Does ICT affect the understanding of ellipsoids, cylinders and cones among students from University of Applied Sciences?

Nicholas Zaranis*

Department of Preschool Education,
University of Crete,
Panepistimioupoli Gallou, Rethymno,
74100 Rethymno, Greece
Email: nzaranis@edc.uoc.gr
*Corresponding author

George M. Exarchakos

Department of Civil Engineering,
Piraeus University of Applied Sciences,
250 Petrou Ralli & Thivon Str.,
12244 Egaleo, Greece
Email: gexar@teipir.gr

Abstract: Our research compares the improvement of the students' stereometry competence of ellipsoids, cylinders and cones using two teaching approaches. The first one employs our ICT-oriented learning method specifically targeting the Van Hiele model for stereometry concepts. The second method is based on the traditional approach of teaching university students. The study deals with second year undergraduate students form the Department of Civil Engineering at Piraeus University of Applied Sciences. The sample was divided into two groups (experimental and control). The results showed that the teaching approaches of our intervention, with the additional use of ICT using the background of the Van Hiele model, contribute significantly more to the development of university students' stereometry competence as compared to other traditional methods.

Keywords: ICT; ellipsoids; cylinders; cones; higher education.

Reference to this paper should be made as follows: Zaranis, N. and Exarchakos, G.M. (2018) 'Does ICT affect the understanding of ellipsoids, cylinders and cones among students from University of Applied Sciences?' *Int. J. Technology Enhanced Learning*, Vol. 10, No. 4, pp.269–288.

Biographical notes: Nicholas Zaranis graduated from the Department of Electrical and Computer Engineering of the NTUA. He took his MSc in ICT from the University of Essex. Also, he received his Master of Science and his PhD from the University of Athens. He has worked for a series of years in the private sector as Electrical Engineer in Hewlett Packard Hellas and in public sector as teacher in Secondary Education. He is currently Associate Professor in the Department of Preschool Education at the University of Crete. His research interests include ICT in education, educational software, and teaching of mathematics using ICT.

George M. Exarchakos is Teaching Staff in the Department of Civil Engineering at the Piraeus University of Applied Sciences and teaches the university course 'Drawing with ICT'. He is a Civil Engineer from the Department of Civil Engineering at the Piraeus University of Applied Sciences. Also, he received his Master of Science in Information and Communication Technology in Education from the University of Athens. He took his PhD from the University of Athens in the area of teaching Geometry using ICT for University students. His research interests include ICT in education and teaching of Geometry using ICT.

1 Introduction

ICT plays an essential role in achieving the university curriculum objectives in a plethora areas and issues, if supported by developmentally appropriate educational software applications (Di Paola et al., 2013; Dwyer, 2007, Papadakis et al., 2016a, 2017). In the most ideal environment, computers are seen as instruments for teaching and learning processes (Burnett, 2009; Fisher et al., 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.

Researchers propose that the appropriate use of computers is associated with the ability of students to more effectively understand the various mathematical concepts. A great number of studies show a positive relationship between the use of ICT and the development of mathematical comprehension at every level of education (Vale and Leder, 2004; Walcott et al., 2009; Wong et al., 2007; Zaranis et al., 2013; Zaranis and Valla, 2017).

However, the authors of many studies have reported that although computers have many helpful attributes, their effectiveness as an educational tool is limited by the educational software in place. Software made in agreement with the terms of educational system can help achieve effective learning under the guidance of educators. Scientists realised that the software used in the education of mathematics is a very significant consideration in the learning process (Howie and Seugnet Blignaut, 2009; Papadakis et al., 2016b).

Dynamic multiple implementations in software help students' visualisation because students can investigate, solve, and comprehend mathematical concepts using various methods. Providing only information or images is not enough to compel students to visualise or to use a different understanding of mathematical knowledge (Antohe, 2010; Haciomeroglu et al., 2009; Mantzakos and Kalogiannakis, 2017). Proper software offers an elevated level of engagement in trigonometry and coordinate geometry (Borovik, 2011; Sahaa et al., 2010; Zengina et al., 2011). Establishing basic knowledge of cylinders and cones is expected to be simple since students see examples in their day-to-day lives; although, students find it difficult to learn stereometry concepts (Wong et al., 2011).

In this research, teaching tools have been developed in order to engage students to comprehend 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 an active and constantly evolving theory of teaching and learning mathematics (Van den Heuvel-Panhuizen, 2001). Indicative of this are the learning and teaching trajectories with intermediate attainment targets which were first conducted for the subject of mathematical calculation at kindergarten and extended to the subject of geometry (Van den Heuvel-Panhuizen and Buys, 2008). In the whole trajectory of the RME teaching theory, five main characteristics of understanding geometry concepts (Van den Heuvel-Panhuizen, 2001) 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;
- 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 school curriculum. The van Hiele model uses five levels (Van Hiele, 1986).

- Visual Level: This level is characterised 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 recognise these shapes by their properties.
- Level of Informal Deduction: At this level, students can infer properties of a shape and recognise 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 form the Department of Civil Engineering at Piraeus University of Applied Sciences. The BUSSM used only the first three levels of the Van Hiele model, because it was applied on the basic concepts of ellipsoids, cylinders and cones. The students that participated in this research have not covered the subject of basic stereometry since the last two classes of primary education. The teaching intervention was a three weeks syllabus program focusing on projections, intersections and expansions of ellipsoids, cylinders and cones.

