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3D visualization types in multimedia applications for science learning: A case study for 8th grade students in Greece

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ABSTRACT

This research aims to determine whether the use of specific types of visualization (3D illustration, 3D animation, and interactive 3D animation) combined with narration and text, contributes to the learning process of 13- and 14- years-old students in science courses. The study was carried out with 212 8th grade students in Greece. This exploratory study utilizes three different versions of an interactive multimedia application called "Methods of separation of mixtures", each one differing from the other two in a type of visuals. The results indicate that multimedia applications with interactive 3D animations as well as with 3D animations do in fact increase the interest of students and make the material more appealing to them. The findings also suggest that the most obvious and essential benefit of static visuals (3D illustrations) is that they leave the time control of learning to the students and decrease the cognitive load.

1. Introduction

The fundamental question is not whether media affects learning but how to take advantage of the various media so that instructions and learning can be more effective, as Kozma and his advocates stated (Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006). During the last 10 years, several guidelines for multimedia instruction have been proposed (Tabbers, 2002), however these lack coherence. Therefore, technical developments rather than considerations have resulted in the search for guidelines. Moreover, empirical research for these guidelines is often inconclusive or even contradictory. Two research lines that seem to be more promising in that respect are Sweller's cognitive load theory (2003), and Mayer's generative theory of multimedia learning (2001).

Mayer's research program is directed towards two interconnected goals: "a theoretical goal of contributing to a cognitive theory of how people learn from words and pictures, and a practical goal of contributing to the design of effective multimedia instruction for adults" (Mayer, 2002; Robinson, 2004). Despite some promising current research programs, the overwhelming consensus is that "with few exceptions, there is not a body of research on the design, use, and value of multimedia systems," (Moore, Burton, & Myers, 2004). Also, multimedia learning studies carried out until recently have not taken into consideration important factors that could influence the appropriate selection of media and have thus failed to yield conclusive multimedia design guidelines (Samaras et al., 2006).

Nevertheless, there is a strong argument for developing multimedia tools from within a disciplinary area to ensure appropriate treatment of the material and, more importantly, correct identification of the teaching and learning difficulties and their potential solutions (Muller, Eklund, & Shanna, 2006). Multimedia research has recently focused on dynamic media and is searching for didactical sellings where animations consistently support learning. However, static visual presentations continue to have educational benefits, which will survive good animations (Guttormsen & Kaiser, 2006).

In recent years researchers studied the metacognition and especially the purposes it serves. A possible definition is that metacognition is thinking about thinking: What do I know? What do I not know? Will I ever find an answer? Knowing what we don't know helps us focus our questions, and how long and hard we look for an answer depends on how likely it seems that we'll find an answer (Brem & Andrea, 2000). According to another researcher "a metacognitive learner is one who understands the tasks of monitoring, integrating, and extending, their own learning" (Gunstone, 1994). A few others have called attention to the importance of social factors in the development of metacognitive skills. It has been suggested that the development of metacognitive skills may be facilitated by social interactions with others (e.g. teachers, parents, peers) (Reeve & Brown, 1985). Activities such as decision making, reflective thinking, problem solving and

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metacognition are key aspects of higher order cognition. In multimedia environments, interactivity is the key to creating these forms of activities (Oliver, 1996).

Christopherson (1997) defines visual literacy as a critical ability, which enables people to use visual images accurately and to behave appropriately. According to him, a visual literate person can:

(1) interpret, understand, and appreciate the meaning of visual messages;
(2) communicate more effectively by applying the basic principles and concepts of visual design;
(3) produce visual messages using computers and other technologies; and
(4) use visual thinking to conceptualise solutions to problems (Ferk, Vrtacnik, Blejec, & Gril, 2003). Visualizations provide means for making visible phenomena that are too small, large, fast, or slow to see with the unaided eye. In addition, they illustrate invisible or abstract phenomena that cannot be observed or experienced directly (Buckley, 2000).

Spatial ability may be defined as the ability to generate, retain, retrieve, and transform well-structured visual images. It is not a unitary construct. There are, in fact, several spatial abilities, each emphasising different aspects of the process of image generation, storage, retrieval, and transformation. Spatial abilities are pivotal constructs of all models of human abilities (Lohman, 1993). According to Barnea (2000) spatial ability involves representing, rotating, and inverting objects in three dimensions when they are presented in two dimensions. Therefore, Barnea-structured visualization skills vary according to the different levels of difficulty:

(1) 'Spatial visualization', the ability to understand accurately three-dimensional (3D) objects from their two-dimensional (2D) representation.
(2) 'Spatial orientation', the ability to imagine what a representation will look like from a different perspective.
(3) 'Spatial relations', the ability to visualize the effects of operations such as rotation, reflection and inversion, or to mentally manipulate objects (Ferk et al., 2003).

Moreover, human cognitive architecture includes a working memory of limited capacity and duration with partially separate visual and auditory channels, and an effective infinite long-term memory holding many schemas that can vary in their degree of automation. These cognitive structures have evolved to handle information that varies in the extent to which elements can be processed successively in working memory or, because they interact, must be processed simultaneously, imposing a heavy load on working memory. Cognitive load theory uses this combination of information and cognitive structures to guide instructional design (Sweller, 2002). According to Sweller, Van Merrienboer, and Paas (1998) there are three types of cognitive load: intrinsic, extraneous, and germane. The first type, intrinsic cognitive load, occurs during the interaction between the nature of the material being learned and the expertise of the learner. The second type, extraneous cognitive load, is caused by factors that are not central to the material to be learned, such as presentation methods or activities that split attention between multiple sources of information, and these should be minimised as much as possible. The third type, germane cognitive load, enhances learning and results in task resources being devoted to schema acquisition and automation. Intrinsic cognitive load cannot be manipulated, in contrast to extraneous and germane cognitive load (Sorden, 2005). Intrinsic, extraneous, and germane cognitive loads form an equation in which the sum total of the three cannot exceed the working memory resources if learning is to occur (Paas, Renkl, & Sweller, 2003).

