International Journal of Web-Based Learning and Teaching Technologies
Volume 13 • Issue 1 • January-March 2018

How ICT Affects the Understanding of Stereometry Among University Students

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ABSTRACT

The purpose of this research is to compare the level of competence in stereometry of the university students taught using the authors' ICT oriented learning method based on the Van Hiele model for stereometry concepts, as opposed to traditional teaching methodology. The study deals with second year undergraduate students form the Department of Civil Engineering at Piraeus University. The sample was divided into two groups. The experimental group consisted of 99 students who were taught about basic concepts of solid geometry with the support of computers based on the Van Hiele model. Also, there were 90 students in the control group which were taught with traditional methodology using a dry erase board. The study results showed that teaching and learning through ICT is an interactive process for second year university students and has a positive effect on learning solid geometry concepts using the background of the Van Hiele model.

KEYWORDS

Computers, Cubes, Spheres, Stereometry, Undergraduate Education

INTRODUCTION

Today, it is increasingly accepted that various ICT applications are developmentally appropriate technological resources for students in primary, secondary and higher education (Ak-kaya, Tatar, & Kagizmanli, 2011; Howard, Miles, & Rees-Davies, 2012; Wong, Yin, Yang, & Cheng, 2011; Zaranis, & Baralis, 2015). Researchers agree that the computer can be used as a tool to support learning and to assist in communication, collaboration, creativity and language development in education (Passey, 2006; Reisa & Ozdemirb, 2010; Walcott, Mohr, & Kastberg, 2009; Zaranis, 2011). The active, appropriate use of ICT can support and extend traditional materials in significant ways.

Technology, in this enlarged view, also acts as a catalyst for students' social interaction and moreover provides additional features for a rich learning environment that is consistent with modern times. International research on the application of computers in education shows that it has a positive effect on the learning of various subjects (Chou & Liu, 2005; Zaranis, Kalogiannakis, & Papadakis, 2013). These technologies can therefore play an essential role in achieving the university curriculum objectives in all areas and issues, if supported by developmentally appropriate software applications embedded in suitable training scenarios (Di Paola, Pedone, & Pizzurro, 2013).

DOI: 10.4018/IJWLTT.2018010103

ICT AND STEREOMETRY

In the most ideal environment, information and communication technologies are seen as a tool for teaching and learning (Dimakos, & Zaranis, 2010; Sife, Lwoga, & Sanga, 2007; Papadakis, Kalogiannakis, & Zaranis, 2016). They are used as tools for students to become more familiar with new technologies and the integration of research, communication and understanding across the spectrum of the curriculum. Particularly, in the field of knowledge of mathematics, results revealed that computer assisted learning can considerably help students in the development of appropriate mathematical skills and cultivating deeper conceptual thought in comparison to the traditional mathematical teaching method (Reisa, & Ozdemirb, 2010; Wong, Hsu, Wu, Lee, & Hsu, 2007).

As recorded by the indications of international literature (Dissanayake, Karunananda, & Lekamge, 2007; Trouche & Drijvers, 2010; Wong, et al., 2007) the use of ICT helped students to understand mathematical concepts in primary, secondary and higher education. Regarding that, instructors have to find new methods to attract students based on their interest in computer-related fields and the industry needs (Shih, Jackson, Hawkins Wilson. & Yuan, 2014); we set out to investigate the impact of our new stereometry model in the learning process and whether or not it produces better outcomes for university students.

Various researches' results relate the appropriate use of computers with the ability of students to more efficiently understand the different mathematical notions. Indeed, a large number of studies show a positive correlation between the use of computers and the development of mathematical thinking at every level of education (Clements, 2002; Dimakos, Zaranis, Tsikopoulou, 2009; Walcott, et al., 2009; Wong, et al., 2007).

However, a lot of researchers reported that although they have great features, computers are only as beneficial as the educational software used. Software made in accordance with the acquisitions of the educational system can contribute to the effective learning with the help of practice made under the guidance of teachers. Researchers realized that the software implemented for mathematics education is a very important factor in the teaching process (Flores, 2002; Trouche & Drijvers, 2010).

Dynamic multiple representations in software aids to facilitate students' visualization due to the fact that students can explore, solve, and communicate mathematical concepts through various methods. To simply provide images or information is not sufficient to encourage students to visualize or to use different representations (Haciomeroglu, Bu, Schoen & Hohenwarter, 2009). This software can offer great levels of engagement in parabola and symmetry (Akkaya et al., 2011; Zengina et al., 2011; Reisa, & Ozdemirb 2010; Wong, et al., 2011). Learning concepts of stereometry such cubes and spheres is expected to be very easy since students see examples in their day-to-day lives. However, students have difficulty when learning even the basics stereometry concepts (Akkaya et al., 2011; Wong, et al., 2011).

