEDURE

The sample of the study consisted of 120 students. They were divided into 6 groups of 20; two groups were going to use the VEs (VE1 and VE2), two were going to use the online courses (LMS1 and LMS2), while the last two were the control groups (CG1 and CG2) and were not going to use any application or any other kind of learning material. Groups VE1, VE2, LMS1, and LMS2 had one week at their disposal to study the learning material. Since all the applications were accessible online, there were no restrictions regarding how many times and for how long one would access the application that was assigned to him/her. These research settings were used mainly for two reasons. Control groups were included so that it would be possible to compare the learning outcomes of both types of applications against what pre-service teachers already know. Secondly, although one (bigger) group of students could use both the VEs and another both the online courses, the authors view was that, together, both the VEs, or both the online courses for that matter, contained too much information that had to be assimilated in a very a short period of time. Because of that, it was possible that participants would be overwhelmed and/or lose their interest in participating in the study. One has to be reminded that the whole setting was based on informal educational settings; it was not a formal academic course. Therefore, the participants' interest in using the applications was a crucial factor (Livingstone, 2001).

For data collection purposes a total of 4 questionnaires were devised:

Questionnaire 1 (Q1): It was to be administered to groups CG1, LMS1, and VE1. It consisted of 4 questions regarding demographic data and 24 questions, divided into 2 groups, regarding space exploration. All questions were relevant to the material presented in both types of applications. The focus of the first group of questions was in concepts' comprehension (cc1) while the second one tested knowledge acquisition (ff1). Each group was divided into 2 sub-groups of 6 questions each.

Questionnaire 2 (Q2): It was to be administered to groups CG2, LMS2, and VE2. Its structure was the same as in Q1 (cc2, ff2), but the questions were about the solar system.

Questionnaire 3 (Q3): It was to be administered to groups LMS1 and LMS2. Its purpose was the technical, functional and efficacy evaluation of the online courses by the students.

Questionnaire 4 (Q4): It was to be administered to groups VE1 and VE2. Its structure was the same as in Q3, but it dealt with the evaluation of the virtual worlds.

The groups and sub-groups of questions in Q1 and Q2 are presented in Table 1.

Prior to using the applications, participants were gathered and briefed regarding the procedures. They were asked to study the material and they were also informed that they were going to be evaluated. At the end of the week all groups, including the control ones, were gathered once again, to complete Q1, Q2, Q3, and Q4. The reason for not administering the questionnaires online was to avoid possible cheating and to ensure the reliability of data. Since both the LMS and the Opensimulator server keep log files regarding logging on and off, these records were also going to be used for assessing how much time participants spent in studying the applications.

Table 1. Groups of questions in Q1 and Q2

Questionnaire	Groups of questions	Sub-Groups of questions
Q1	Concepts' comprehension questions (cc1)	Rocket engines and stages: how they function, differences, comparisons
		Man-made satellites: how they function, types, purposes, differences, comparisons
	Facts and figures Questions (ff1)	Missions to the Moon and Mars and to the rest of the solar system
		Curious-interesting facts and figures about rockets and satellites
Q2	Concepts' comprehension questions (cc2)	Planets: sizes, distances, orbits, gravity, comparisons
		Planets' satellites: sizes, gravity, comparisons
	Facts and figures Questions (ff2)	Composition of the planets and the Sun
		Curious-interesting facts and figures about planets and satellites

The aforementioned procedure was to examine the following hypotheses:

H1: The use of a virtual environment regarding space exploration produces significantly better learning outcomes compared to an online course with the same content.
H1a: These results are significantly better at the level of concepts' understanding.
H1b: These results are significantly better at the level of knowledge acquisition.
H2: The use of a virtual environment regarding the solar system produces significantly better learning outcomes compared to an online course with the same content.
H2a: These results are significantly better at the level of concepts' understanding.
H2b: These results are significantly better at the level of knowledge acquisition.

Results Analysis

The majority of participants (80%) were females, reflecting, more or less, the actual gender distribution of students. All of them were at the age range of 20-25. Also, a 65% considered themselves as being "average computer users." All of them had successfully attended at least one mandatory course in computer usage and a 60% had taken at least one course in advanced uses of ICT in education.

For the analysis of the results in Q1 and Q2, a score was computed for each group of questions (min. = 0, max. = 12) and in total (min. = 0, max. = 24), on the basis of the number of correct answers. Mean scores, per application, per group of participants, and per group of questions, are presented in Table 2 while mean total scores are also presented in Figure 4.

