Chapter 8
The Use of ICT and the Realistic Mathematics Education for Understanding Simple and Advanced Stereometry Shapes Among University Students

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Theoretical Background

ICT plays a main role in achieving the university curriculum objectives in a plethora of subjects and issues, if supported by developmentally appropriate educational software applications (Di Paola, Pedone, & Pizzurro, 2013; Dwyer, 2007; Papadakis, Kalogiannakis, & Zaranis, 2016). In the most ideal environment, computers are seen as instruments for teaching and learning processes (Burnett, 2009; Fisher, Denning, Higgins, & Loveless, 2012; Sutherland et al., 2004). They are used as educational devises for students to become even more familiar with modern technologies and the integration of communication, research, and comprehension of the curriculum.

As recorded by the international literature (Dissanayake, Karunananda, & Lekamge, 2007; Trouche & Drijvers, 2010; Wong, Yin, Yang, & Cheng, 2011), the use of ICT helped students to comprehend 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 explore the impact of our new stereometry model in the learning process and whether or not it produces better outcomes for university students.

The results of the various surveys concern the appropriate use of computers with the ability of students to understand the different mathematical concepts. Also, a large number of studies show a positive correlation between the use of computers and the progress of mathematical thinking at every level of education (Clements,

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2002; Dimakos, Zaranis, & Tsikopoulou, 2009; Walcott, Mohr, & Kastberg, 2009; Wong et al., 2011).

However, a lot of researchers found 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; Judge, 2005; Keong, Horani, & Daniel, 2005; Trouche & Drijvers, 2010).

Dynamic multiple implementations in software help students' visualization because students can investigate, solve, and understand mathematical concepts using various methods. Providing only information or images is not enough to force students use a different understanding of mathematical knowledge (Antohe, 2010; Zengina, Furkanb, & Kutluca, 2011). Proper software offers a higher level of engagement in coordinate geometry (Dimakos & Zaranis, 2010; Sahaa, Ayubb, & Tarmizi, 2010).

In this research, teaching tools have been developed in order to engage students to understand stereometry concepts with the approach of the van Hiele model. Based on this idea, the software is designed for the purpose of this study and was based on the van Hiele model and the Realistic Mathematics Education (RME).

RME is a theory of teaching and learning mathematics. Indicative of this are the learning and teaching trajectories with intermediate attainment targets which were first conducted for the subject of mathematics and extended to the subject of geometry. In the whole trajectory of the RME teaching theory, five main characteristics of understanding geometry concepts (Freudenthal, 1973; Van den Heuvel-Panhuizen & Buys, 2008) are involved: introducing a problem using a realistic context, identifying the main objects of the problem, using appropriate social interaction and teacher intervention to refine the models of the problem, encouraging the process of reinvention as the problem develops, and focusing on the connections and aspects of mathematics in general.

Moreover, the theory of the van Hiele model, based on RME, deals specifically with geometric thought as it develops through several levels of sophistication under the influence of a university curriculum. The van Hiele model uses five levels (Van Hiele, 1986).

- Visual Level: This level is characterized by the students' perception of geometric shapes as entities, according to their appearance.
- Level of Analysis: At this level, 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 of Informal Deduction: At this level, students can infer properties of a shape and recognize categories of figures; they understand class inclusion and definitions.
- Level of Deduction: At this level, students can construct geometric proofs at secondary school level and understand their meaning. They understand the role of definitions, axioms, and theorems in Euclidean geometry.

- Level of Rigor: At this level, students understand that definitions are arbitrary and need not actually refer to any particular implementation. Also, they can study non-Euclidean geometry with understanding.

Following the theoretical framework that combines the van Hiele model and the use of ICT for undergraduate students, we designed a new model referred to as the Basic University Students Stereometry Model (BUSSM). This model applied to second year undergraduate students from the Department of Civil Engineering at Piraeus University of Applied Sciences. The BUSSM used only the first three levels of the van Hiele model focusing on projections, intersections, and expansions of points, line segments, planes, cubes, spheres, ellipsoids, cylinders, and cones, and it was a 5-week syllabus program.