In this study, some materials have been developed in order to enable students to more easily understand basic concepts of stereometry with the approach of the Van Hiele model. Based on this convention, the software is designed, developed and tested for the purpose of this study and was inspired by the framework of Van Hiele model (Crowley & Mary, 1987) based on Realistic Mathematics Education (RME). RME supported and developed mainly on Freudenthal's (1968) view of mathematics as a "human activity". According to his perspective, in order for mathematics to be of human value, it has to be taught so as to be useful, it has to be closely related to reality, close to students and relevant to the society (Van den Heuvel-Panhuizen & Wijers, 2005). Moreover, the theory of the van Hiele model deals specifically with geometric thought as it develops through several levels of sophistication under the influence of a school curriculum. The van Hiele model uses five levels (Perdikaris, 2011).

- **Level 1 (Visual):** Geometric concepts are viewed as total entities rather than as having components or attributes. This level is characterized by the students' perception of geometric shapes as entities, according to their appearance.
- **Level 2 (Analysis):** At this level, the properties of geometrical figures become relevant. The objects of thought are classes of shapes, which the students have learned to analyze as having properties. Students begin to distinguish between the properties of geometric shapes, making an analysis of the data perceived and to recognize these shapes by their properties.
- **Level 3 (Informal Deduction):** At this level, the properties observed the previous level are arranged. The objects of thought are geometric properties and the students have learned to form abstract combinations. The students understand that these basic properties or sets of properties may include additional properties. Also, students can infer properties of a shape and recognize categories of figures. Class inclusion is understandable. Definitions make sense. Informal arguments can be followed and given.
- **Level 4 (Deduction):** The details of the study are sequences of statements. Students understand the significance of deduction as a means for the construction and development of the geometric theory. Students can construct geometric proofs at secondary school level and understand their meaning. They understand the role of undefined terms, definitions, axioms and theorems in Euclidean geometry.
- **Level 5 (Rigor):** At this level, students understand that definitions are arbitrary and need not actually refer to any particular implementation. The object of thought is inductive geometric systems, for which the student compares axiomatic systems. Students can study non-Euclidean geometry with understanding.

Following the theoretical framework that binds the van Hiele model of geometric thinking and the use of ICT for university students, we designed a new model referred to as the Basic University Students Stereometry Model (BUSSM). This model applied on the second year undergraduate students form the Department of Civil Engineering at Piraeus University of Applied Sciences. The BUSSM used only the first three levels of Van Hiele model, because it was applied in an introductory lesson. The students in this class had not addressed solid geometry since the introduction of it in primary education. The teaching intervention was a two weeks syllabus program focusing on three-dimensional space, regarding projection and intersection of points, segments, planes, cubes and spheres. The main objective of this study was to examine the effects of instructional intervention using the BUSSM for the purpose of the teaching of basic stereometry concepts and then to compare this model to the traditional teaching method according to the university curriculum. Thus, we set out to investigate the following research questions:

1. Will the students taught with educational intervention based on BUSSM have a significant improvement on their stereometry achievement in comparison to those taught using the traditional teaching method according to the university curriculum?
2. What is the mathematical level of the students who had the highest benefit from BUSSM according to their stereometry achievement?

METHODOLOGY

Subjects

The study was carried out during the 2013-14 academic year in the Department of Civil Engineering at Piraeus University of Applied Sciences. It was an experimental research which compared the BUSSM teaching process to traditional teaching based on second year undergraduate students' curriculum.

The sample was 189 second year students of the above department, who were divided into two groups randomly. In the experimental group (EG), the teaching intervention on solid shapes, made with the use of ICT and in the control group (CG) the teaching intervention was designed with the traditional method. Students of both groups participated in the course "Drawing with ICT" during the fourth semester.

The experimental group (EG), had 99 students and consisted of four classes of 30 or 31 students. In the EG involved 122 students, but 23 students dropped the course or completed only one test (pre-test or post-test) and as a result were not included in the sample. The participation rate in EG was 80.49%. The classes in the experimental group used ICT as part of the teaching procedure.

The control group (CG), had 90 students and consisted of 4 classes of 29 or 30 students. In the CG 118 students participated, but 28 students dropped the course or completed only one test (pre-test or post-test) and were not included in the sample. The participation rate in CG was 76.27%. Teachers who were involved in the study had university degrees in Mathematics and a Master Degree in ICT.

Research Design

The present research was conducted in three phases:

1. In the first phase, the pre-test was given to the students of the experimental and control groups.
2. In the second phase of the teaching intervention took place. Students in the experimental and control groups participated in the university course "Drawing with ICT" in the fourth semester. At the beginning of this course students were taught various 3D software features and capabilities. At the end of the course the students were able to draw 3D sterometry shapes using various computer programs. Following that, at the end of the course, the students were divided into two groups randomly and voluntarily participated in the research.
3. In the third and final phase of the study, after the teaching intervention, the same test was given to all students in both the experimental and control groups as a post-test to measure their improvement on basic stereometry concepts.

Ethical considerations and guidelines on the privacy of students and other relevant ethical issues in social research were carefully considered throughout the process of research. Requirements relating to information, informed consent, confidentiality and use of data held carefully, both orally and in writing, by informing academic staff and students of the purpose of the study and of their rights to refrain from participation. Therefore, the names of the participants and their scores on either of the tests were not made public at any time during this study.