1.1 Research questions

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

In comparison to those taught using the traditional teaching method according to the university curriculum, will the students taught with educational intervention based on BUSSM have a significant improvement on the understanding of the following subjects:

1. Stereometry shapes?
2. Ellipsoids?
3. Cylinders?
4. Cones?

The answers to the above four questions should be taken into account and used by a range of stakeholders such as students, teachers, researchers, curriculum designers etc. at university level.

2 Methodology

2.1 Sample

The study was 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, 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 one of the two required tests (pre-test or post-test) 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 teaching procedure.

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

2.2 Research design

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

1 The pre-experimental phase the beginning of April 2014. Its purpose was to isolate the effects of the treatment by looking for inherent inequalities in the geometry achievement of the two groups. The pre-test was given to the students of the experimental and control groups.

2 The experimental phase or intervention phase during which the manipulation of the independent variables 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 to use various 3D software features and capabilities on applications such as: AutoCad, ArchiCad, CadWare, which are ideal for use in the learning process (Abu Ziden et al., 2012; Bellin and Suchman Simone, 1997; Oruabena et al., 2016). The objective of this course is to familiarise 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 realise 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 sterometry 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 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 post-test to measure their improvement on advanced stereometry concepts.

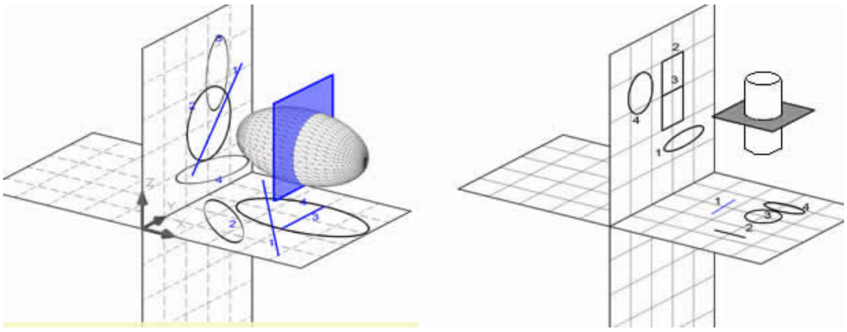
Ethical considerations and guidelines on the privacy of students and other relevant ethical issues in social research were carefully considered throughout the process of research. Requirements relating to information, informed consent, confidentiality and use of data held carefully, both orally and in 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.

2.3 Measures

In the pre-experimental phase, the first phase, the pre-test was administered to assess the students' advanced stereometry competence and it contained thirty four tasks in total. There were pencil-and-paper tasks in which students were asked to identify the projections, intersections and expansions of ellipsoids, cylinders and cones (Figure 1). There was about an equal number of tasks for the evaluation of each of the three solid 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.

Since the numbers of questions varied across tasks, a mean proportion of correct responses for each of the thirty four tasks were produced by dividing the number of correct responses by the total number of problems on that task. The pre-test and post-test were administrated in the class with explicit and specific instructions from the teachers and each test lasted about thirty minutes. The responses were scored and coded and the data set was collected from the results of the stereometry test.

Figure 1 Evaluation sheet for the projection of the ellipsoid (a) and the projection of the cylinder (b)



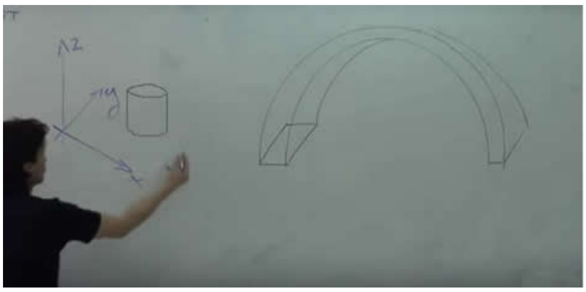
(a) (b)

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 post-test to measure their improvement.

2.4 Teaching for control group

The control group learned advanced stereometry concepts with the traditional approach. The total time of each class was six hours long and the course lasted three weeks in total. It included concepts such as: projections, intersections and expansions of ellipsoids, cylinders and cones. Only traditional teaching methods (Figure 2) using the dry erase board were implemented. The teacher presented the theory about advanced concepts of stereometry. After the presentation of the theory students were encouraged to ask questions regarding the lesson. At the end of each module, example problems were solved by the teacher on the dry erase board. Afterwards the teacher answered any questions the students may have had.

Figure 2 Teaching stereometry with traditional way

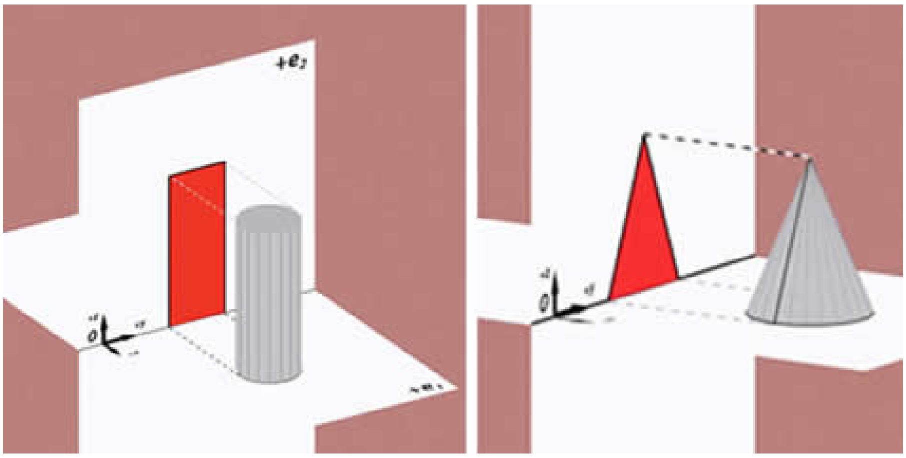


2.5 Teaching for experimental group

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 of ellipsoids, cylinders and cones in a three-dimensional coordinate system. The teaching of these concepts lasted two hours. During the first hour the students were thought according to the first two levels of the Van Hiele model. During the second half of the lesson the concepts of the projections of ellipsoids, cylinders and cones (Figure 3) were presented based on the third level of the Van Hiele model.