On the question whether learning for children is different from learning for adults, the answer is that children are not simply little adults, not capable of reasoning as an adult until they reach the age of 15. Whereas adults and adolescents can be expected to examine auditory–visual events systematically and completely, learning for children is a different experience. The human brain is not fully developed until late adolescence and, in some males, not until early adulthood. Moreover, age differences in children show a wider range of variability in task performance than age differences among adults (Mann, 2007). Metacognitive knowledge gradually grows in the years thereafter, but the development of metacognitive skills is not expected to set in before the age of 11–12 (Veenman & Spaans, 2005). Also it does seem that skills of visualization improve with age during childhood and adolescence (Gilbert, 2005). Spatial ability is said to be influenced by the age as well as by the gender, the culture, the learning opportunities, and the everyday environment (Ferk et al., 2003). Consistent with the views of Luria (1976) and Vygotsky (1978), there is an argument that awareness of self-regulatory activity has its roots in social interactions with others. Others, in the developing child's world, initially take responsibility for articulating metacognitive processes. With time, this responsibility is ceded to the child, who is required to take charge of her or his own thinking behaviours (Reeve & Brown, 1985). Finally it has been suggested that the development of metacognitive skills may be facilitated by social interactions with others (e.g. teachers, parents, peers) (Reeve & Brown, 1985).

Computer based multimedia material offers different means of supporting 3D information representations (Huk, 2006). Viewing dynamic and 3D animations is assumed to be a possible way of changing and improving students' incomplete mental models (Wu & Shah, 2004). Nevertheless, based on various researchers (Gerjets & Scheiter, 2003; Paas et al., 2003a), it is found that 3D models may lead to cognitive overload problems in hypermedia-learning environments in particular, as such environments are assumed to generate a heavy cognitive load. On the other hand, the findings of Ferk et al. (2003) research revealed that some representations of molecular 3D structure are better understood and can be more readily used by students in solving tasks of different complexity. To all students the concrete representations seem to be more useful than abstract representations. Secondary school students and university students achieved the best results when using photographs of 3D molecular models or computer-generated models, while primary school students scored better when using concrete 3D models. Several studies have described the implementation of 3D representations in diverse scientific disciplines such as medicine, zoology, biochemistry, geometry, and electromagnetism (Huk, 2006). However, empirical studies that focus on the impact of 3D visualizations on learning are, to date, rare and inconsistent (Keller, Gerjets, Scheiter, & Garsoffky, 2004). Recent research has shown that spatial ability has an impact on the comprehension of 3D computer visualizations (Keehner, Montello, Hegarty, & Cohen, 2004). It is also interesting to note that recent experimental results show that learners with high spatial ability had a more positive attitude on 3D content than learners with low spatial ability. Huk (2006) observed a more prolonged use of 3D models by high spatial ability students than by students with low spatial ability. This pattern might be either: (a) the result of a cognitive load problem for low spatial ability learners or (b) the expression of a more serious distraction effect of the sophisticated 3D models for students with low spatial ability. Data suggest that the presence of 3D models resulted in a cognitive overload for students with low spatial ability, while high spatial ability students benefited from the 3D models, as their total cognitive load remained within working memory limits (Huk, 2006). Moreover Tavanti and Lind (2001) and Cockburn (2004) found and strongly suggested that: 3D effects make no difference to the effectiveness of spatial memory in monocular static display. In addition, the effectiveness of spatial memory is not affected by the presence or absence of three dimensional perspective effects in monocular static displays.

In some ways animation can provide a very dramatic visual effect, but its impact on learning appears to be much more subtle (Large, Beheshti, Breuleux, & Renaud, 1994). Dynamic visualizations and animations are often perceived to be synonymous, although animations are a subset of dynamic visualizations (Khalil, Paas, Johnson, & Payer, 2005). Ainsworth and Van Labeke (2004) identified three classes of dynamic visualizations based on how time is represented: time-persistent, time-implicit, and time-singular representations. Lewalter (2003) research indicates that dynamic visuals are not generally superior to static visuals because learners with animations did not score better than learners with static visuals with regard to recall and only marginally better regarding comprehension. The growing preference for animations appears to be based on little more than intuition, and research evidence is beginning to challenge the widespread assumption that animations are intrinsically superior to static graphics (Narayanan & Hegarty, 2000). In addition, evidence is accumulating that the instructional effects of animations may not always be beneficial. Possible reasons for this lack of benefit include: (a) the imposition on learners of excessive information processing demands (‘overwhelming’) and (b) a reduction in the extent to which learners engage in valuable processing activities (‘underwhelming’) (Lowe, 2002).

Considering the recall of information, pictures have a superior effect. The picture’s superiority in explicit memory tasks is due to its stronger associative perceptual information than that of words. Pictures enable the extraction and retention of information that readers do not encode effectively. Pictures highlighting details effectively increased the recall of those details, and picture-depicting relationships effectively increased recall of that relational information (Khalil et al., 2005). The most salient benefits of static presentations (static pictures) have shown to be essential in the learning process as they allow control of the learning space by the learners. Also, the static pictures reduce cognitive load (CL) because the learners only see one major learning step at a time; they encourage germane processing because the learners are (implicitly) encouraged to explain the changes from one frame to the next for themselves (Mayer, Hegarty, Mayer, & Campbell, 2005). Finally, in order to evaluate their effectiveness in supporting teaching and learning in science, we must take under consideration that there are times when pictures can aid learning, times when pictures do not aid learning but do no harm either, and times when pictures do not aid learning and are distracting” (Rieber, 2000).