Educational Measures

In the first phase, the pre-test was given to the experimental and control groups at the beginning of April 2014 to isolate the effects of the treatment by looking for inherent inequities on the stereometry achievement potential of the two groups. The pre-test examined the students' basic stereometry knowledge and it contained twenty tasks in total. The pre-tests were administrated in the class with explicit and detailed instructions from the teachers. Included in this assessment were pencil-and-paper tasks in which the students were asked to identify the projections of basic shapes including planes (Figure 1 - a), spheres, cubes (Figure 1 - b), points and line segments. Each task had a weighted grade that came from the students' answers. Scores were computed for each of the individual tasks of the stereometry test. Since the numbers of problems varied across tasks, a mean proportion of correct responses for each of the twenty tasks were produced by dividing the number of correct responses by the total number of problems on that task. The basic assessment test was part of a general examination for solid geometry which lasted thirty minutes. The responses were scored and coded and the data set was collected from the results of the basic stereometry test.

Similarly, during the third and final phase of the study, after the teaching intervention, the same test was given to all students in both the experimental and control groups, as a post-test in the middle of June 2014 to measure their improvement.

Teaching Intervention for Control Group

The control group was taught stereometry shapes with the traditional way. The teaching of these concepts was four hours long in total and lasted two weeks. It included concepts such as: projection and intersections of points, line segments, planes, cubes and spheres in a three-dimensional coordinate system. The typical teacher centered method (Figure 2) using the dry erase board was used. The teacher presented the theory about basic concepts of stereometry and followed with questions from the students. After the completion of each module, exercises were solved by the teacher on the dry erase board and students were encouraged to ask questions about what they did not understand.

Teaching Intervention for Control Group

The experimental group was taught with the help of ICT according to our model, presenting the same concepts as the control group. The teaching intervention was completed in two stages, according to the Basic University Students Stereometry Model.

The first stage began with educational software for the projection of points, line segments and planes, in a three-dimensional coordinate system (Figure 3 – a, b) . The teaching of these concepts lasted two hours. During the first hour the students were thought according to the first and second Van Hiele levels. At the second teaching hour the concepts of points, line segments (Figure 4 - a) and planes were presented based on the third Van Hiele level. The second stage consisted of educational software for teaching projections and intersections of cubes and spheres (Figure 4 - b), and lasted two hours. At this stage, the first hour the concepts introduced was based on first and second Van Hiele levels. The second hour the teaching process was based on the third Van Hiele level.

In this teaching approach, practices were created that included in the Van Hiele model. During the teaching intervention, each geometric concept was examined by the students through the first three Van Hiele levels. At the first level, the visual level, students were able to identify, name, reproduce and group similar geometric objects by visual recognition. For instance, students might define that an object is a cube, because it looks like a dice. At the second level, the level of analysis, the students

Figure 1. Evaluation sheet for the projection of the plane E (a) and the projection of the inter-section A of the cube (b)