Figure 3 Teaching projections of a cylinder (a) and a cone (b) with the use of ICT



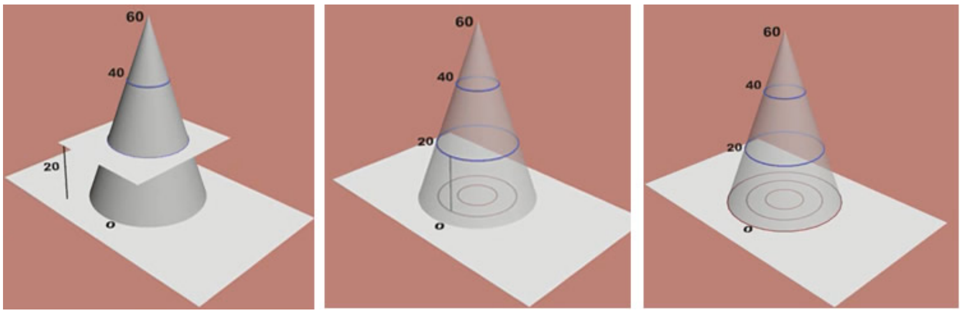
(a) (b)

The second stage consisted of educational software for teaching the intersections of ellipsoids, cylinders and cones, and lasted two hours. During the first hour of this stage the concepts introduced were based on first and second levels of the Van Hiele model. The second hour 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 two hours. During the first hour the concepts introduced were based on the first and second levels of the Van Hiele model. The second hour the teaching process was based on the third level of the Van Hiele model.

In this teaching process, the tasks of the BUSSM intervention were allocated equally to the three subjects of ellipsoids, cylinders and cones. 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 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 recognises 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 recognises the relationships between types of shapes. For example, 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 (Figure 4) 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.

Figure 4 Screenshots from a video tutorial of projections of cone intersections



The AutoCAD program was used for projections and intersections of various stereometry shapes. This is 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 they found the interactive multimedia teaching methods to be a valuable supplement to the conventional teaching process (Prinz et al., 2005). Finally, the Camtasia software was used. Camtasia Studio has been suggested as suitable applied software to create educational content (Bauk and Radlinger, 2013). It had a user-friendly interface for creating multimedia, providing students with a variety of options for educational presentations. It uses the introduction 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.

3 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 stereometry concepts on ellipsoids, cylinders and cones. 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 (Wagner, 2015). The independent variable was the group (experimental group and control group). The dependent variable was the students' post-test score.

3.1 Evaluate the effectiveness of BUSSM for total stereometry achievement

The first analysis was to examine whether the students were on the same level concerning the shapes of ellipsoids, cylinders and cones. This analysis was done before starting to examine the research questions. The t-test for equality of means was significant (t = –3.641, p < 0.001), indicating significant differences initially, in stereometry achievement between the experimental (M = 17.799, SD = 4.249) and control (M = 20.661, SD = 6.260) groups; as a result the two groups were not started from the same level. Also, the control group had a mean score higher than the experimental group; the mean difference in the pre-test scores was –2.862. The results of this test are summarised in Table 1 and Table 2.

Table 1 Group statistics of pre-test scores

Group	*N*	*Mean*	*Std. Dev.*	*Std. Error*
Experimental	99	17.799	4.249	.427
Control	90	20.661	6.260	.659

Table 2 Independent samples t-test of the pre-test scores

Pre-test	*t*	*df*	*Mean difference*	*Sig. (2-tailed)*
t-test	–3.641	154.40	–2.862	.000

In this subsection, we are going to investigate if the first research question confirmed. As it was certified above, the pre-tests had significant differences among the experimental and control groups. Thus, in order to determine if the performance of the experimental group is significant in comparison to the control group after the teaching intervention, an Analysis of Covariance (ANCOVA) was conducted between the post-test scores of both groups. After adjusting for BUSSM scores for total stereometry achievement in the pre-test (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 BUSSM post-test scores for total stereometry achievement, $F(1, 186) = 346.964$, $p < .001$, $\eta^2 = .093$ (Table 3); thus the experimental group performed significantly higher in the BUSSM post-test for total stereometry achievement than the control group.

Table 3 Comparison of student scores for total stereometry achievement in post-test: ANCOVA analysis

Sources	*Type III Sum of Squares*	*df*	*Mean Squares*	*F*	*Sig.*	*Partial Eta Squared*
Pre-test	1048.765	1	1048.765	57.918	.000	.237
Group	346,964	1	346.964	19.161	.000	.093
Error	3,368,038	186	18.108			

Moreover, in order to decide if the performance of the experimental group was 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 17.799 (SD = 4.249) compared to 27.379 (SD = 4.547) for the post-test. At $\alpha = 0.05$ and df = 98, the critical value of the t ratio was less than 0.001 ($t = -16.981$, $p < 0.001$). Therefore, the performance of the experimental group had a significant improvement after the teaching intervention.