2. Materials and methods

2.1. Presentation of the experimental research

Our research aims at finding out whether specific types of visualization (3D illustration, 3D animation, and interactive 3D animation) combined with narration and text, contribute to the learning process of 13- and 14- years-old students in sciences.

Based on the latest educationally acceptable theories and researches in various multimedia visualizations, an interactive multimedia application titled ‘‘Methods of separation of mixtures” was produced from scratch. The application is addressed to 8th grade students in Greece and is created in three different versions, each one differing from the other two with regards to the type of visualization.

In particular, the first version involves interactive 3D animations (Fig. 1), the second version utilizes 3D animations (Fig. 2), and the third version employs 3D illustrations (Fig. 3). All the rest of the application components (narration, text, navigation, auxiliary tools, interface, etc.) are common in all three versions.

A statistical research study then followed, which aimed at finding out whether the three factors, i.e. interactive 3D animation, 3D animation and 3D illustrations, as well as combinations of the three, make learning more efficient, if so, to what extent.

2.2. Hypotheses to be tested in the research

A total of nine hypotheses were formulated and tested in the research. They are summarised as follows:

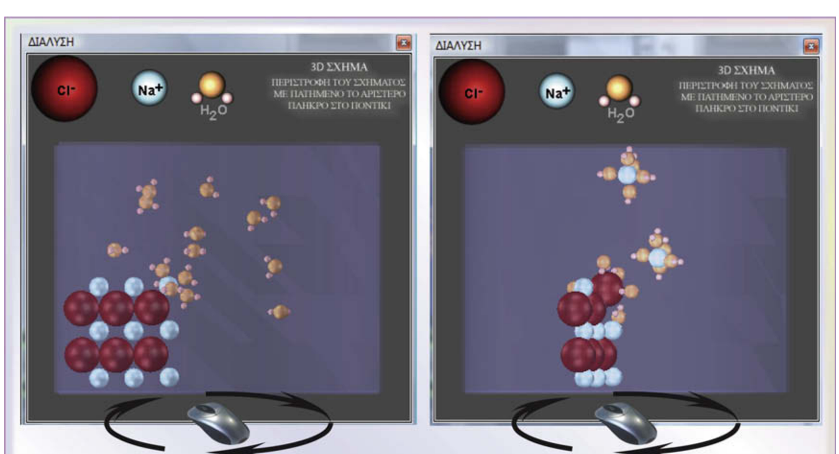

Fig. 1. Interactive 3D animation – The student can: observe the changes that are presented in the animation, use the interactive controls (repetition, pause, play) and the free rotation with the mouse, where the appearing changes can be viewed through different angles.

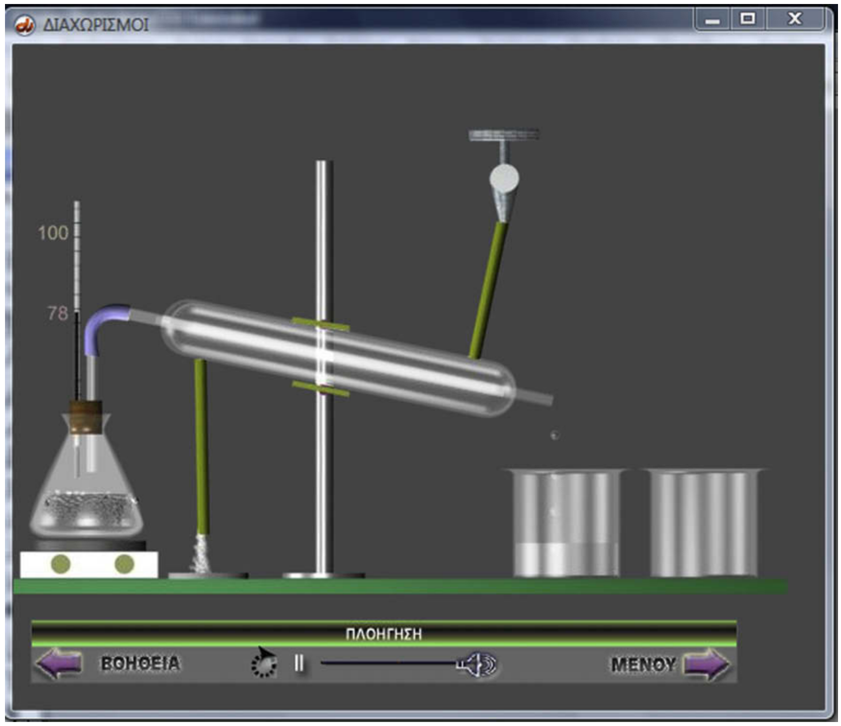

Fig. 2. 3D animation – the student can observe the animation and use the interactive controls (repetition, pause, play), without the choice of rotation.