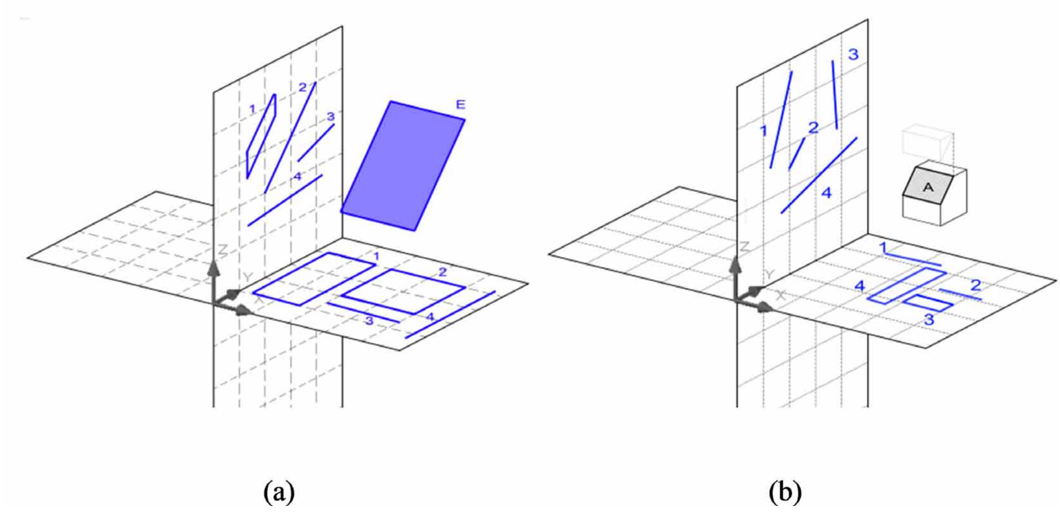


Figure 2. Teaching stereometry with traditional way

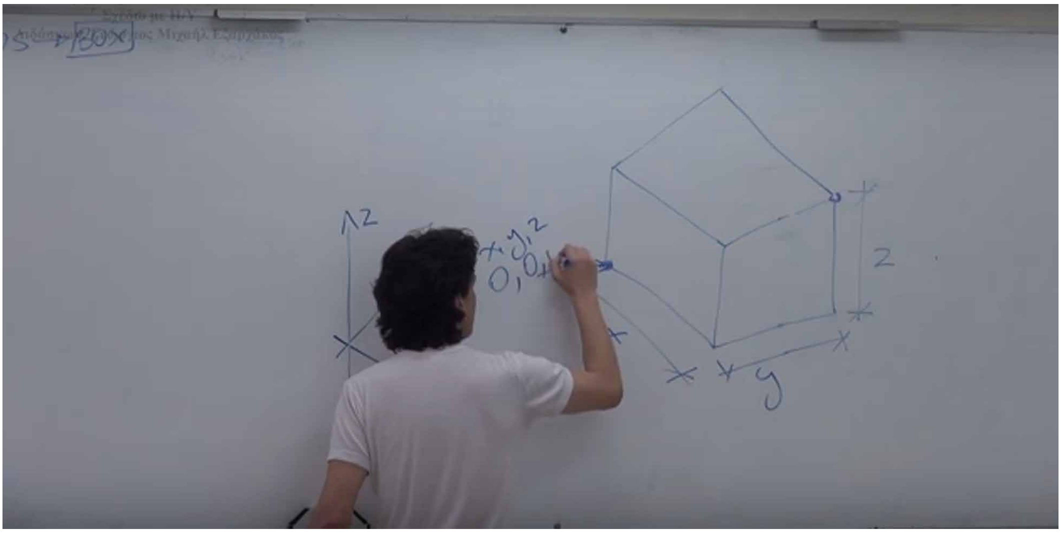
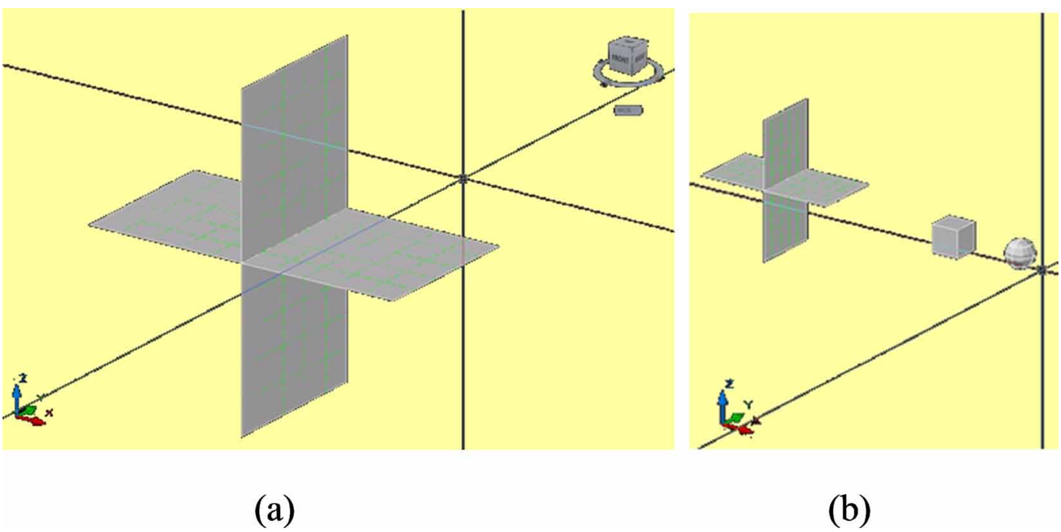
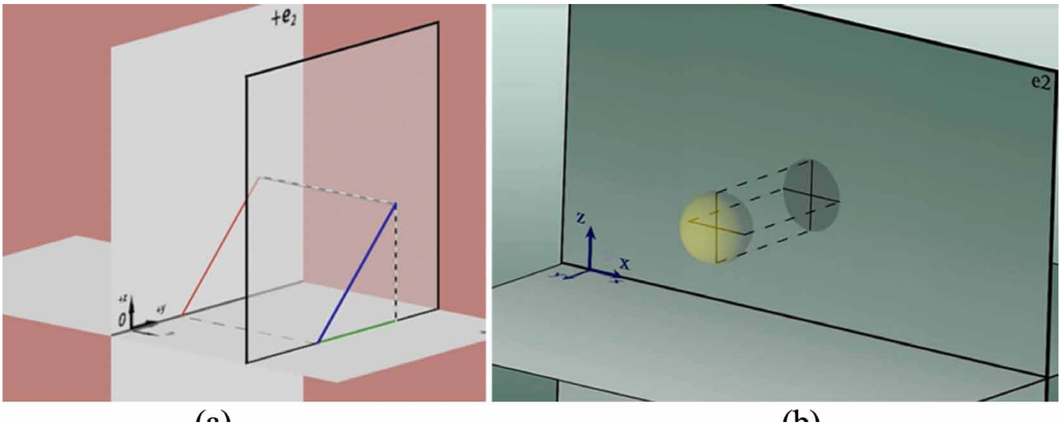


Figure 3. Constructing the Three-Dimensional Coordinate System (a) and the basic solid shapes (b) with the use of ICT



were able to identify shapes by their properties. For example, a student sees a cube as a shape with all plane surfaces equal. At the third level, the level of informal deduction, the student can reason with simple arguments about geometric figures. He recognizes the relationships between types of shapes. For example, he can find out that the projection of a line segment which is vertical to a plane is the same as the projection of a point. During the teaching intervention of these three levels, tutorial videos were demonstrated by the teacher showing shapes, their properties, projections and intersections. Then, a discussion followed on the students' questions. Also, the students had to construct the shapes on the computers using the AutoCAD program. This was a way to understand the properties of the objects and see them from different points of view. Moreover, the students performed projections

Figure 4. Teaching projections of a line segment (a) and a sphere (b) with the use of ICT



and various intersections of the solid shapes. In addition, exercises were given by the teacher and students we required to solve these using the AutoCAD program.