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 20.661 (SD = 6.260) compared to 25.847 (SD = 5.182) for the post-test. At $\alpha = 0.05$ and df = 89, the critical value of the t ratio was less than 0.001 ($t = -10.676$, $p < 0.001$). Therefore, the performance of the control group had a significant improvement after the teaching intervention. Summarising, we can say that both experimental and control groups had significant improvements after the teaching intervention.

3.2 Evaluate the effectiveness of BUSSM for ellipsoids

In this subsection, we are going to examine the second research question. We compare on each teaching group (experimental, control) the scores of ellipsoids, taking into account that the pre-test scores varied significant. As a result an ANCOVA analysis will be performed. Before conducting the analysis of ANCOVA on the students' BUSSM post-test scores for ellipsoids, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances and homogeneity of regression slopes (Pallant, 2001). The result of Levene's test when pre-test for ellipsoids was included in the model as a covariate was not significant, indicating that the group variances were equal, $F(1, 187) = 1.282$, $p = .259$; hence the assumption of homogeneity of variance was not been violated.

After adjusting for BUSSM scores for ellipsoids in the pre-test (covariate), the following results were obtained from the Analysis of Covariance (ANCOVA). There was not a statistically significant main effect for type of intervention on the BUSSM post-test scores for ellipsoids, $F(1, 186) = .073$, $p = .787$, $\eta^2 < .001$ (Table 4); thus the experimental group did not performed significantly higher in the BUSSM post-test for ellipsoids than the control group.

In order to determine if the performance of the experimental group is significant, after the teaching intervention a paired t-test was performed using the grades of this group for a comparison between pre-test and post-test scores for ellipsoids. The mean grade for the pre-test in the study was .637 (SD = .239) compared to .805 (SD = .215) for the post-test (Table 5). At α = .05 and df = 98, the critical value of the t ratio was less than 0.001 (Table 6). Therefore, the post-test score was significantly different from the pre-test score in the experimental group.

Table 4 Comparison of student scores for ellipsoids in post-test: ANCOVA analysis

Sources	*Type III Sum of Squares*	*df*	*Mean Squares*	*F*	*Sig.*	*Partial Eta Squared*
Pre-test	1.704	1	1.704	53.420	.000	.223
Group	.002	1	.002	.073	.787	.000
Error	5.933	186	.032			

Table 5 Paired samples statistics of pre-test and post-test scores in the experimental group

Experimental Group	*N*	*Mean*	*Std. Dev.*	*Std. Error*
Pre-test	99	.637	.239	0.024
Post-test	99	.805	.215	0.021

Table 6 Paired samples test of pre-test and post-test scores in the experimental group

	t	*df*	*Mean*	*Sig. (2-tailed)*
Pair 1 pre-test-post-test	–7.131	98	–0.167	.000

Similarly, to determine if the performance of the control group is significant, after the teaching intervention a paired t-test was performed using the grades of this group for a comparison between pre-test and post-test scores for ellipsoids. The mean grade for the pre-test in the study was .688 (SD = .260) compared to .818 (SD = .186) for the post-test (Table 7). At α = .05 and df = 89, the critical value of the t ratio was less than 0.001 (Table 8). Therefore, the post-test score was significantly different from the pre-test score in the control group.

Table 7 Paired samples statistics of pre-test and post-test scores in the control group

Experimental Group	*N*	*Mean*	*Std. Dev.*	*Std. Error*
Pre-test	90	.688	.260	0.027
Post-test	90	.818	.186	0.019

Table 8 Paired samples test of pre-test and post-test scores in the control group

	t	*df*	*Mean*	*Sig. (2-tailed)*
Pair 1 pre-test- post-test	–5.163	89	–0.129	.000

3.3 Evaluate the effectiveness of BUSSM for cylinders

In this subsection, we are going to examine the third research question. We compare on each teaching group (ICT, control) the scores of cylinders, taking into account that the pre-test scores varied significant. As a result an ANCOVA analysis of students' BUSSM post-test scores for cylinders was performed to evaluate the effectiveness of the intervention. The result of Levene's test when pre-test for cylinders was included in the model as a covariate was not significant, indicating that the group variances were equal, F(1, 187) = .164, p = .686; hence the assumption of homogeneity of variance was not been violated.

After adjusting for BUSSM scores for cylinders in the pre-test (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 BUSSM post-test scores for cylinders, F(1, 186) = 18.126, $p < .001$, $\eta^2 = .089$ (Table 9); thus the experimental group performed significantly higher in the BUSSM post-test for cylinders than the control group.

Table 9 Comparison of student scores for cylinders in post-test: ANCOVA analysis

Sources	*Type III Sum of Squares*	*df*	*Mean Squares*	*F*	*Sig.*	*Partial Eta Squared*
Pre-test	.197	1	.197	69.645	.000	.232
Group	.197	1	.197	69.715	.000	.232
Error	.654	231	.003			

3.4 Evaluate the effectiveness of BUSSM for cones

In this subsection, we are going to examine the fourth research question. We compare on each teaching group (ICT, control) the scores of cones, taking into account that the pre-test scores varied significant. As a result an ANCOVA analysis will be performed. Before conducting the analysis of ANCOVA on the students' FCPST post-test scores for cones to evaluate the effectiveness of the intervention, checks were performed to confirm that there were no violations of the assumptions of homogeneity of variances and homogeneity of regression slopes (Pallant, 2001). The result of Levene's test when pre-test for cones was included in the model as a covariate was not significant, indicating that the group variances were equal, F(1, 187) = .460, p = .498; hence the assumption of homogeneity of variance was not been violated.