Research Questions

The main objective of this study was to investigate the effects of teaching intervention using the BUSSM for basic and advanced stereometry concept and then compare this model to the traditional teaching approach. Thus, we set out to examine the following five research questions:

1. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their general stereometry achievement of basic and advanced stereometry concepts (points, line segments, planes, cubes, spheres, ellipsoids, cylinders, and cones), compared to those taught using the traditional teaching method in the current university curriculum?
2. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their basic stereometry concepts (points, line segments, planes, cubes, and spheres), compared to those taught using the traditional teaching method in the current university curriculum?
3. What is the stereometry level of students who had the highest benefit from BUSSM in basic stereometry concepts (points, line segments, planes, cubes, and spheres)?
4. Will the students who will be taught stereometry based on BUSSM have a significant improvement, in their advance stereometry concepts (ellipsoids, cylinders and cones), compared to those taught using the traditional teaching method in the current university curriculum?
5. What is the stereometry level of students who had the highest benefit from BUSSM in advanced stereometry concepts (ellipsoids, cylinders, and cones)?

The present study makes an important contribution to the literature; it examines and compares the effects of a new model which combines computer and noncomputer activities for teaching the projections and intersections of points, line segments, planes, cubes, and spheres as well as projections, intersections, and expansions of ellipsoids, cylinders, and cones.

Methodology

The present study was conducted in three phases. In the first and third phases, the pretest and posttest were given to the classes, respectively. In the second phase, the teaching intervention was performed.

Sample

The study took place during the 2013–2014 academic year in the Department of Civil Engineering at Piraeus University of Applied Sciences. It was an experimental research which compared the BUSSM teaching model to traditional teaching for second year undergraduate students.

The sample consisted of 189 second year students of the above department, who were divided into two groups randomly. In the experimental group (EG), the teaching approach of solid shapes was made with the use of ICT. In the control group (CG), the teaching approach used the traditional method.

The experimental group (EG) consisted of 99 students and had four classes of 30 or 31 students. In the EG, 122 students participated, but 23 students dropped the course or completed only 1 of the 2 required tests (pretest or posttest), and as a result, these students 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 educational process.

The control group (CG) consisted of 90 students and had four classes of 29 or 30 students. In the CG, 118 students participated, but 28 students dropped the course or completed only 1 of the 2 required tests (pretest or posttest) and were not included in the sample. The participation rate in CG was 76.27%.

Research Design

The design of this study included three phases for all groups, experimental and control ones. There were:

1. The pre-experimental phase was at the beginning of April 2014 and lasted 2 weeks. Its purpose was to isolate the effects of the treatment by looking for inherent inequalities in the stereometry achievement of the two groups. The pretest was given to the students of the experimental and control groups.
2. The experimental phase or intervention phase was at the middle of May 2014 and lasted about 5 weeks. 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 to use various 3D software features and capabilities on applications such as AutoCAD, ArchiCAD, and

CadWare, which are ideal for use in the learning process (Abu Ziden, Zakaria, & Nizam Othman, 2012). The objective of this course is to familiarize students to create various digital designs with the use of computer applications. It is divided into two main parts: the theoretical part and the practical part. In the first part, students use a graphic design program in order to produce building design, topography, and general civil engineering designs. Students are confronted with an introductory educational presentation for the use of various design software. Throughout this part, students realize that all the different software they are presented works in similar ways to perform similar tasks. Using this method, we stimulate the interest of students and help raise their confidence. In the second part, the students apply the knowledge they gained in the first part of this course by performing labs with graphical design software. At the end of the course, the students were able to create 3D stereometry shapes using various graphical design software. Following that, at the end of the course, the students were divided into two groups (experimental and control) randomly and voluntarily participated in the research. The teaching process of the experimental and control groups will be further explained in the following subsections.

3. The post-experimental phase was in the middle of June 2014, which aimed to measure the children's overall improvement. The same test was given to all students in both the experimental and control groups as a posttest to measure their improvement on advanced 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.

Measures

In the pre-experimental phase, the first phase, the pretest was administered to assess the students' basic and advanced stereometry competence, and it contained 54 tasks in total. There were pencil-and-paper tasks in which students were asked to identify the projections of basic shapes including planes (Fig. 8.1a), spheres, cubes (Fig. 8.1b), points, and line segments and the projections, intersections, and expansions of ellipsoids, cylinders, and cones (Fig. 8.2a, b). There was about an equal number of tasks for the evaluation of each of the stereometry shapes. Each task had a weighted score that came from the students' answers. Scores were evaluated for each of the individual tasks of the stereometry test. The pretest and posttest were administrated in the class with explicit and specific instructions from the teachers, and each test lasted about 50 min.