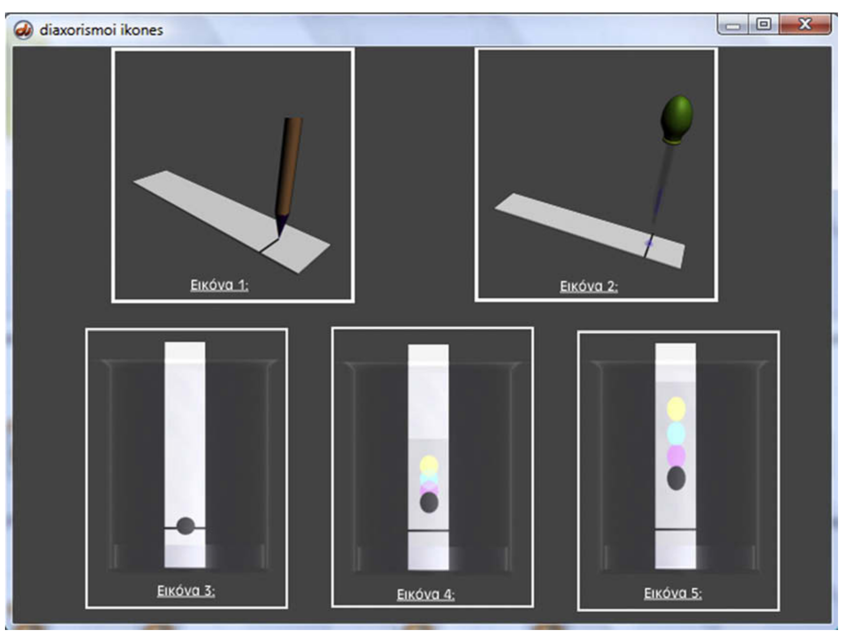

Fig. 3. 3D illustrations (The student can observe the changes from the minimum required static illustrations-key frames).

- The factor "3D static colour illustration" predominates over the other of two factors.
- The factor "3D animation" predominates over the other of two factors.
- The factor "interactive 3D animation" predominates over the other of two factors.
- The factors of the application influence the time of follow-up scenes in each version, the time that is required in order to answer the questions, the percentage of right answers and the time that each student dedicates to each scene.
- The factors of the application influence the number of follow-up scenes.
- There is a relation between the time of follow-up in each version of the application and the time required for answering the questions.
- There is a relation between the time of follow-up in each version of the application and the percentage of right answers to the questions.
- There is a relation between the time that students dedicated to answering the questions and their rate of success.
- The multimedia application interests the students and to what degree, depending on the studied factors of the application.

2.3. Architecture of the educational multimedia application

It is very important to note that in order to achieve specific purposes in our study research, the multimedia application was created from scratch. The steps followed were:

- the drawing and production of all static 3D illustrations,
- the creation of 3D animations, and interactive 3D animations with the appropriate programming,
- the elaboration of the text and sound speech and, finally,
- the careful connection of all of the above elements in the final form of the multimedia application, using the most suitable authoring programme.

The educational multimedia application, which is called ‘‘Methods of separation of mixtures”, explains in detail all the methods of separation which are presented in the current school book of Chemistry, for the 8th grade students. The text material has been enriched with elements from the Greek and international bibliography (Hill & Holman, 1995; Hill & Kolb, 1998; Kotz & Purcel, 1991). Overall, the multimedia application includes the following thematic units: distillation, fractional distillation, pouring, centrifugation, filtering, evaporation, paper chromatography, sieving, and magnetic separation.

2.4. Description of the educational multimedia application

Each scene of the multimedia application is displayed in the main window, in which a concrete thematic unit is presented with the help of visualization (3D static colour illustration or 3D animation or interactive 3D animation). In addition, four auxiliary windows are presented: the navigator bar, the window text (which is displayed whenever the user wishes to read it), the window ‘‘instruments” and the window ‘‘useful” (Fig. 4). These windows are floating, as they can be moved to any part of the screen.

The window menu, which is presented when the button ‘‘menu” is pressed on the navigator bar, consists of the collapsible sub-menus: ‘‘file”, ‘‘units”, ‘‘finding”, ‘‘exercises”, ‘‘bibliography”, and ‘‘authors”. In the collapsible sub-menu ‘‘units”, the user can return in any individual unit of the multimedia application. Also, in the collapsible sub-menu ‘‘finding” the user can find any experimental appliance that exists in the multimedia application.

The 3D animations and interactive 3D animations have an operation of «repetition, pause, play», which make easier the comprehension of the phenomenon or the conception that they describe. In addition, the interactive 3D animations feature the operation of free rotation with the mouse.

2.5. Questions and management of the answers

In the last part of the multimedia application students are called to answer questions of various types. A total of nine questions were divided into three groups. The first group includes multiple-choice questions, the second involves questions of completion of blanks, while in the third group the questions are visualized. The percentage of correct answers is recorded and presented at the end of the multimedia application. The questions in all three versions are precisely the same and are presented in the same way.

Also, in every question the student has the opportunity to check whether he/she gave a correct or a wrong answer. In the case of a wrong answer the student has the chance to try once more, after which the question is locked.