After adjusting for BUSSM scores for cones in the pre-test (covariate), the following results were obtained from the ANCOVA analysis. A statistically significant main effect was found for type of intervention on the BUSSM post-test scores for cones, F(1, 186) = 10.032, p = .002, η^2 = .051 (Table 10); thus the experimental group performed significantly higher in the BUSSM post-test for cones than the control group.

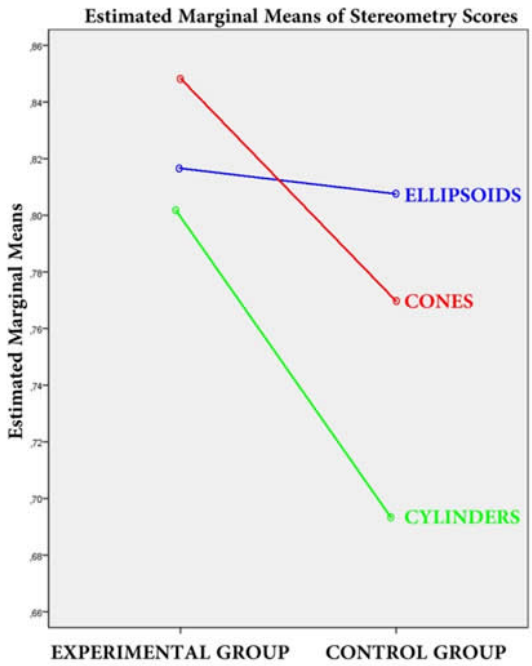
Table 10 Comparison of student scores for cones in post-test: ANCOVA analysis

Sources	*Type III Sum of Squares*	*df*	*Mean Squares*	*F*	*Sig.*	*Partial Eta Squared*
Pre-test	1.277	1	1.277	46.985	.000	.202
Group	.273	1	.273	10.032	.002	.051
Error	5.055	186	.027			

Moreover, in order to examine which of the three solid geometry shapes had the highest improvement, their Partial Eta Squared compared. Cylinders had higher Partial Eta Squared than cones and ellipsoids had lower Partial Eta Squared of all (Tables 4, 5, 6).

Thus, we conclude that cylinders in experimental group had the highest achievement of cones and ellipsoids. Moreover, cones had higher than ellipsoids, as illustrated in Figure 5.

Figure 5 Stereometry scores improvement after the teaching intervention



The results of this study are in agreement with the results of many surveys (Antohe, 2010; Zengina et al., 2011; Borovik, 2011; Haciomeroglu et al., 2009; Sahaa et al., 2010; Di Paola et al., 2013; Vale and Leder, 2004; Wong et al., 2007) 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 (Mantzakos and Kalogiannakis, 2017; Walcott et al., 2009; Zaranis and Baralis, 2015; Zaranis, 2012), had similar results to our research in Greek primary, secondary school and university students, stressing that students interacting with software enriched with developmentally appropriate math activities led to the understanding of mathematical concepts.

4 Discussion

The overall aim of the study was to investigate the effect of the teaching approach using the Basic University Student Stereometry Model for the purpose of teaching advanced 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 stereometry achievement 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 (Borovik, 2011; Di Paola et al., 2013) which imply that ICT helps students to understand mathematical notions more effectively. As a result, the first research question was answered positively. In addition, as it mentioned in the results section, students in both the experimental and the control groups scored higher for stereometry shapes after receiving the teaching intervention than before the teaching process.

Moreover, we found that the students that were taught ellipsoids with educational intervention based on BUSSM did not have a significant improvement compared to those taught using the traditional teaching method according to the university curriculum. However, throughout the study, the experimental group had slightly greater stereometry achievement than the control group (Figure 5). In addition both experimental and control groups had a significant improvement after the teaching intervention. As a result, the teaching process had a positive impact on students in both groups. Despite that, the difference was not statistically significant. Therefore, the second research question has not confirmed. Our results did not completely agree with the results of other analogous studies which indicate the positive effects of a computer based model of teaching geometry (Wong et al., 2007; Zaranis, 2011). The results of these researches refer to general geometrical shapes and not to ellipsoid like solid stereometry shapes. We consider ellipsoids to be simpler stereometry shapes in relation to cylinders and cones, as circles are simpler than triangles and squares (Wong et al., 2011). The surface of ellipsoids is curved and is simpler to understand than the surface of cylinders and cones which both have curved and flat surfaces. Also, the projections and intersections of ellipsoids are literally circles or ellipses. On the contrary the projections and intersections of cylinders may be more complicated and can be circles, ellipses, parabola and rectangles. Moreover, the projections and intersections of cones are complicated and can be circles, ellipses, triangles and parabola (Timur and Gül Kaleli, 2015). Concluding the above, we found out that our teaching intervention with ICT, for the simple solid shapes of stereometry, such as ellipsoids, will help students slightly improve their performance compared to those taught by the traditional method. On the contrary, the BUSSM teaching process yielded a significant improvement in the understanding the more complex solid shapes of stereometry, such as cylinders and cones compared to the results of the traditional method.

Also, our findings suggest that the students were taught cylinders with educational intervention based on BUSSM had a significant improvement compared to those taught using the traditional teaching method. Our outcomes overlie the results of other similar studies which indicate the positive effects of a computer based teaching model for geometric shapes (Antohe, 2010; Sahaa et al., 2010). Thus, the third research question was answered positively.