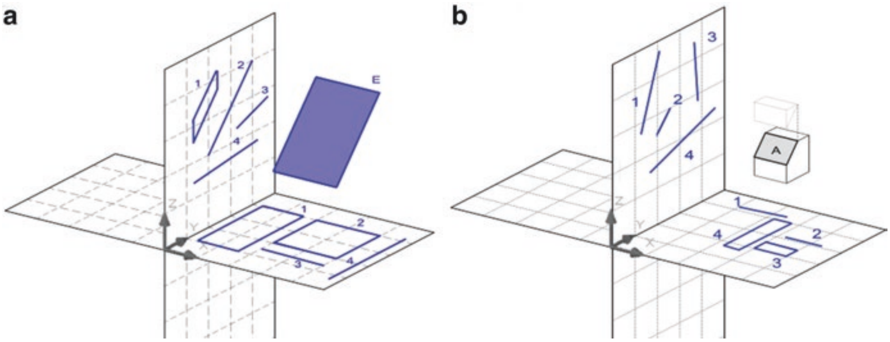

Fig. 8.1 Evaluation sheet for the projection of the plane E (**a**, left) and the projection of the intersection A of the cube (**b**, right)

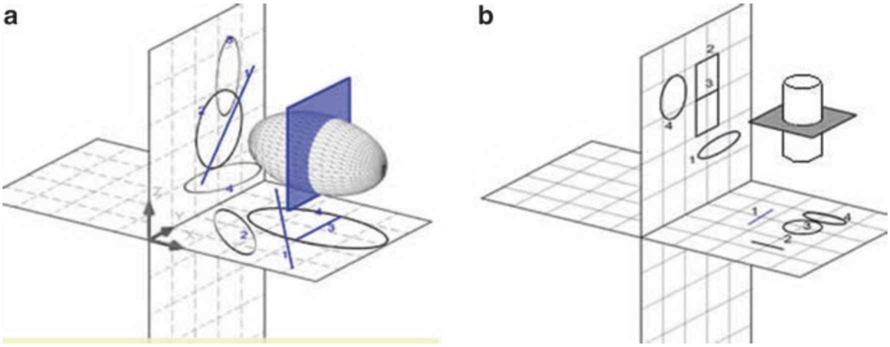

Fig. 8.2 Evaluation sheet for the projection of the ellipsoid (**a**, left) and the projection of the cylinder (**b**, right)

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

Teaching for Control Group

The control group learned basic and advanced stereometry concepts with the traditional approach. The total time of each class was 10 h long, and the course lasted 5 weeks in total. It included concepts such as projection and intersections of points, line segments, planes, cubes, and spheres and also projections, intersections, and expansions of ellipsoids, cylinders, and cones in a three-dimensional coordinate system. Only traditional teaching methods (Fig. 8.3) using the dry-erase board were implemented. The teacher presented the theory about basic and advanced concepts of stereometry. After the presentation of the theory, students were encouraged to ask

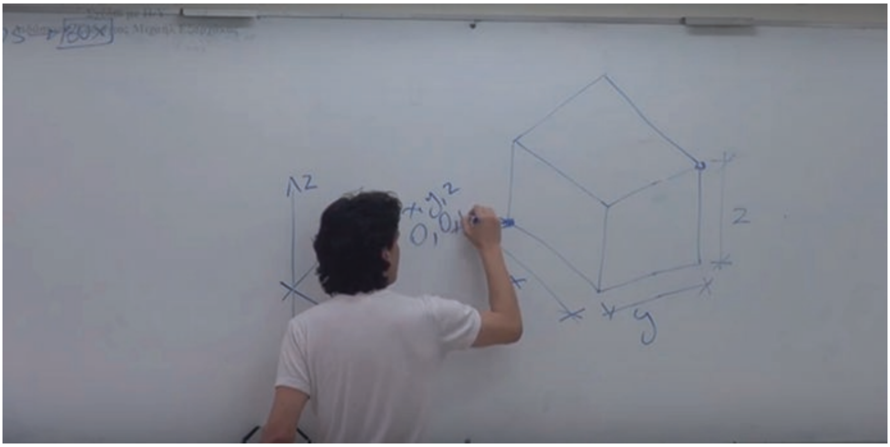

Fig. 8.3 Teaching stereometry with traditional way

questions regarding the lesson. At the end of each module, example problems were solved by the teacher on the dry-erase board. Afterward, the teacher answered any questions the students may have had.

Teaching for Experimental Group

The experimental group was taught using ICT intervention according to our model, presenting the same concepts as the control group. The teaching approach was completed in three stages, according to the Basic University Students Stereometry Model (BUSSM).

The first stage started with educational software for teaching the projections and intersections of points, line, segments, planes (Fig. 8.4a, b), cubes, and spheres in a three-dimensional coordinate system. The teaching of these concepts lasted 4 h. During the first 2 h, the students were taught according to the first two levels of the van Hiele model. During the second half of the lesson, the concepts of points, line, segments, planes, cubes, and spheres were presented based on the third level of the van Hiele model.