Results Analysis of Total Scores Q1 and Q2

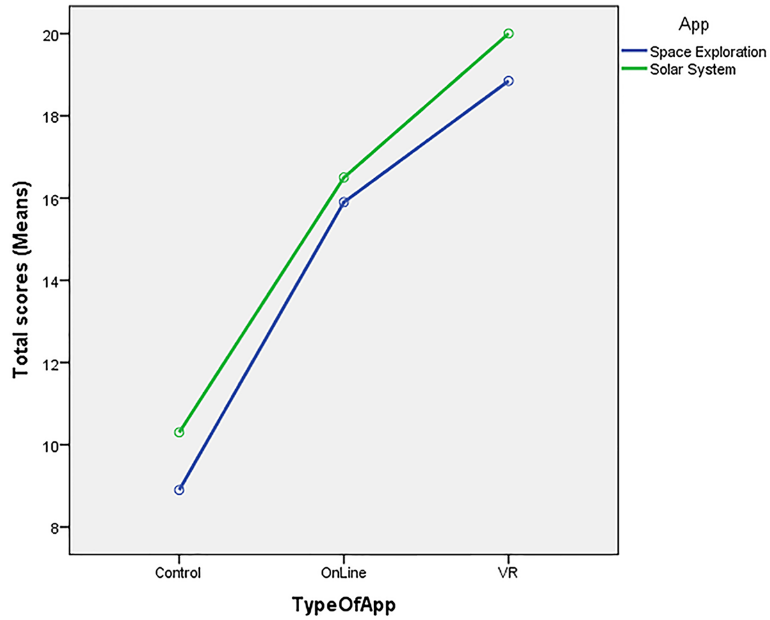
A One-way ANOVA was to be conducted in order to compare the effects of the type of application used (control, LMS1, and VE1) on the total scores in Q1 and in Q2. Prior to conducting these tests, it was checked whether the assumptions of ANOVA testing were violated. All groups had the same number of participants ($N = 20$), there were no outliers and the data was normally distributed, as assessed by Q-Q plots and Shapiro-Wilk test (p >.05 in all cases). Homogeneity of variance was also not violated, as assessed by Levene's Test of Homogeneity of Variance (p =.76 for Q1 and p =.13 for Q2). Since all assumptions were met, the authors proceeded with the analysis. The analysis of the variance showed that the type of application used, had a significant effect on total scores in Q1, $F(2, 57) = 464.13$, $p < .001$ and in Q2, $F(2, 57) = 338.77$, $p < .001$.

Table 2. Means and standard deviations of the applications' questions groups

	Space Exploration (Q1)						**Solar System (Q2)**					
	CG1 (*N* = 20)		**LMS1 (*N* = 20)**		**VE1 (*N* = 20)**		**CG2 (*N* = 20)**		**LMS2 (*N* = 20)**		**VE2 (*N* = 20)**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
a	4.60	0.75	8.50	0.76	10.35	0.88	5.15	0.93	8.10	0.91	10.35	0.93
b	4.30	0.57	7.40	0.88	8.50	0.76	5.15	0.67	8.40	0.94	9.65	0.75
c	8.90	0.97	15.90	1.07	18.85	1.14	10.30	1.13	16.50	1.43	20.00	0.97

Note. a = concepts' comprehension questions, b = facts and figures questions, c = total

Figure 4. Applications' total scores comparison chart



Post-hoc comparisons were conducted using the Tuckey HSD test on all possible pairwise contrasts. The authors found that all pairs of groups were significantly different at the p <.05 level.

Q1: The mean total score in Q1 for the group VE1 (M = 18.85, SD = 1.14) was significantly higher than that of group LMS1 (M = 15.90, SD = 1.07) and both were significantly higher than that of group CG1 (M = 8.90, SD = 0.97).

Q2: The mean total score in Q2 for the group VE2 (M = 20.00, SD = 0.97) was significantly higher than that of group LMS2 (M = 16.50, SD = 1.43) and both were significantly higher than that of group CG2 (M = 10.30, SD = 1.13).

Taken together, these results suggest that the type of application a participant used, had a statistically significant effect on his/her total score in Q1 or in Q2. More specifically, the use of a VE produces statistically significant better learning outcomes compared to an online course with the same content. Therefore, H1 and H2 were confirmed.