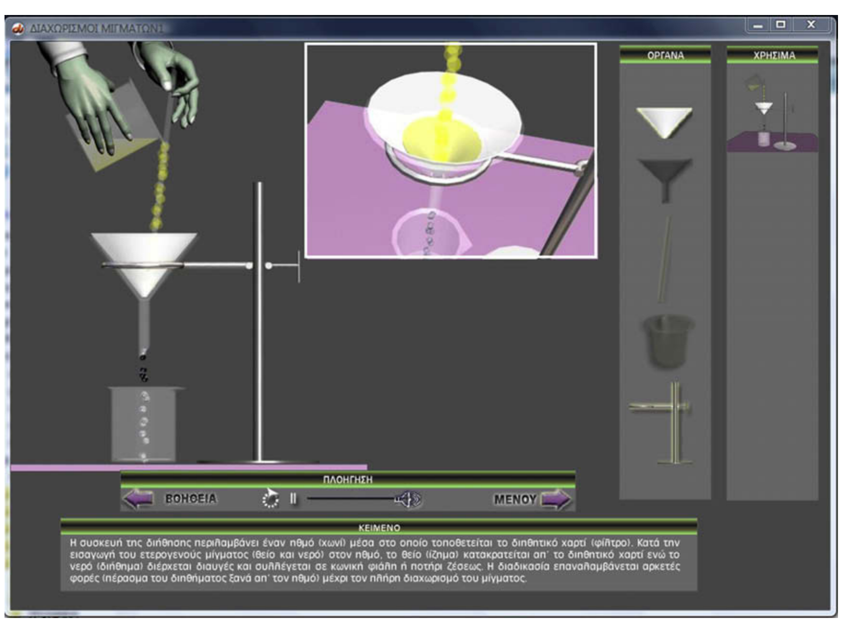

Fig. 4. Auxiliaries’ windows in one of the main scenes (filtering, in particular).

2.6. Collection of information

During the execution of the multimedia application three files are stored in the computer's hard disk. In the first file the results of the evaluation test are registered. In the second file, the time that each user spends in each screen of the multimedia application as well as the number of visits in the same scene are registered. Similarly, in the third file the time that each user needs to answer each question is recorded. These three files are stored as text-files (∗.txt) and then are imported in an Excel spreadsheet.

From the above files the following information can be extracted:

- The percentage of correct answers per student.
- The questions that were answered correctly by each student.
- The time that each student used to answer each question.
- The total time that each student has dedicated in the question part of the multimedia application.
- The number of times each student has visited every question.
- The time that each student has dedicated in each scene of the multimedia application.
- The number of times each student has visited each scene.
- The total time each student has dedicated in the scenes of the multimedia application, apart from those with the questions.
- The number of different scenes that each student has visited.
- The number of questions that each student has checked.

2.7. Research methodology

Sample: 212 students participated in the main research (63 in the first sample, 71 in the second, and 78 in the third sample). The sample was selected randomly at clumps from various schools of Greece. The random selection of each sample was dictated by the fact that in every classroom there were students of different intellectual ability, gender, economic status, etc. Seated at separate computers, each student worked one version of the multimedia application during one school hour.

In order for the outcome of our research to be as thorough as possible, a pilot research was made, in which 30 students from each sample were used.

Variables: The independent and dependent variables that are examined appear in Table 1.

3. Results

3.1. Pilot research

Nine questions were used so that the contribution of the multimedia application version was thoroughly and carefully checked, regarding the record performance of the students in the cognitive object. These questions were checked for their validity and reliability. Specifically, the Cronbach's Alpha indicator as well as, the correlation of Pearson (Total Item Correlation) between all the questions was calculated. Thus, for the sample with the interactive 3D animation, the Cronbach's Alpha indicator was 0.627 and, according to the values of the Total Item Correlation, three of the questions are considered to be inadequate, one of them is marginally suitable, another one suitable, while three questions are perfectly suitable. For the sample with 3D animation the Cronbach's Alpha indicator was 0.718. According to the above, one question is considered to be inadequate, one is marginally suitable, and one is suitable while six questions are considered to be perfectly suitable. Finally, for the sample with 3D illustrations the Cronbach's Alpha indicator was 0.777. Thus, one question is found to be marginally suitable, three questions are suitable, while five questions are found to be perfectly suitable. It is worth mentioning that none of the questions were found inadequate, and after completion of the checks in all questions it was found that four of them needed changes.

3.2. Main research

In all three versions of the multimedia application the mean time allocated by the students to every one scene, as well as the duration of the narration in each scene is shown in Fig. 5. It should be noted that the narration duration is the same in all three versions. In particular, a deviation was observed for the time that students dedicated to Scene 1 in comparison to the remaining scenes. Even though at the beginning of each version of the multimedia application there is an introductory scene in which the students obtain additional technical direc-

Table 1
Independent and depended variables

Variables	
Independent	**Dependent**
a. Version of multimedia application with interactive 3D animation	1. Percentage of correct answers for each student
b. Version of multimedia application with 3D animation	2. Total time that was required for answering the questions
c. Version of multimedia application with 3D illustrations	3. Number of questions that were checked by each student
	4. Total time of follow-up of the multimedia application, excluding the questions
	5. Time of follow-up of each scene of the multimedia application, excluding the questions
	6. Number of different scenes that each student watched, excluding the questions
	7. The students' answer in each question
	8. The time that each student used in order to answer each question
	9. How many times each student dealt with each question

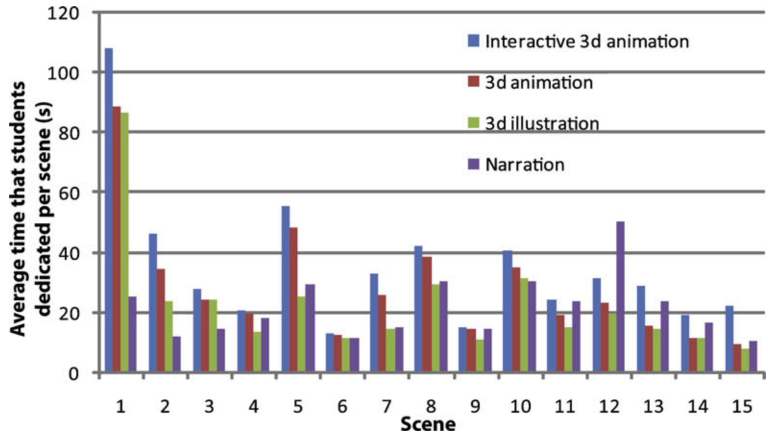

Fig. 5. Diagram of the average time allocated by the students to each scene.

tions on the operation of the application, the time that the students allocated for this introductory scene was not recorded. This is due to the fact that students tried to understand better the way of operation of the multimedia application and, thus, asked additional questions. Also, a number of students needed motivation for the use of the PC as well as for the program. For this reason the results for the first scene are not included in the following statistical analysis (i.e. the total number of scenes which will be examined are 14 – cf. Fig. 6).