The second stage consisted of educational software for teaching the intersections and projections of ellipsoids, cylinders, and cones (Fig. 8.5) and lasted 4 h. During the first 2 h of this stage, the concepts introduced were based on first and second levels of the van Hiele model. During the second 2 h, the teaching process was based on the third level of the van Hiele model.

The third stage consisted of educational software for teaching the expansions of ellipsoids, cylinders, and cones and lasted 2 h. During the first hour, the concepts introduced were based on the first and second levels of the van Hiele model. During the second hour, the teaching process was based on the third level of the van Hiele model.

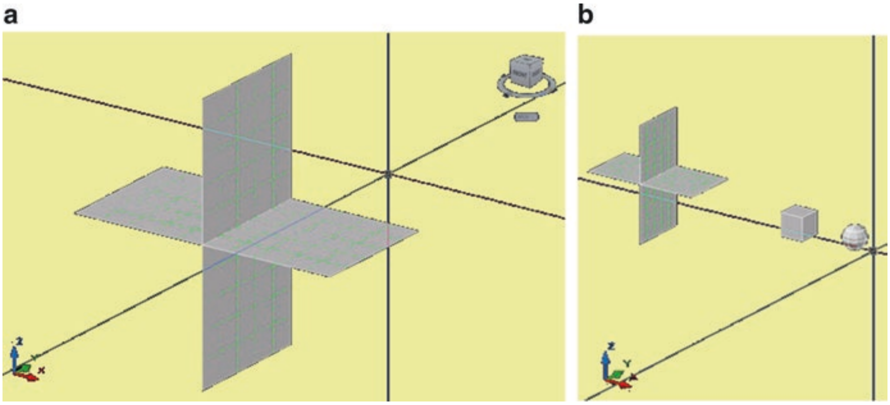

Fig. 8.4 Constructing the three-dimensional coordinate system (**a**, left) and the basic solid shapes (**b**, right) with the use of ICT

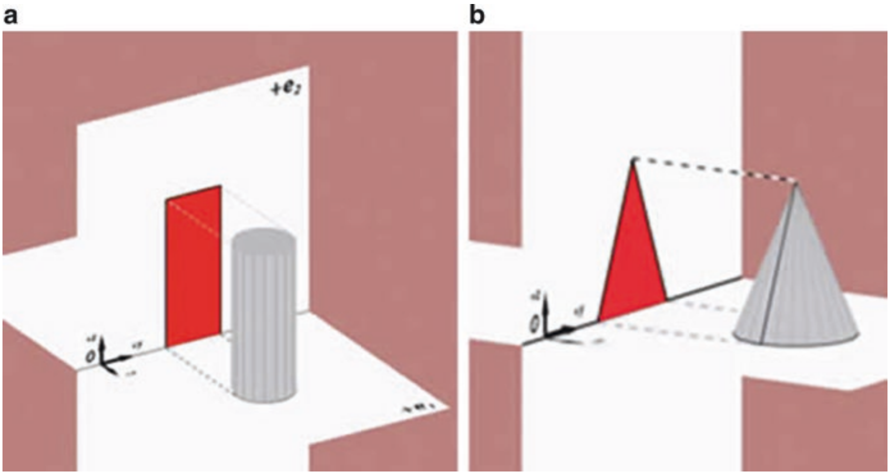

Fig. 8.5 Teaching projections of a cylinder (**a**, left) and a cone (**b**, right) with the use of ICT

In this teaching process, the tasks of the BUSSM intervention were allocated equally to all subjects. Also, during the teaching intervention, exercises were created that were included in the van Hiele model. During the teaching approach, each stereometry concept was investigated 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 together stereometry objects using visual recognition. For instance, students might define that an object is a cube, because it looks like a dice. Also, students might say that an object is a cylinder, because it looks like a tin can. At the second level, the level of analysis, the students were able to identify stereometry shapes by their properties. For example, a student sees a cube as a shape with all plane surfaces equal. Also, a student recognizes that a cylinder has two circular plane surfaces, one at its base and another at its top, and also that it has a curved surface in the middle. At the third level, the level of informal deduction, the student can reason with simple arguments about stereometry figures. The student 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. Also, the student can find out that a sphere is an ellipsoid which has distinct semi-axes of equal length. During the teaching approach of these three levels, video tutorials (Fig. 8.6) were presented by the educator displaying solid shapes and their properties, projections, and intersections (e.g., a video tutorial with projections of cone intersections). A discussion then followed to answer any questions the students may have had. Also, the students had to construct the shapes on the computers using the AutoCAD program system (Abu Ziden et al., 2012). This was an interactive way to view and understand the properties of the stereometry objects and see them from many different points of view. Moreover, the students performed projections and various intersections of the stereometry shapes. In addition, exercises were assigned by the teacher, and students were required to solve them using the AutoCAD program.