Moreover, the findings of this research suggest that the students were taught cones with educational intervention based on BUSSM had a significant improvement compared to those taught using the traditional teaching method. Our findings agree with similar researches which indicate the positive effects of a computer based teaching model for geometric shapes (Haciomeroglu et al., 2009; Remtulla, 2010). Thus, the fourth research question was answered positively.

An important statistical outcome of the present study was that the partial eta squared for cylinders (η^2 = .232, Table 9) is higher than it was for cones (η^2 = .051, Table 10). Also, the partial eta squared for cones (η^2 = .051, Table 10) is higher than it was for ellipsoids ($\eta^2 < .001$, Table 4). This outcomes supports that, our teaching intervention had a greater impact in the learning of cylinders than in the learning of cones. Cones had a greater impact in learning ellipsoids for university students, as it is depicted in Figure 4. Our findings agree with other similar researches supporting the effective role of ICT in education and more specifically in mathematical reasoning (Shih et al., 2014; Sutherland et al., 2004; Vale and Leder, 2004).

On the matter of the educational value of this research, its findings should be taken into account by teachers, researchers and curriculum designers. Specifically, our designed teaching intervention could be set up as a pilot study in order to examine to what extent ICT helps university students comprehend advanced stereometry shapes. Moreover, the teaching method based on the van Hiele model can be applied to various mathematical subjects. The application of ICT gives the opportunity for university teachers to develop new activities for students understanding advanced stereometry concepts.

The result of this study can be extended by developing various related studies in stereometry and geometry at the university level and all level of secondary education. It would be interesting to design an advanced model combining ICT activities along with pen and paper activities as a blended learning approach and to examine if this combination produces better results.

As far as the limitations of this study are concerned, 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 generalisability 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 generalised 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.

Finally, the attempted computer aided educational process revealed a widespread interest in the tasks involved on the part of the students. It is an on-going challenge for the reflective educators to decide how this technology can be better used in higher education; especially in light of current research on the positive effects of such applications.

References

Abu Ziden, A., Zakaria, F. and Nizam Othman, A. (2012) 'Effectiveness of AutoCAD 3D Software as a Learning Support Tool', *International Journal of Emerging Technologies in Learning*, Vol. 7, No. 2, pp.57–60.

Antohe, V. (2010) 'New methods of teaching and learning mathematics involved by GeoGebra', *First Eurasia Meeting of GeoGebra (EMG)*, 11–13 May.

Bauk, S. and Radlinger, R. (2013) 'Teaching ECDIS by Camtasia Studio: Making the Content more Engaging', *International Journal on Marine Navigation and Safety of Sea Transportation*, Vol. 7, No. 3, pp.375–380.

Bellin, D. and Suchman Simone, S. (1997) *The CRC Card Book*, Addison-Wesley, Reading, MA.

Borovik, A. (2011) 'Information technology in university-level mathematics teaching and learning: a mathematician's point of view', *Research in Learning Technology*, Vol. 19, No. 1, pp.73–85.

Burnett, C. (2009) 'Research into literacy and technology in primary classrooms: an exploration of understandings generated by recent studies', *Journal of Research in Reading*, Vol. 32, No. 1, pp.22–37.

Di Paola, F., Pedone, P. and Pizzurro, M.R. (2013) 'Digital and interactive Learning and teaching methods in descriptive geometry', *Procedia-Social and Behavioral Sciences*, Vol. 106, pp.873–885.

Dwyer, J. (2007) 'Computer-based learning in a primary school: differences between the early and later years of primary schooling', *Asia-Pacific Journal of Teacher Education*, Vol. 35, No. 1, pp.89–103.

Fisher, T., Denning, T., Higgins, C. and Loveless, A. (2012) 'Teachers' knowing how to use technology: exploring a conceptual framework for purposeful learning activity', *Curriculum Journal*, Vol. 23, No. 3, pp.307–325.

Haciomeroglu, E.S., Bu, L., Schoen, R.C. and Hohenwarter, M. (2009) 'Learning to develop mathematics lessons with GeoGebra', *MSOR Connections*, Vol. 9, No. 2, pp.24–26.

Howie, S. and Blignaut, A.S. (2009) 'South Africa's readiness to integrate ICT into mathematics and science pedagogy in secondary schools', *Educ Inf Technol*, Vol. 14, pp.345–363.

Mantzakos, N. and Kalogiannakis, M. (2017) 'A support distance learning program in mathematics for first year engineering students', *Education and Information Technologies*, https://doi.org/10.1007/s10639-017-9641-y.

Oruabena, B., Eniekenemi, E. and Chidiebere, U.B. (2016) 'The use of Archicad Software Program and its effects on students academic performance in building drawing in Government Technical College, Ahoada, Revers State', *International Journal of Advanced Academic Research Sciences, Technology & Engineering*, Vol. 2, No. 5, pp.26–31.

Papadakis, S., Kalogiannakis, M. and Zaranis, N. (2017) 'Designing and creating an educational app rubric for preschool teachers', *Education and Information Technologies*, Vol. 22, No. 6, pp.3147–3165.

Papadakis, St., Kalogiannakis, M. and Zaranis, N. (2016a) 'Comparing tablets and PCs in teaching mathematics: an attempt to improve mathematics competence in early childhood education', *Preschool & Primary Education Journal*, Vol. 4, No. 2, pp.241–253.

Papadakis, St., Kalogiannakis, M. and Zaranis, N. (2016b) 'Developing fundamental programming concepts and computational thinking with ScratchJr in Preschool Education. A case study', *International Journal of Mobile Learning and Organisation*, Vol. 10, No. 3, pp.187–202.