Concerning the questions, after correction and modification of them, the check of their reliability and validity was repeated and it was found that all nine questions were found suitable. Thus, in the final form of the multimedia application it appeared that: in the version with interactive 3D animation the value of Cronbach's Alpha was equal to 0.722 and for the correlation of Pearson between the questions was found greater than 0.3 for all the questions, in the version with 3D animation the value of Cronbach's Alpha was equal to 0.815 and the correlation of Pearson was found higher than 0.3 for all questions, and finally, in the version with 3D illustrations the value of Cronbach's Alpha was equal to 0.827 and the correlation of Pearson was found higher than 0.4 for all questions.

As the ANOVA assumptions were violated the non parametric tests of Kruskal-Wallis (H) and Mann–Whitney U (the Bonferroni correction was also taken into consideration) were used for the analysis of the results and the control of correlations was realised by using the Spearman's rho indicator. In scenes 2 and 5, as it was expected, no statistically significant difference between the three versions of the application was observed because of the similarity in the way of presentation (for Scene 2 $H = 2.889$, df = 2, $p = 0.236$ and for Scene 5 $H = 5.081$, df = 2, $p = 0.079$).

In the case where object of the study is the time allocated by the students in each version of the application without the questions (Fig. 7), the Kruskal Wallis test gave $H = 11.306$, df = 2, and $p < 0.05$. It was obvious that a statistically significant difference between the three versions appeared. Then, the performing tests of Mann–Whitney-U gave statistically significant differences between the versions with: interactive 3D animation and 3D illustrations ($U = 1690.000$, $N_1 = 78$, $N_3 = 63$, $p < 0.017$), and also 3D animation and 3D illustrations ($U = 1652.000$, $N_2 = 71$, $N_3 = 63$, $p < 0.017$). Thus, the version with interactive 3D animation and 3D animation gave no statistically significant difference ($U = 2485.000$, $N_1 = 78$, $N_2 = 71$, $p > 0.017$).

Fig. 8, on the other hand, shows in which version of the multimedia application the students studied the most scenes. Specifically, a statistically significant difference between the three versions was found ($H = 10.105$, df = 2, $p < 0.05$). The performing tests of Mann–Whitney-U gave statistically significant differences between the versions with: interactive 3D animation and 3D illustrations ($U = 1789.500$ $N_1 = 78$, $N_3 = 63$, $p < 0.017$), and also 3D animation and 3D illustrations ($U = 2076.000$, $N_2 = 71$, $N_3 = 63$, $p < 0.017$). The version with interactive 3D animation and 3D animation gave no statistically significant difference ($U = 2507.500$, $N_1 = 78$, $N_2 = 71$, $p = 0.266$).

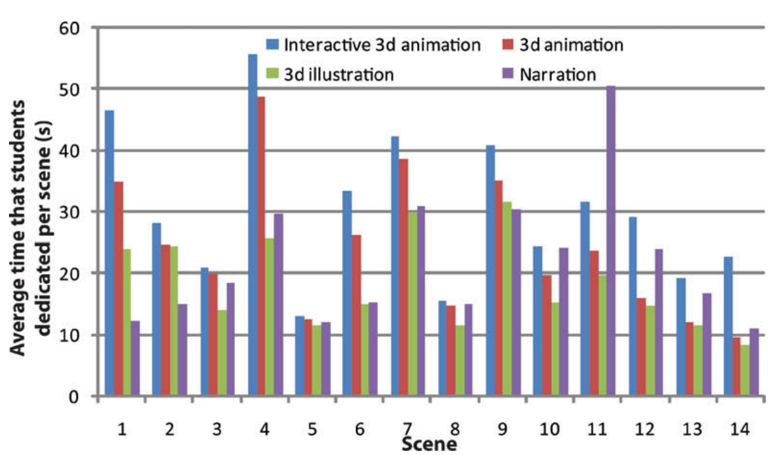

Fig. 6. Diagram of the average time that the students allocated to each scene.

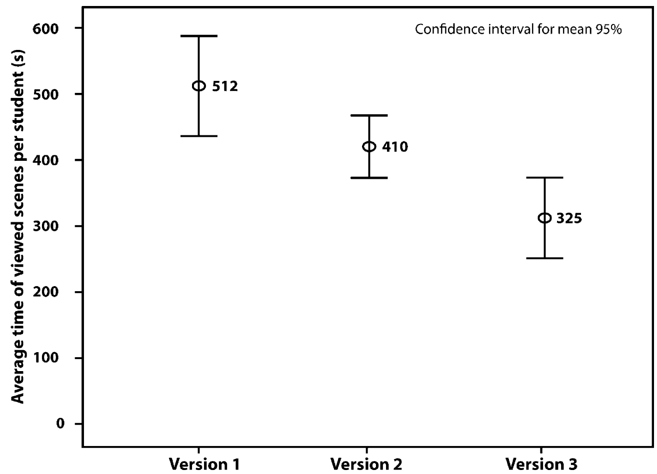

Fig. 7. Average time allocated by the students to the three versions of the multimedia application (excluding the questions).