The AutoCAD program was used for projections and intersections of various solid shapes. This is software that enables the creation of models using and specifying coordinates based on the Cartesian axes system. With this software the student can "create" objects in two or three dimensions see various views of projections, "link" objects in Cartesian coordinate system and create new intersections of objects. There is also the possibility of having the student perform a process to see the result rotating in real time; the whole object or part of it. With this software, the student can determine, in a three dimensional environment, the results of operations and fully understand the properties of shapes. Still, it was used the 3D Studio Max program that can create and move of three-dimensional bodies. Finally, the Camtasia software was used to process moving images and add comments on the screen.

RESULT

A set of analyses was conducted to determine the effects of the BUSSM intervention on second year university students' stereometry achievement for their knowledge of basic stereometry concepts. The pre-test and post-test were taken by 189 students. Analysis of the data was carried out using the SPSS (ver. 21) statistical analysis computer program. The independent variable was the group (experimental group and control group). The dependent variable was the difference between the students' post-test and pre-test scores.

Evaluating the Effectiveness of Teaching Intervention for Basic Stereometry Achievement

The first analysis was an introductory analysis was the first step in order to examine whether the students were on the same level concerning the basic stereometry shapes. This analysis was done before starting to examine the research questions. The t-test for equality of means was not significant ($t = -1.585$, $p = 0.115$), indicating no significant differences initially, in stereometry achievement between the experimental ($M = 11.184$, $SD = 2.991$) and control ($M = 11.979$, $SD = 3.809$) groups. Though, the control group had a mean score higher than the experimental group, the mean difference in the pre-test scores was -0.795. As a result for the rest of the article we intent to examine the gain score of each group. We define the gain score as the difference between the post-test score and pre-test score.

In order to determine if the performance of the experimental group is significant in comparison to the control group after the teaching intervention an independent sample t-test was con-ducted between the gain score values. The independent variable had the same two levels as in the previous test: experimental and control. The t-test for equality of means was significant ($t = 2.032$, $p = 0.044$) indicating significant differences in gain scores between the experimental and control groups, as summarized in Table 1 and Table 2.

In order to determine if the performance of the experimental group is significant, a paired t-test was performed using the score of this group for a comparison between pre-test and post-test scores. The mean score for the pre-test in the study was 11.184 (SD = 2.991) compared to 15.195 (SD = 2.776) for the post-test. At $\alpha = 0.05$ and $df = 98$, the critical value of the t ratio was less than 0.001. Therefore, the post-test score was significantly different from the pre-test score of the experimental group.

Similarly, to determine if the performance of control group is significant, a paired t-test was performed using the score of this group for a comparison between pre-test and post-test scores. The mean score for the pre-test in the study was 11.979 (SD = 3.809) compared to 15.167 (SD = 3.237) for the post-test. At $\alpha = 0.05$ and $df = 89$, the critical value of the t ratio was less than 0.001. Therefore, the post-test score was significantly different from the pre-test score of the control group.

Evaluating the Stratification of Students in Basic Stereometry Achievement According to their Pre-Test Scores

Moreover, a stratification of experimental and control group according to their pre-test scores was divided into three equal categories: less than 9.75 (33.33th percentile - low), 9.75 to 12.75 (33.33th to 66.66th percentile - medium), and more than 12.75 (66.66th percentile - high). In the following Table 3 the students' performance is presented including both groups (i.e. the experimental and the control group) before teaching process.

Table 3 shows that 28.3% of the students of the experimental group exhibited high grading, 38.4% exhibited medium grading, whereas 33.3% exhibited low grading. Likewise, 41.1% of the control

Table 1. Group statistics for the gain scores

Group	N	Mean	Std. Dev.	Std. Error
Experimental	99	4.011	2.751	0.276
Control	90	3.187	2.818	0.297