Results Analysis of Scores in Concepts and Facts and Figures Questions in Q1 and Q2

Prior to conducting statistical analysis on the results of the two groups of questions in Q1 (cc1, ff1) and in Q2 (cc2, ff2), it was checked whether the assumptions of ANOVA testing were violated. Some minor issues regarding the normality of data were found. Like other parametric tests, the analysis of variance assumes that the data fit the normal distribution. On the other hand, literature suggests that ANOVA is robust to moderate deviations from normality -as in this case- and the false positive rate is not affected very much by this violation of the assumption (Glass, Peckham, & Sanders, 1972; Harwell, Rubinstein, Hayes, & Olds, 1992; Lix, Keselman, & Keselman, 1996).

Since there were no outliers, the absolute values of the skewness and kurtosis for the data were no more than twice their respective standard errors and the homogeneity of variance was not violated, as assessed by Levene's Test of Homogeneity of Variance (p =.56 for cc1, p =.16 for ff1, p =.97 for cc2, and p =.10 for ff2), the authors decided to proceed with the analysis. The analysis of variance showed that the type of application used (CG1, LMS1, and VE1), had a significant effect of on scores in cc1 [$F(2, 57) = 270.20$, $p < .001$] and on scores in ff1 [$F(2, 57) = 168.98$, $p < .001$]. The type of application used (CG2, LMS2, and VE2), also had a significant effect of on scores in cc2 [$F(2, 57) = 158.55$, $p < .001$] and on scores in ff2 [$F(2, 57) = 171.34$, $p < .001$].

Post-hoc comparisons were conducted using the Tuckey HSD test on all possible pairwise contrasts. It was found that all pairs of groups were significantly different at the p <.05 level:

- **Cc1:** The mean total score in cc1 for the group VE1 (M = 10.35, SD = 0.88) was significantly higher than that of group LMS1 (M = 8.50, SD = 0.76) and both were significantly higher than that of group CG1 (M = 4.60, SD = 0.75).
- **Ff1:** The mean total score in ff1 for the group VE1 (M = 8.50, SD = 0.76) was significantly higher than that of group LMS1 (M = 7.40, SD = 0.88) and both were significantly higher than that of group CG1 (M = 4.30, SD = 0.57).
- **Cc2:** The mean total score in cc2 for the group VE2 (M = 10.35, SD = 0.93) was significantly higher than that of group LMS2 (M = 8.10, SD = 0.91) and both were significantly higher than that of group CG2 (M = 5.15, SD = 0.93).
- **Ff2:** The mean total score in ff2 for the group VE2 (M = 9.65, SD = 0.75) was significantly higher than that of group LMS2 (M = 8.40, SD = 0.94) and both were significantly higher than that of group CG2 (M = 5.15, SD = 0.67).

The above results suggest that the type of application a participant used had a statistically significant effect on his/her scores in concepts' comprehension and in knowledge acquisition in both applications (solar system and space exploration). Therefore, the authors concluded that the use of a VE produces a statistically significant better understanding regarding concepts and better knowledge acquisition compared to an online course with the same content. As a result, H1a, H1b, H2a, and H2b were confirmed.

Results Analysis of Q3, Q4 and of the Log Files

Participants made positive remarks regarding their experiences while using the VEs. Actually, 65% stated that their most "strong" point was the realistic representation of the virtual worlds. Also, 85% claimed that they found no "weak" points regarding the learning material. Moreover, students stated that the applications did achieve their educational goals (80%), that they helped them in having a better understanding of subjects related to Astronomy (80%), that they visualized situations difficult to visualize in another way (75%), and that they were attention-grabbing (65%). On the negative side, the following were reported: specialized knowledge is required for developing such applications (70%), their development is time-consuming and therefore, it is difficult for them to get involved in such an endeavor (60%), it requires powerful computers (50%), and technical problems may arise (50%). Finally, 95%

of the participants stated that they would use a virtual world in their everyday teaching, provided that ready-made applications are available.

As for the online courses, the most common positive remarks were: the good and well-organized presentation of the learning material (80%), that the courses helped them in having a better understanding of subjects related to Astronomy (80%), that they found no weaknesses regarding the learning material (75%), and that the educational goals were achieved (75%). No negative remarks were made.

Apart from that, 30% of the VEs' users stated they encountered some kind of technical and/or usage problems. The most common were: application lagging-unsatisfactory application's display speed due to hardware issues-outdated computer (8 cases), connection problems-low Internet speed (6 cases), orientation problems (5 cases), and handling the avatar (3 cases). No particular problems were reported while using the online courses.

Based on the log files, participants spent an average of about two hours, each day, using the VEs and exploring the virtual worlds and about an hour studying the online courses. While the distribution of hours spent using the online courses is more or less even (with the exception of Day 5), the same does not hold true for the VEs; more time was spent during the first days and less during the last, as shown in Table 3.