The AutoCAD program was used for projections and intersections of various stereometry shapes. This is the software that enables the creation of stereometry models using and specifying coordinates based on the Cartesian axes system (Abu Ziden et al., 2012). Using this software, the student can create objects in two and even three dimensions to see a various range of projections. Also the students used the software to link objects in Cartesian coordinate system and create new intersections of stereometry objects. The students even had the ability to rotate the entire stereometry shapes or parts of them in real time. Using this software, the student can determine the results of operations and fully understand the properties of shapes in a three-dimensional environment. The 3D Studio Max program was then used to create and move three-dimensional stereometry shapes. Students in several investigations with the 3D Studio Max program found the interactive multimedia teaching methods to be a valuable supplement to the conventional teaching process (Prinz, Bolz, & Findl, 2005). Finally, the Camtasia software was used. Camtasia Studio has been suggested as suitable applied software to create educational content (Bauk & Radlinger, 2013). It had a user-friendly interface for creating multimedia, providing students with a variety of options for educational presentations. It uses the introduc-

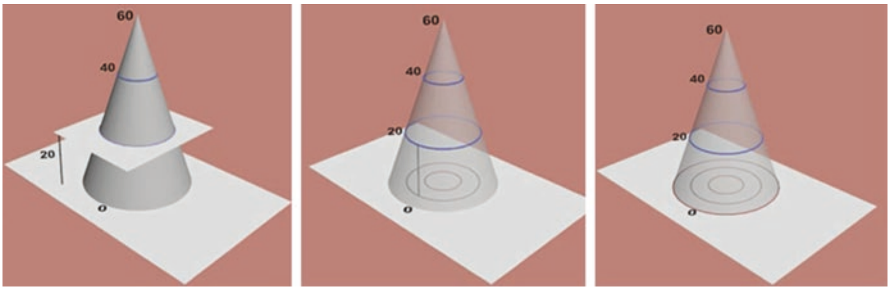

Fig. 8.6 Screenshots from a video tutorial of projections of cone intersections

tion of sound, video, and various animations in order to make teaching and learning more interesting and to highlight the most important subjects. In our application, it has been used to process animated images and add comments on the screen.

Results

Analysis of the data was carried out using the SPSS (ver. 19) statistical analysis computer program. The independent variable was the group (experimental group and control group). The dependent variable was the students' posttest score.

Evaluate the Effectiveness of BUSSM for General Stereometry Achievement

The first analysis was a *t*-test among the students' pretest scores of stereometry achievement in order to examine whether the experimental and control groups start from the same level. There was a significant difference in the students' pretest scores for experimental ($M = 0.534$, SD = 0.100) and control groups ($M = 0.613$, SD = 0.169); $t(141.635) = -3.838$, $p < 0.001$. As a result, an ANCOVA analysis will be processed.

Before conducting the analysis of ANCOVA on the students' posttest scores for general stereometry achievement to evaluate the effectiveness of the intervention, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances (Pallant, 2001). The result of Levene's test when pretest for general mathematical achievement was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 1.073$, $p = 0.302$; hence, the assumption of homogeneity of variance was not been violated.

After adjusting for scores for general stereometry achievement in the pretest (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the posttest scores for general stereometry achievement, $F(1, 186) = 35.899$, $p < 0.001$, partial eta squared = 0.162 (Table 8.1); thus, the experimental group performed significantly higher in the posttest for general stereometry achievement than the control group.

Table 8.1 Comparison of student scores for total mathematical achievement in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	3.072	1	3.072	128.299	0.000	0.408
Group	0.859	1	0.859	35.899	0.000	0.162
Error	4.453	186	0.024			

Table 8.2 Comparison of student scores on basic stereometry concepts in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	2.005	1	2.005	151.581	0.000	0.449
Group	0.155	1	0.155	11.680	0.001	0.059
Error	2.460	186	0.013			

Evaluate the Effectiveness of BUSSM for Basic Stereometry Concepts

Then, a *t*-test analysis performed among the students' pretest scores of basic stereometry concepts (projections and intersections of points, line, segments, planes, cubes, and spheres) in order to examine whether the experimental and control groups start from the same level.