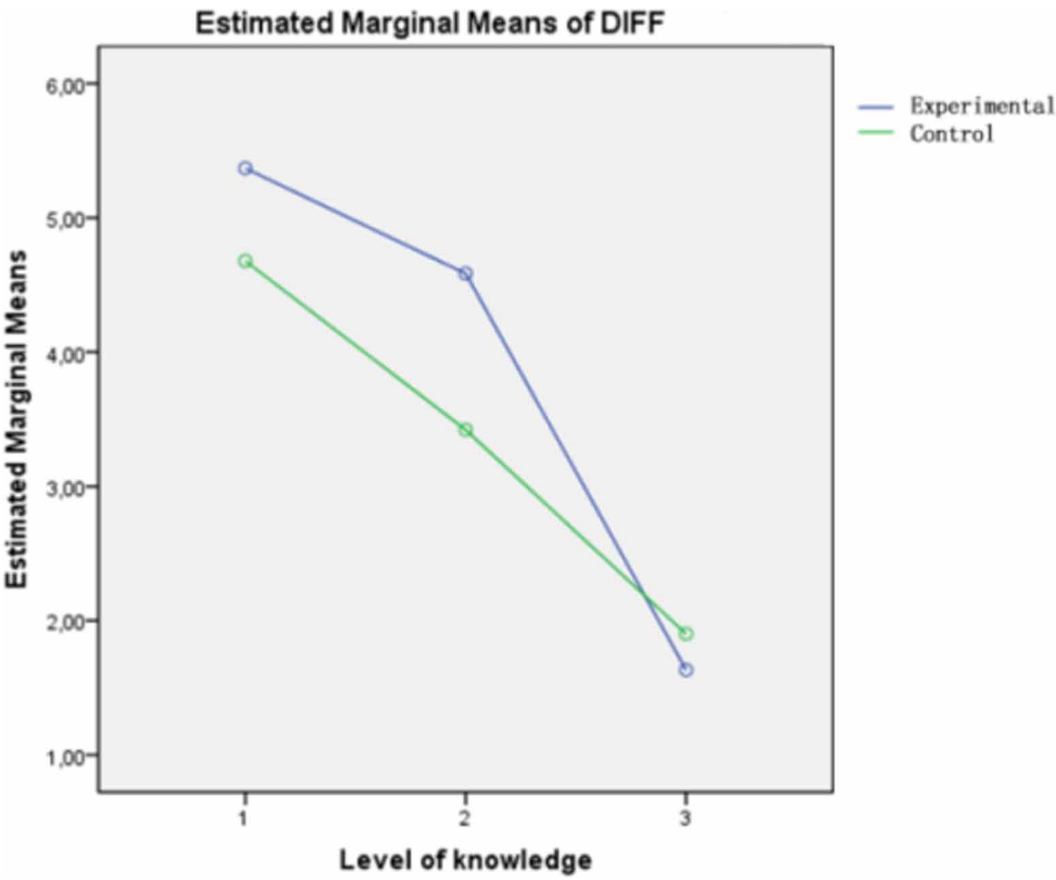
Table 2. Independent samples T-test of the gain scores

Pre-test	t	df	Mean difference	Sig. (2-tailed)
t-test	2.032	187	0.823	0.044

Table 3. Frequencies of the two groups in the pre-test of stereometry achievement

Pre-test	Experimental Group		Control Group	
Grading	N	f %	N	f %
Low	33	33.3	28	31.1
Medium	38	38.4	25	27.8
High	28	28.3	37	41.1
Total	99	100.0	90	100.0

Figure 5. Stereometry score improvement after the teaching intervention



group exhibited high grading, 27.8% medium and 31.1% low. In other words, students' performance in the medium category of the experimental group appeared to be superior (38.4%) compared with of the control group (27.8%).

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of stereometry achievement (low versus medium versus high) on their improvement of the score of difference (post-test minus pre-test score). There was not a significant interaction between the effects of class and mathematical level on students' according to their success in stereometry test, $F(2, 183) = 1.391$, $p = .251$, Partial Eta Squared = .015. On the contrary, the effect of stereometry level was significant ($F(2, 183) = 29.028$, $p < .001$, Partial Eta Squared = .241), with the improvements of stereometry score in the medium and high levels were lower (medium - M = 5.052, SD = 2.439, high- M = 1.785, SD = 2.466) than those in the low level (M = 15.405, SD = 2.459) after the teaching intervention (Table 4, Figure 5). Moreover, the effect of group was not significant ($F(1, 183) = 2,159$, $p = .143$, Partial Eta Squared = . 012), with children in the experimental group scoring higher (M = 4.011, SD 2.751) than those in the control group (M = 3.187, SD = 2.818) after the teaching intervention.

The Bonferroni post hoc tests indicated that students' improvement in stereometry score of the experimental group of the low-level and medium-level groups differed significantly from students' improvement of the high-level ($p < .001$) group.

Table 4. Mean and Standard Deviation of stereometry's score improvement

Level	Class	M	SD	N
Low	Experimental	5.369	2.173	33
	Control	4.678	2.752	28
	Total	5.052	2.459	61
Medium	Experimental	4.584	2.429	38
	Control	3.420	2.330	25
	Total	4.122	2.439	63
High	Experimental	1.632	2.284	28
	Control	1.901	2.620	37
	Total	1.785	2.466	65
Total	Experimental	4.011	2.751	99
	Control	3.187	2.818	90
	Total	3.618	2.806	189

The results of this study are consistent with the results of many surveys (Di Paola, et al., 2013; Haciomeroglu et al., 2009; Reisa & Ozdemirb, 2010; Wong, et al., 2007; Zaranis, 2011; Zengina et al., 2011) according to which the involvement and engagement of students in a computer environment, can assist greatly in the discovery, cultivation, understanding and learning of mathematical concepts. Also, numerous studies (Dimakos, Zaranis, Tsikopoulou, 2009; Dimakos, & Zaranis, 2010; Walcott, et al., 2009; Zaranis, 2012; Zaranis, & Baralis, 2015), had similar results to our research in in Greek primary and secondary school students, stressing that students interacting with software enriched with developmentally appropriate math activities led to the understanding of mathematical concepts.