RECOMMENDATIONS

The study took a 2X2X2 approach to investigate the effects of an educational intervention related to Astronomy, having as target-group pre-service teachers. The learning material was divided into 2 major categories; space exploration and the solar system. Both are considered basic; they do not deal with complex concepts (e.g., black holes), they do not require deep understanding of mathematics and physics and they are close to the everyday experiences of an average person, since at some point of our life we were taught about both -to some extent- and quite frequently related subjects are on the mainstream news. Secondly, the learning material was divided into 2 sub-units; concepts and facts and figures. Astronomy is not just about memorizing facts and figures, although they are useful. It requires the understanding of concepts, at least on a basic level (e.g., relative sizes, gravity, rotations, and orbits) (Vosniadou, 1991; Gazit et al., 2005). Finally, two content delivery/teaching methods were used; online courses and VEs.

Table 3. Minutes studying the applications

	Online Courses	VEs
Day 1	74	223
Day 2	69	165
Day 3	76	142
Day 4	66	105
Day 5	45	71
Day 6	63	68
Average	65.50	129.00

Note. The average time spent each day was calculated on the basis of the active users (users who were logged in at that day). Not all participants used the LMS or the VEs every day.

The rationale behind the decision to use this research method comes from the ascertainment that when teaching Astronomy, one should not rely just on the use of textbooks and illustrations (Baxter, 1989). Additional educational tools are needed to enhance Astronomy teaching and learning (Young, Farnsworth, Grabe, & Guy, 2012). Online courses are a well-established teaching method with learning outcomes equivalent to those resulting from conventional, face-to-face instruction (Swan, 2003; Neuhauser, 2010). Literature also suggests that VEs facilitate knowledge acquisition and since objects are visualized in three dimensions, it is possible to help students in having a better understanding of Astronomy related topics (e.g., Schneps et al., 2014; Chen et al., 2007).

The study confirms previous research findings underlining the low knowledge level of the general population in subjects related to Astronomy (e.g., Gazit et al., 2005; Barnett et al, 2000). It also confirms that pre-service educators do not know much about Astronomy (e.g., Kanli, 2015; Trumper, 2006a). Both control groups had low scores in Q1 and Q2, on average 9 and 10 correct answers respectively (out of 24). It is quite impressive the fact that in some cases participants gave profoundly wrong and beyond the common sense answers. For example, half of the participants in the control group CG2 claimed that the Sun (Helios in Greek) is made out of helium. On another question regarding the tallest mountain in the solar system (Olympus, Mars), 40% of them claimed that it is on Earth, obviously mislead by the fact that mountain Olympus also happens to be the tallest mountain in Greece (but by far shorter than Mount Everest). Similar was the situation regarding relative sizes of planets, how rockets and man-made satellites function, missions to other planets and so on. The assumption that all groups that used an application had the same initial knowledge level as the control groups is justified, since they all come from the same population pool (students at the Department of Primary School Education), therefore similar mistakes would be expected.

Having such a low starting point, it was expected that any kind of an educational intervention would have had good results. Indeed, the progress was impressive, as it is observed in Figure 4 and confirmed by the statistical analysis. For that matter, the question that logically emerges is which of the two content delivery/teaching methods produced better learning outcomes. The statistical analysis showed that the VEs produced better results -as a whole- compared to their online counterparts. This led to the need for further investigating if there were different learning outcomes in concepts and/or in facts and figures. Once again, the statistical analysis showed that both VEs surpassed their online equivalents. Therefore, it can be concluded that, at least for basic Astronomy subjects, the VEs can produce good results in situations that require knowledge acquisition, but also in situations that require concepts' understanding. Thus, the study confirms previous research findings regarding VEs' potential in helping pre-service teachers understand concepts related to Astronomy (e.g., Keating et al., 2002; Trumper, 2006b; Shin et al., 2006). This might be attributed to a number of VEs' characteristics that were all incorporated into both VE applications:

- **The Capacity to Visualize Situations and Concepts, Whereas in Real Life it is Impossible:** Visualizations and the representation of the content in a non-textually-mediated way are important factors in understanding abstract and complex phenomena as diSessa (2000) as well as Squire et al. (2004) suggested.
- **Free Exploration of the Virtual Environment:** Free exploration enables users to focus on what they find interesting (Pan et al., 2006).
- **Interactions:** Interactions with the virtual objects are important for active learning as Mikropoulos and Natsis (2011) pointed out.