There was a significant difference in the students' pretest scores of basic stereometry concepts for experimental (M = 0.547, SD = 0.135) and control groups (M = 0.599, SD = 0.190); $t(159.123) = -2.117$, $p = 0.036$. As a result, an ANCOVA analysis will be processed.

Also, before conducting the analysis of ANCOVA on the students' posttest scores for basic stereometry concepts to evaluate the effectiveness of the intervention, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances (Pallant, 2001). The result of Levene's test when pretest for basic stereometry concepts was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 0.001$, $p = 0.977$; hence, the assumption of homogeneity of variance was not been violated.

After adjusting for scores for basic stereometry concepts in the pretest (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the posttest scores for basic stereometry concepts, $F(1, 186) = 11.680$, $p = 0.001$, partial eta squared = 0.059 (Table 8.2); thus, the experimental group performed significantly higher in the posttest for basic stereometry concepts than the control group.

Evaluating the Stratification of Students in Basic Stereometry Concepts After the Teaching Intervention According to Their Success in Pretest

Moreover, a stratification of experimental and control groups according to their success in basic stereometry concepts of the pretest was divided into three equal categories: less than 0.499 (33.33th percentile—low), 0.500–0.613 (33.33th to 66.66th percentile—medium), and more than 0.614 (66.66th percentile—high). In Table 8.3, the students' performance is presented including both groups (i.e., the experimental and the control groups) before teaching intervention.

Table 8.3 shows that 20.2% of the students of the experimental group exhibited high grading and 41.4% exhibited medium grading, whereas 38.4% exhibited low grading. Likewise, 48.9% of the control group exhibited high grading, 24.4% medium, and 26.7% low. In other words, students' performance in the medium category of the experimental group appeared to be superior (i.e., 41.4% compared with 24.4% of the control group).

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement (low versus medium versus high) on their improvement on basic stereometry concepts (posttest minus pretest score). There was not a significant interaction between the effects of class and mathematical level on students' according to their success in basic stereometry concepts, $F(2, 183) = 0.969$, $p = 0.381$, partial eta squared = 0.010. On the contrary, the effect of mathematical level was significant ($F(2, 183) = 16.730$, $p < 0.001$, partial eta squared = 0.155), with the improvements of basic stereometry concepts in the low and medium levels higher (low, $M = 5.089$, SD = 2.624, medium, $M = 4.580$, SD = 2.551) than those in the high level ($M = 2.352$, SD = 2.094) after the teaching intervention (Table 8.4, Fig. 8.7). Also, the effect of group was also significant ($F(1, 183) = 6.419$, $p = 0.012$, partial eta squared = 0.034), with children in the experimental group scoring higher ($M = 4.724$, SD = 2.369) than those in the control group ($M = 3.187$, SD = 2.818) after the teaching intervention.

Table 8.3 Frequencies of the two groups in the pretest of general stereometry achievement

Pretest	Experimental group		Control group	
Grading	*N*	*f*%	*N*	*f*%
Low	38	38.4	24	26.7
Medium	41	41.4	22	24.4
High	20	20.2	44	48.9
Total	99	100.0	90	100.0

Table 8.4 Mean and standard deviation of mathematical improvement in basic stereometry concepts according to the levels of general mathematical achievement of the pretest

Level	Class	*M*	SD	*N*
Low	Experimental	5.215	2.551	38
	Control	4.889	2.778	24
	Total	5.089	2.624	62
Medium	Experimental	5.127	2.135	41
	Control	3.562	2.9763	22
	Total	4.580	2.551	63
High	Experimental	2.968	1.611	20
	Control	2.071	2.241	44
	Total	2.352	2.094	64
Total	Experimental	4.724	2.369	99
	Control	3.187	2.818	90
	Total	3.992	2.698	189

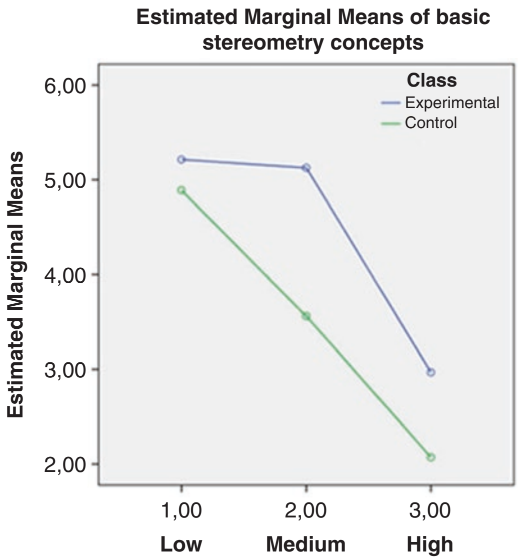

Fig. 8.7 Mathematical improvement in basic stereometry concepts after the teaching intervention according to the levels of general mathematical achievement of the pretest

The Bonferroni post hoc tests indicated that students' improvement in basic stereometry concepts of the experimental group of the low-level and medium-level groups differed significantly from students' improvement of the high-level group ($p < 0.001$ for low-level and $p = 0.018$ for medium-level).