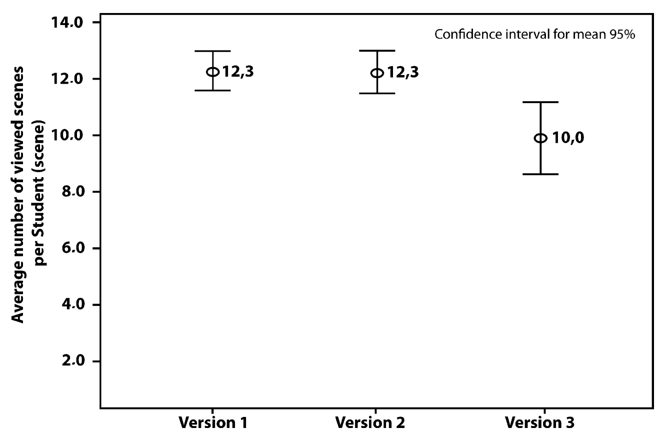

Fig. 8. Average number of viewed scenes by the students of the three versions of the application.

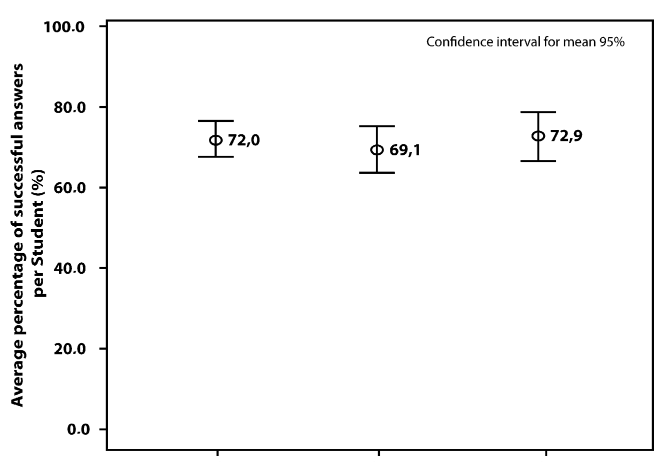

Fig. 9. The percentage of correct answers to the nine questions in the three versions.

In addition, Fig. 9 shows the percentage of correct answers to the nine questions, for each version of the multimedia application, while Fig. 10 shows the total time that student needed to answer questions. In both cases it was found no statistically significant differences between the three versions of the multimedia application ($H = 0.919$, df = 2, $p = 0.632$ and $H = 0.360$, df = 2, $p = 0.835$).

Finally, Table 2 shows the basic correlations between the dependent variables, in each version in the overall main research.

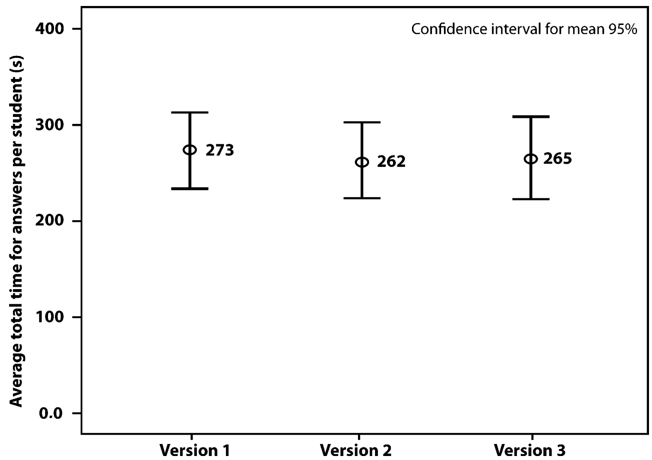

Fig. 10. The total time that student needed to answer questions in the three versions.

Table 2
Basic correlations between the dependent variables

Correlations	Version 1	Version 2	Version 3
Between time allocated by the students to watch the multimedia application and time that they used to answer the questions	$\rho = 0.429^{**}$ df = 76 $p < 0.001$	$\rho = 0.410^{**}$ df = 69 $p < 0.001$	$\rho = 0.508^{**}$ df = 61 $p < 0.001$
Between time allocated by the students to watch the multimedia application and the number of different scenes each student watched (excluding the questions)	$\rho = 0.498^{**}$ df = 76 $p < 0.001$	$\rho = 0.522^{**}$ df = 69 $p < 0.001$	$\rho = 0.719^{**}$ df = 61 $p < 0.001$
Between the percentage of success and the checking that they made to see if their answer was correct	$\rho = 0.463^{**}$ df = 76 $p < 0.001$	$\rho = 0.585^{**}$ df = 69 $p < 0.001$	$\rho = 0.540^{**}$ df = 61 $p < 0.001$
Between the percentage of success and the time allocated by the students to watch the multimedia application	$\rho = -0.214^{*}$ df = 76 $p = 0.030$	$\rho = -0.229^{*}$ df = 71 $p = 0.027$	$\rho = 0.173$ df = 61 $p = 0.087$
Between the percentage of success and the time that they used in answering the questions	$\rho = -0.139$ df = 76 $p = 0.112$	$\rho = -0.034$ df = 69 $p = 0.390$	$\rho = 0.312^{*}$ df = 61 $p = 0.006$

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

4. Discussion

In all three versions of the multimedia application it was observed that the students allocated a lot more time in the first scene in comparison to the remaining scenes. Obviously, at the start the students needed time in order to examine closely the tools that were presented to them for use in each of the remaining scenes. That is, they tried to become familiar with the way of handling them, as well as to observe and comprehend the overall possibilities of the multimedia application. It is remarkable that more than just a few students were hesitant and afraid to use the computer. For this reason, additional motivation was essential, even though directions on the use of multimedia application had initially been given to them, before its start, by way of an example scene. At that point, students had the possibility of asking questions and queries with regard to the use of the multimedia application. So, it is obvious that in an interactive multimedia application, the first main scene should not contain essential knowledge for the student, because the learning process is not yet effective.