- **Manipulation of Space and Time:** The ability to manipulate time and space as suggested by Mintz et al. (2001).

The applications' good results come at a price. The development of a virtual environment is a time-consuming process and the user might face technical and/or usage problems. Indeed, 30% of the students in both groups that used the VEs faced such problems. Problems might lead to the obstruction of the learning process and users might lose their interest (Coban, Karakus, Karaman, Gunay, & Goktas, 2015). Secondly, the learning subject has to be carefully chosen, because, while Astronomy is suitable for 3D visualization, other subjects are not. Nevertheless, one has to balance between the expected outcomes and the cost of achieving these outcomes. Also, one has to consider the starting point. If there is already a good knowledge level of a given subject within the target group, VEs might prove to be redundant.

The study's results have implications for administrators and educators in higher education. The fact that pre-service teachers have a limited understanding of basic Astronomy concepts is alarming. Astronomy is a multidisciplinary science; mathematics, physics, chemistry play a significant role. Low knowledge level in Astronomy might be an indicator of low knowledge level in the aforementioned sciences. This possibly holds true for Greece's pre-service teachers, since the majority of them have a theoretical rather than a scientific background (Stamelos & Emvalotis, 2001). It is a contradiction to expect teachers to be potent in their job while at the same time they lack understanding of major scientific subjects.

Therefore, an intervention to rectify the situation is crucial as Trumper (2003) suggested. There are certain guidelines for this intervention. One has to start with the basics and gradually move to more complicated concepts since (a) results indicate that participants lack a basic understanding of Astronomy concepts and (b) new knowledge is constructed based on prior knowledge (Ertmer & Newby, 2013). Formal instruction, in the form of compulsory or elective Astronomy courses, is not suggested (Korur, 2015). Instead, interactive learning strategies (Prather, Rudolph, & Brissenden, 2009), methods that enable the active engagement of the learner (Small & Plummer, 2014), and computer simulations within a conceptual change model of instruction (Bell & Trundle, 2008) are proposed. Also, since modern pedagogy suggests that we learn at our own pace and through active participation (e.g., Martin et al., 2011; Mikropoulos & Natsis, 2011), it appears that online teaching methods -as the ones presented in this study- are more appropriate, especially when dealing with adults (Murphy, Walker, & Webb, 2013). On the basis of the study's results, if one had to choose between the online courses and the VEs, the later seem to be more preferable than the former.

FUTURE RESEARCH DIRECTIONS

Further validations are needed to examine VEs effectiveness in more advanced and complicated Astronomy subjects. Even though both types of applications produced good results, considering the low starting point, it is unknown what might have happened if participants already knew quite a lot about the subjects that were presented to them. Thus, it would be useful to test similar applications having as target-groups students from different academic fields and backgrounds (e.g., students studying at Astronomy or Physics departments). The study was limited only to Greece's pre-service teachers. Since the educational systems vary, comparative studies across countries could be conducted to identify differences or similarities to the findings of the present study.

CONCLUSION

Though the study's results demonstrate that 3D VEs are quite effective in teaching basic Astronomy concepts to pre-service teachers, compared to online courses, there are limitations that merit further discussion. Since both were online applications, it is possible that participants who were not confident technology users faced problems that occluded their learning process and, as a consequence, did not perform well. This may have affected the study's results. Second, despite being meticulous in methodology, one can never be certain about the accuracy -or honesty- of the participants' responses. Finally, data were collected from pre-service teachers in Greece. Therefore, the study's results cannot be generalized to other samples.

Taking all limitations into consideration and in conclusion, the authors believe that the educational uses of 3D VEs for Astronomy teaching have a highly promising potential. It should be noted that this project is a work in progress. The goal is to further investigate different scenarios, under different situations and settings. However, the data that were obtained reinforce the authors belief that this type of learning environments have a positive impact on the educational process.

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KEY TERMS AND DEFINITIONS

3D Virtual Environment: A computer technology that replicates an environment, real or imaginary, in three dimensions.

Astronomy Education: The methods and the learning material being used for teaching Astronomy to all levels of education.

Immersion: In the context of a virtual environment, it is the illusion of being "present" in the simulation.

Interaction: User's actions result in reactions from the simulation's objects and vice versa.

Learning Management System (LMS): A software platform that is used for the delivery and management of instructional content.

Misconception (Scientific): Preconceived notions that explain scientific phenomena, but have no basis in actual scientific facts.

Simulation: A computer generated imitation of a real-world process or environment.