Evaluate the Effectiveness of BUSSM for Advanced Stereometry Concepts

Initially, a *t*-test analysis was performed among the students' pretest scores for advanced stereometry concepts (intersections and projections of ellipsoids, cylinders, and cones) in order to examine whether the experimental and control groups start from the same level. There was a significant difference in the students' pretest scores of advanced stereometry concepts for experimental ($M = 0.526$, SD = 0.109) and control groups ($M = 0.621$, SD = 0.177); $t(145.541) = -4.373$, $p < 0.001$. As a result, an ANCOVA analysis will be processed.

Also, the analysis of ANCOVA on the students' posttest scores for subtraction was performed to evaluate the effectiveness of the intervention. The result of Levene's test when pretest for advanced stereometry concepts was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 3.159$, $p = 0.077$; hence, the assumption of homogeneity of variance was not been violated.

Table 8.5 Comparison of student scores for advanced stereometry concepts in posttest: ANCOVA analysis

Sources	Type III sum of squares	df	Mean squares	*F*	Sig.	Partial eta squared
Pretest	0.904	1	0.904	60.580	0.000	0.246
Group	0.408	1	0.408	27.320	0.000	0.128
Error	2.776	186	0.015			

After adjusting for scores for advanced stereometry concepts in the pretest (covariate), the following results were obtained from the analysis of covariance (ANCOVA). A statistically significant main effect was found for type of intervention on the posttest scores for advanced stereometry concepts, $F(1, 186) = 27.320$, $p < 0.001$, partial eta squared = 0.128 (Table 8.5); thus, the experimental group performed significantly higher in the TEMA-3 posttest for advanced stereometry concepts than the control group.

Evaluating the Stratification of Students in Advanced Stereometry Concepts After the Teaching Intervention According to Their Success in Pretest

Moreover, a stratification of experimental and control groups according to their success in general mathematical achievement was divided into three equal categories, less than 0.499 (33.33th percentile—low), 0.500–0.613 (33.33th to 66.66th percentile—medium), and more than 0.614 (66.66th percentile—high), as it has been showed in Table 8.3.

A two-way ANOVA was conducted that examined the effect of class (experimental versus control) and the students' level of mathematical achievement in advanced stereometry concepts (low versus medium versus high) on their improvement after the teaching intervention (posttest minus pretest score). There was not a significant interaction between the effects of class and mathematical level on students' in advanced stereometry concepts, $F(2, 183) = 0.714$, $p = 0.491$, partial eta squared = 0.008. On the contrary, the effect of mathematical level in advanced stereometry concepts was significant ($F(2, 183) = 18.509$, $p < 0.001$, partial eta squared = 0.168), with the improvements of advanced stereometry concepts in the low and medium levels higher (low, $M = 10.746$, SD = 5.921, medium, $M = 8.191$, SD = 5.205) than those in the high level ($M = 4.421$, SD = 3.737) after the teaching intervention (Table 8.6, Fig. 8.8). Also, the effect of group was significant ($F(1, 183) = 34.211$, $p < 0.001$, partial eta squared = 0.158).

The Bonferroni post hoc tests indicated that students' improvement in advanced stereometry concepts of the experimental group of the low-level group differed significantly from students' improvement of the high-level ($p < 0.001$) group.

Table 8.6 Mean and standard deviation of mathematical improvement in advanced stereometry concepts according to the levels of general mathematical achievement

Level	Class	*M*	SD	*N*
Low	Experimental	12.369	6.461	38
	Control	8.175	3.820	24
	Total	10.746	5.921	62
Medium	Experimental	9.994	4.313	41
	Control	4.830	5.134	22
	Total	8.191	5.205	63
High	Experimental	6.536	2.664	20
	Control	3.460	3.781	44
	Total	4.421	3.737	64
Total	Experimental	10.207	5.414	99
	Control	5.052	4.560	90
	Total	7.752	5.638	189

Discussion

The overall aim of the study was to investigate the effect of the didactic intervention, using the Basic University Students Stereometry Model (BUSSM). Especially, mathematical activities and software based on Realistic Mathematics Education were designed for the purpose of teaching the mathematical concepts of basic and advanced stereometry concepts (Freudenthal, 1973; Van den Heuvel-Panhuizen & Buys, 2008). In this survey, we found that students taught with educational intervention based on BUSSM had significant improvement in their general stereometry achievement compared to those taught using the traditional teaching method according to the university curriculum. Our findings agree with similar studies (Antohe, 2010; Judge, 2005; Keong et al., 2005; Walcott et al., 2009; Zaranis, 2011), which implied that ICT helps students understand mathematical concepts more effectively. As a result, the first research question was answered positively.