DISCUSSION

The general purpose of the study was to investigate the impact of teaching intervention using the Basic University Student Stereometry Model for the purpose of teaching basic stereometry concepts. In this research, we found that the students who were taught with educational intervention based on BUSSM had a significant improvement on their basic stereometry achievement in comparison to those taught using the traditional teaching method according to the university curriculum. Our findings agree with similar researches (Di Paola, et al., 2013; Sife, et al., 2007; Wong, et al., 2007) which implied that ICT helps students to understand mathematical notions more effectively. As a result, the first research question was answered positively.

Moreover, the results of the study agree with other researches (Akkaya et al., 2011; Zengina et al., 2011; Reisa, & Ozdemirb, 2010; Wong, et al., 2011) which suggest that ICT helps students' understanding of geometric relationships, making mathematical generalizations. In addition, the current research shows that the stratification of students groups according to their improvement in the testing (low, medium, high) is inversely proportional to the level of their success. Thus, the students who were in the lower level of the pre-test results had the highest benefit from BUSSM according to their basic stereometry achievement. Our results overlap with the results of other analogous studies which indicate the positive effects of a computer based-model of teaching math (Dissanayake, et al., 2007; Flores, 2002; Trouche & Drijvers, 2010). As a result, the second research question was confirmed.

Regarding the educational implementation of the present study, the findings of the research should take into account in order to be used by a range of stakeholders such as students, teachers, researchers, curriculum designers etc. Specifically, the designed teaching approach could be set up the University curriculum as a pilot study in order to examine if this approach help students to understand basic stereometry shapes. Moreover, the learning method based on Realistic Mathematics Education (RME) and the van Hiele model can interfere in various mathematical subjects as a research plan. That implementation gives the opportunity, the University teachers to develop new activities for understanding mathematical concepts. We may say that students participated in this approach stimulate their interest using the ICT technology.

As far as it concerns the limitations of this study, the first limitation is that the data collected was from the participants residing in the city of Athens, the capital of Greece. The second limitation was the generalizability of this study which was limited to participants attending their second year of the Department of Civil Engineering at Piraeus University of Applied Sciences. Therefore, the results from this research can be generalized only to similar groups of students. The results may not adequately describe students from other regions of Greece and from other university departments. However, as the study was of small scale and context specific, any application of the findings should be done with caution.

Considering the above limitations of this work, the undertaking computer assisted educational procedure using the Basic University Student Stereometry Model, it is an ongoing challenge for the reflective teacher to decide, how this technology can be best utilized in higher education.

REFERENCES

Akkaya, A., Tatar, E., & Kagizmanli, T. B. (2011). Using dynamic software in teaching of the symmetry in analytic geometry: The case of geogebra. *Procedia: Social and Behavioral Sciences*, *15*, 2540–2544. doi:10.1016/j.sbspro.2011.04.141

Chou, S.-W., & Liu, C.-H. (2005). Learning effectiveness in a Web-based virtual learning environment: A learner control perspective. *Journal of Computer Assisted Learning*, *21*(1), 65–76. doi:10.1111/j.1365-2729.2005.00114.x

Clements, D. H. (2002). Computers in early childhood mathematics. *Contemporary Issues in Early Childhood*, *3*(2), 160–181. doi:10.2304/ciec.2002.3.2.2

Crowley, M. L. (1987). The van Hiele Model of the Development of Geomemc Thought. In M. Montgomery Lindquist (Ed.), *Learning and Teaching Geometry, K-12* (pp. 1–16). Reston, Va.: National Council of Teachers of Mathematics.

Di Paola, F., Pedone, P., & Pizzurro, M. R. (2013). Digital and interactive learning and teaching methods in descriptive geometry. *Procedia: Social and Behavioral Sciences*, *106*, 873–885. doi:10.1016/j.sbspro.2013.12.100

Dimakos, G., & Zaranis, N. (2010). The influence of the Geometer's Sketchpad on the Geometry Achievement of Greek School Students. *The Teaching of Mathematics*, *13*(2), 113-124. Retrieved 29/3/2011 from http://elib.mi.sanu.ac.rs/files/journals/tm/25/tm1324.pdf)

Dimakos, G., Zaranis, N., & Tsikopoulou, S. (2009). Developing Appropriate Technologies in Teaching Axial Symmetry in Compulsory Education. In N. Alexandris & V. Chrissikopoulos (Eds.), *Proceedings of the 13th Panhellenic Conference in Informatics – Workshop in Education. Proceedings of PCI 2009*. Department of Informatics, Ionian University & Department of Informatics, University of Piraeus, Corfu, Greece, 107-116.

Dissanayake, S. N., Karunananda, A. S., & Lekamge, G. D. (2007). Use of computer technology for the teaching of primary school mathematics. *OUSL Journal*, *4*, 33–52.