Prinz, A., Bolz, M. and Findl, O. (2005) 'Advantage of three dimensional animated teaching over traditional surgical videos for teaching ophthalmic surgery: a randomised study', *The British Journal of Ophthalmology*, Vol. 89, No. 11, pp.1495–1499.

Remtulla, K.A. (2010) 'Media Mediators': advocating an alternate paradigm for critical adult education ICT policy', *Journal for Critical Education Policy Studies*, Vol. 7, No. 3, pp.300–324.

Sahaa, R.A., Ayubb, A.F.M. and Tarmizi, R.A. (2010) 'The effects of GeoGebra on mathematics achievement: enlightening coordinate geometry learning', *Procedia Social and Behavioral Sciences*, Vol. 8, pp.686–669.

Shih, H., Jackson, J., Hawkins Wilson, C. and Yuan, P.C. (2014) 'Using MIT app inventor in an emergency management course to promote computational thinking', *121st ASEE Annual Conference & Exposition*, Indianapolis.

Sutherland, R. et al. (2004) 'Transforming teaching and learning: embedding ICT into everyday classroom practices', *Journal of Computer Assisted Learning*, Vol. 20, No. 6, pp.413–425.

Timur, K. and Gül Kaleli, Y. (2015) 'Using dynamic geometry software for the intersection surfaces', *Journal of Education and Training Studies*, Vol. 3, No. 5, pp.195–205.

Vale, C. and Leder, G. (2004) 'Student views of computer-based mathematics in the middle years: does gender make a difference?' *Educational Studies in Mathematics*, Vol. 56, pp.287–312.

Van den Heuvel-Panhuizen, M. and Buys, K. (Eds) (2008) 'Young children learn measurement and geometry. A learning-teaching trajectory with intermediate attainment targets for the lower grades in primary school', Sense Publishers, Rotterdam/Tapei.

Van den Heuvel-Panhuizen, M. (2001) 'Realistic mathematics education as work in progress', Lin, F.L. (Ed.): *Common Sense in Mathematics Education, Proceedings of 2001, the Netherlands and Taiwan Conference on Mathematics Education*, Taipei, Taiwan, 19–23 November, pp.1–40.

Van Hiele, P.M. (1986) *Structure and Insight: a theory of Mathematics Education*, Academic Press, Orlando, FL.

Wagner, W.E. (2015) *Using IBM SPSS Statistics for Research Methods and Social Science Statistics*, 5th ed., SAGE Publication Inc., Los Angeles.

Walcott, C., Mohr, D. and Kastberg, S. (2009) 'Making sense of shape: an analysis of children's written responses', *Journal of Mathematical Behavior*, Vol. 28, No. 1, pp.30–40.

Wong, W.K., Hsu, S.C., Wu, S.H., Lee, C.W. and Hsu, W.L. (2007) 'LIM-G: learn-initiating instruction model based on cognitive knowledge for geometry word problem comprehension', *Computers & Education*, Vol. 48, No. 4, pp.582–601.

Wong, W.K., Yin, S.K., Yang, H.H. and Cheng, Y.H. (2011) 'Using computer-assisted multiple representations in learning geometry proofs', *Educational Technology & Society*, Vol. 14, No. 3, pp.43–54.

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

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

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

Zaranis, N., Kalogiannakis, M. and Papadakis, S. (2013) 'Using mobile devices for teaching realistic mathematics in kindergarten education', *Creative Education*, Vol. 4, pp.1–10.

Zaranis, N. and Valla, V. (2017) 'Tablet computer assisted counting and calculating activities for kindergarten children', in Gómez Chova, L., López Martínez, A. and Candel Torres, I. (Eds): *EDULEARN17 Proceedings, 9th International Conference on Education and New Learning Technologies*, 3–5 July, Barcelona, Spain, pp.9680–9689.

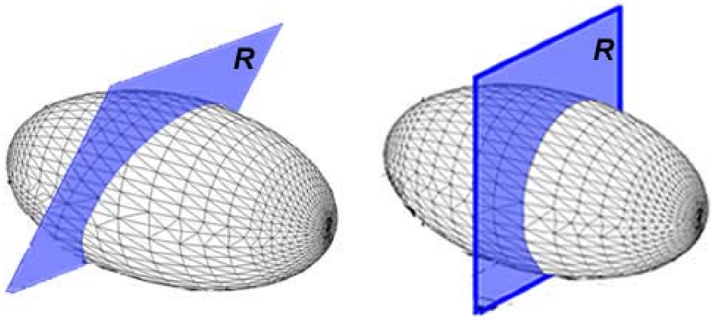
Zengina, Y., Furkanb, H. and Kutluca, T. (2011) 'The effect of dynamic mathematics software geogebra on student achievement in teaching of trigonometry', *Procedia – Social and Behavioral Sciences*, Vol. 31, pp.183–187.

Appendix

The measurement test of the students' stereometry knowledge

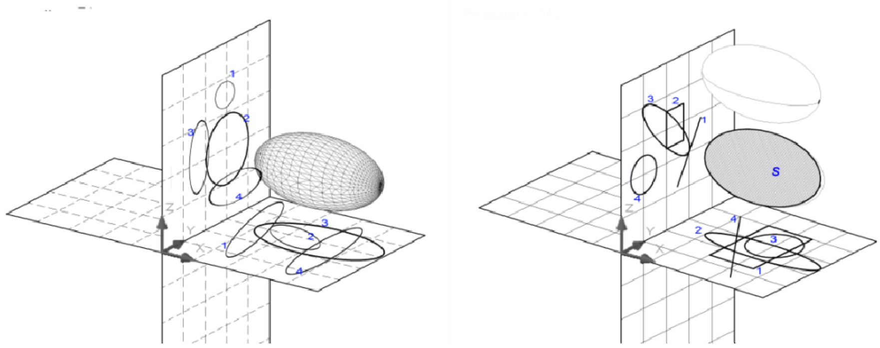
The measurement test of the students' stereometry knowledge contains thirty four tasks in total. There are tasks in which students are asked to identify projections, intersections and expansions of ellipsoids, cylinders and cones. These tasks had an increasing degree of difficulty and vary from simple to more complex. Some characteristic examples for each section of the test are displayed below.