Moreover, we found that students taught with the educational intervention based on BUSSM had significant improvement in basic stereometry concepts, such as projections and intersections of points, line segments, planes, cubes, and spheres in comparison to those taught using the traditional teaching method according to the university curriculum. Our results coincide with the results of other similar studies showing the positive impact of a computer-based model of teaching mathematics (Dissanayake et al., 2007; Kroesbergen, Van de Rijt, & Van Luit, 2007). Therefore, the second research question was confirmed.

Also, our findings suggest that students belonging to the low and medium level of general stereometry achievement being taught basic stereometry concepts with educational intervention based on BUSSM had significant improvement, compared to the students in the high levels of general mathematical achievement. Our results exceeded the outcomes of other similar studies showing the positive results of a computer-based model of teaching mathematical concepts for the low-level students (Keong et al., 2005; Zaranis, 2011). So the third research question was addressed.

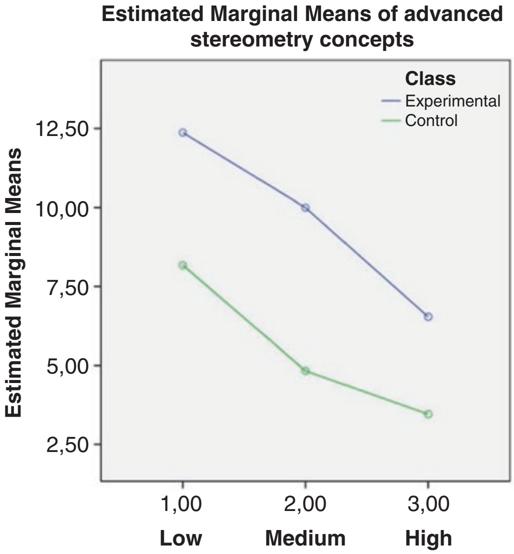

Fig. 8.8 Mathematical improvement in advanced stereometry concepts after the teaching intervention according to the levels of general mathematical achievement

Furthermore, as mentioned in the results section, the students taught with educational intervention based on BUSSM had a significant improvement on advance stereometry concepts, such as projections, intersections, and expansions of ellipsoids, cylinders, and cones, than those taught using traditional teaching according to the university curriculum. Our results agree with the results of other similar studies showing the positive outcomes of a computer-based model of teaching mathematical concepts (Dimakos & Zaranis, 2010; Howie & Blignaut, 2009; Starkey, Klein, & Wakeley, 2004; Trouche & Drijvers, 2010; Wong et al., 2011). Therefore, the fourth research question was also answered positively.

Moreover, our findings suggest that students with a low level of general stereometry achievement being taught advance stereometry concepts with educational intervention based on BUSSM had significant improvement, compared to those with a high level of general mathematical achievement students. Our results exceeded the outcomes of other similar studies showing the positive results of a computer-based model of teaching mathematical concepts for the low-level students (Dimakos et al., 2009; Keong et al., 2005). Thus, the fifth research question was also addressed.

Regarding the educational value of the present study, its findings should be taken into account by a range of stakeholders such as students, teachers, researchers, and universities' curriculum designers. Specifically, our designed teaching approaches could be set up as a broad range study in order to examine to what extent they help students to understand stereometry concepts. Moreover, the learning method based on Realistic Mathematics Education (RME) using ICT can interfere in various mathematical subjects, e.g., algebraic equations, probabilities, etc.

The above discussion should be referenced in light of some of the limitations of this study. The first limitation of the study is that the data collected was from the participants residing in the city of Athens, Greece. The second limitation was the generalizability of this study which was limited to participants attending the Department of Civil Engineering at Piraeus University. As a result, the outcomes from this research can be generalized only to similar groups of students. The results may not adequately describe students from other regions of Greece. However, as the study was on specific context, any application of the findings should be done with caution.

Furthermore, the undertaken computer-assisted educational procedure revealed an extended interest for the tasks involved from the part of the students. It is an ongoing challenge for the reflective university teachers to decide how this technology can be best utilized in education. This study is one small piece in the puzzle of mathematics education in university level.

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