Flores, A. (2002). Learning and teaching mathematics with technology. *Teaching Children Mathematics*, *8*(6), 308–310.

Freudenthal, H. (1968). Why to teach mathematics so as to be useful? *Educational Studies in Mathematics*, *1*(1-2), 3–8. doi:10.1007/BF00426224

Haciomeroglu, E. S., Bu, L., Schoen, R. C., & Hohenwarter, M. (2009). Learning to develop mathematics lessons with geogebra. *MSOR Connections*, *9*(2), 24–26. doi:10.11120/msor.2009.09020024

Howard, J., Miles, G., & Rees-Davies, L. (2012). Computer use within a play-based early years curriculum. *International Journal of Early Years Education*, *20*(2), 175–189. doi:10.1080/09669760.2012.715241

Papadakis, St., Kalogiannakis, M., & Zaranis, N. (2016). Comparing tablets and PCs in teaching mathematics: An attempt to improve mathematics competence in early childhood education. *Preschool & Primary Education Journal*, *4*(2), 241–253. doi:10.12681/ppej.8779

Passey, D. (2006). Technology enhancing learning: Analysing uses of information and communication technologies by primary and secondary school pupils with learning frameworks. *Curriculum Journal*, *17*(2), 139–166. doi:10.1080/09585170600792761

Perdikaris, S. C. (2011). Using fuzzy sets to determine the continuity of the van Hiele levels. *Journal of Mathematical Sciences & Mathematics Education*, *5*(1), 39–46.

Reisa, Z. A., & Ozdemirb, S. (2010). Using geogebra as an information technology tool: Parabola teaching. *Procedia: Social and Behavioral Sciences*, *9*, 565–572. doi:10.1016/j.sbspro.2010.12.198

Shih, H., Jackson, J. M., Hawkins Wilson, C. L., & Yuan, P. (2014, June). Using MIT App Inventor in an Emergency Management Course to Promote Computational Thinking. *Paper presented at 2014 ASEE Annual Conference*, Indianapolis, Indiana. Retrieved from https://peer.asee.org/23269

Sife, A. S., Lwoga, E. T., & Sanga, C. (2007). New technologies for teaching and learning: Challenges for higher learning institutions in developing countries. *International Journal of Education and Development Using Information and Communication Technology*, *3*(2), 57–67.

Trouche, L., & Drijvers, P. (2010). Handheld technology for mathematics education: Flashback into the future. ZDM. *The International Journal on Mathematics Education*, *42*(7), 667–681. doi:10.1007/s11858-010-0269-2

Van den Heuvel-Panhuizen, M., & Wijers, M. (2005). Mathematics standards and curricula in the Netherlands. *ZDM. Zentralblatt für Didaktik der Mathematik*, *37*(4), 287–307. doi:10.1007/BF02655816

Walcott, C., Mohr, D., & Kastberg, S. (2009). Making sense of shape: An analysis of children's written responses. *The Journal of Mathematical Behavior*, *28*(1), 30–40. doi:10.1016/j.jmathb.2009.04.001

Wong, W. K., Hsu, S. C., Wu, S. H., Lee, C. W., & Hsu, W. L. (2007). LIM-G: Learner-initiating instruction model based on cognitive knowledge for geometry word problem comprehension. *Computers & Education*, *48*(4), 582–601. doi:10.1016/j.compedu.2005.03.009

Wong, W. K., Yin, S. K., Yang, H. H., & Cheng, Y. H. (2011). Using computer-assisted multiple representations in learning geometry proofs. *Journal of Educational Technology & Society*, *14*(3), 43–54.

Zaranis, N. (2011). The influence of ICT on the numeracy achievement of Greek kindergarten children, In A. Moreira, M.J. Loureiro, A. Balula, F. Nogueira, L. Pombo, L. Pedro, P. Almeida, (Eds.), *Proceedings of the 61st International Council for Educational Media and the XIII International Symposium on Computers in Education (ICEM&SIIE'2011) Joint Conference*, 390-399, University of Aveiro, Portugal, 28-30 September 2011.

Zaranis, N. (2012). The use of ICT in Preschool Education for geometry teaching. In R. Pintó, V. López, & C. Simarro (Eds.), *Proceedings of the 10th International Conference on Computer Based Learning in Science, Learning Science in the Society of Computers*, Barcelona, Spain, June 26-29 (pp. 256-262).

Zaranis, N., & Baralis, G. (2015). A pilot project comparing the effectiveness of using ICT for teaching addition and subtraction with first grade students. In *Proceedings of The International Conference on Engineering MIS 2015.* New York, NY: ACM. doi:10.1145/2832987.2832995

Zaranis, N., Kalogiannakis, M., & Papadakis, S. (2013). Using Mobile Devices for Teaching Realistic Mathematics in Kindergarten Education. *Creative Education, 4*(7 A1), 1-10.

Zengina, Y., Furkanb, H., & Kutluca, T. (2011). The effect of dynamic mathematics software geogebra on student achievement in teaching of trigonometry. *Procedia - Social and Behavioral Sciences*, *31*, 183 – 187. doi:.10.1016/j.sbspro.2011.12.038