Figure A1 Select the answer. What is the shape of each intersection (a, b) of the ellipsoids and each plane R respectively? (1) Circle, (2) Ellipse, (3) Rectangle, (4) Parabola



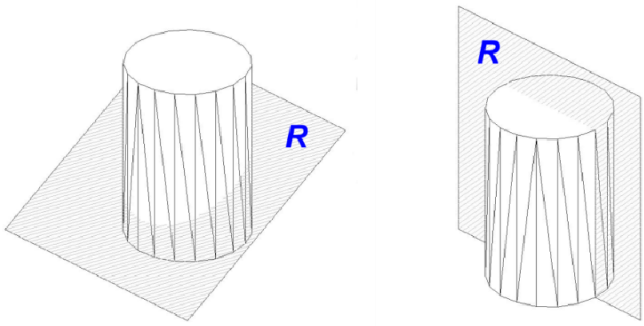
(a) (b)

Figure A2 (a) Find the projections of ellipsoid on XY and YZ planes among the shapes 1 through 4 and (b) find the projections of ellipsoid's intersection S on planes XY and YZ among the shapes 1 through 4



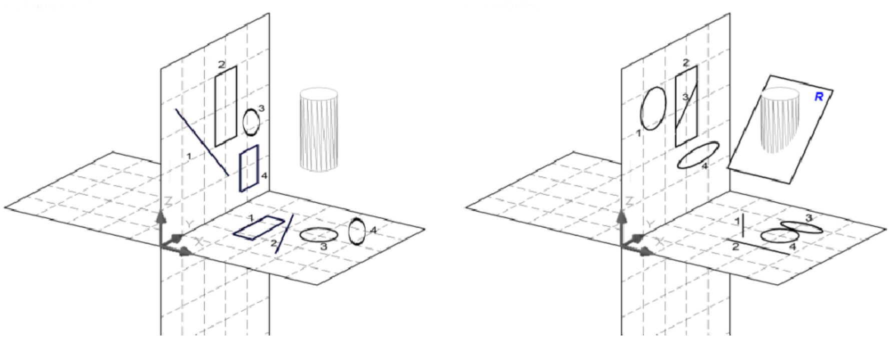
(a) (b)

Figure A3 Select the answer. What is the shape of each intersection (a, b) of the cylinders and each plane R respectively? (1) Circle, (2) Ellipse, (3) Rectangle, (4) Triangle



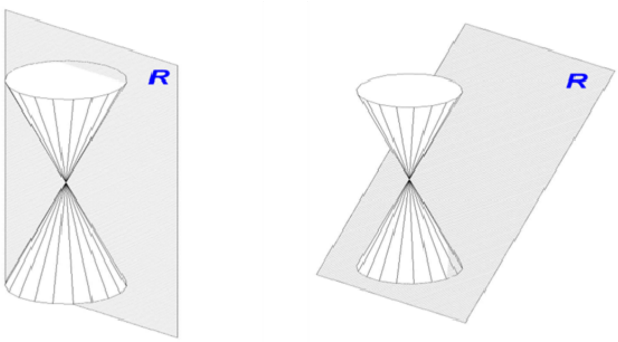
(a) (b)

Figure A4 (a) Find the projections of ellipsoid on XY and YZ planes among the shapes 1 through 4 and (b) find the projections of ellipsoid's intersection S on planes XY and YZ among the shapes 1 through 4



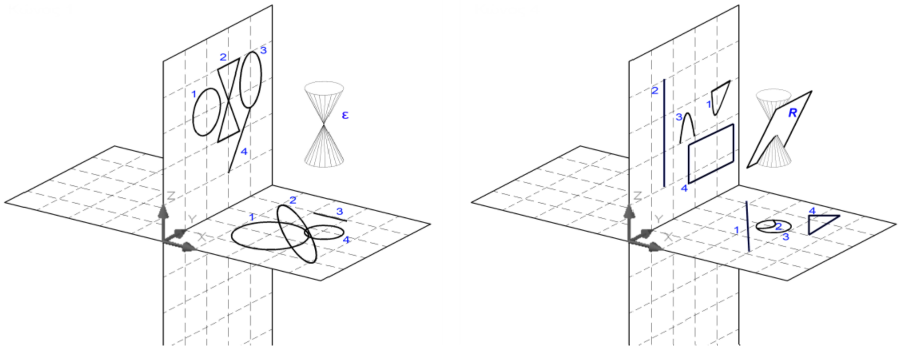
(a) (b)

Figure A5 Select the answer. What is the shape of each intersection (a, b) of the cones and each plane R respectively? (1) Circle, (2) Ellipse, (3) Rectangle, (4) Triangle



(a) (b)

Figure A6 (a) Find the projections of cone on XY and YZ planes among the shapes 1 through 4 and (b) find the projections of cone's intersection with plane R on planes XY and YZ among the shapes 1 through 4



(a) (b)