Regarding the mean time allocated by the students to each scene, especially in Scenes 2 and 5, no statistically significant differences were found. The results for Scene 2 coincides with the report of Sweller (2003) in the "Form Effect", according to which, two messages with similar elements should be presented via different sensory forms. On the other hand, the result for Scene 5 leads us to assume that the interjection of another format of visualization in a scene application does not influence the behaviour of the student or the effectiveness of application. The use of static illustrations in the version of multimedia application with interactive 3D can be considered as a small intervention, i.e. it cannot alter the results.

In the version with interactive 3D animations, the students allocated more time to watching the scenes of the application (without the questions), compared to the one with static illustrations. It was observed that interactive 3D animations and 3D animations have determined time duration and, in consequence, influence the time to watch the scenes of a multimedia application (Ainsworth & Van Labeke, 2004). On the contrary, the static illustrations do not determine the time, respectively (Velez, Silver, & Tremaine, 2006). Thus, while in the first two versions the time is increased, in the third version it is smaller.

More time is also allocated by the students in order to comprehend animations, as compared to static illustrations. This is due to the fact that the multimedia application in the two first versions contains interactive controls (repetition, pause, play and rotation in interactive 3D) and, consequently, the students made use of these possibilities.

Many times, students not familiar with the application are probably unable to extract relative information from the dynamic visuals at the rate at which these are developing. This leads the students in repeating the 3D animation or the interactive 3D animation that they watch, so that they have enough time in order to process these elements and interpret them (Sanger, Brecheisen, & Hynek, 2001). Nevertheless, because the relation of the user with the interactive controls can sometimes lead to the imposition of extraneous cognitive load, despite the imposition of germane cognitive load, the addition of these elements of control is not always beneficial (Chandler, 2004). Without the suitable metacognitive ability, the beginners are unable to use effectively such forms of controls (Lowe, 2004). In the present study, it is obvious that the intellectual level of 13–14 year-old students does not allow them to have completely developed the metacognitive abilities (Veenman & Spaans 2005) and the spatial ability (Ferk et al., 2003) and, thus, they can not conceive the visualizations completely (Gilbert, 2005).

Furthermore, it was observed in the present study that the first two versions of the application were proved to be almost equivalent with regard to the number of scenes that the students watched. Also, the number of scenes watched was decreased in the version with static illustrations (especially as time was passing). The above results show that the interest of students remained undiminished for the entire duration of watching the first two versions of the multimedia application, while in the third version, the interest was limited, decreasing with time (as the students followed the sequence of scenes). Consequently, it could be concluded that multimedia applications with interactive 3D animation as well as, with 3D animation do indeed increase the interest of students, and make such applications more attractive (Eysink, Dijkstra, & Kuper, 2001; Weiss, Knowltou, & Morrison, 2002; Chang T.& Chang D., 2004; Mayer & Moreno, 2002).

It is also interesting to note that in the questions section, the percentages of correct answers by the students were not influenced considerably in either one of the three versions. The above result, despite the beneficial effects that interactive 3D animations and 3D animations have (Brooks & Rose 2003; Hoffman & Vu 1997; Ivanov, Rumjantsev, Skvortsov, & Archakov 1996; Nikolakis, Fergadis, Tzovaras, & Strintzis, 2004; Noguchi, Matsubayashi, Yamashita, & Cingoski, 2004; Robertson, Johnston, & Nip 1995; Sanger & Greenbowe, 2000; Sanger et al., 2001; Wu & Shah 2004; Yang, Andre, & Greenbowe, 2003), can be explained in a satisfactory manner. The most obvious and essential benefits of static illustrations that are observed in the process of learning are summarised as follows: the static illustrations give students the time to control learning, decrease the cognitive load because each time students deal individually with an important step of learning, encourage the relevant action as well as the effort to explain the changes from one frame to another (Mayer et al., 2005). Also, as Huk (2006) observed and pointed out, the 3D models are used more by students of high spatial ability than by students of low spatial ability. This preference can be considered that it is either (a) the result of the problem of cognitive load that students with low spatial ability face or (b) a way that expresses the detachment of attention of students with low spatial ability from complex 3D models. Certain researchers, Gerjets and Scheiter (2003), Paas et al. (2003), realised that the 3D models potentially can lead to problems of cognitive overloading, especially in environments of high level learning, as this type of environment is supposed to–produce a heavy cognitive load. Likewise, Tavanti and Lind (2001) and Cockburn (2004) suggested that: the 3D applications do not have any difference in the effectiveness of spatial memory in an obviously static representation. Also, the effectiveness of spatial memory is unassailable from the presence or the absence of applications of 3D prospect in obviously static representations.

Nevertheless, the research results of Lewalter (2003) and Wu and Shah (2004) show that the dynamic visuals are not superior to the static ones. Since in the multimedia application there are control tools of animation, the beginners have the advantage to re-examine sections of visuals with animation and to observe individual frames as static graphics. Of course, the addition of such controls is not always beneficial (Chandler, 2004), as it was mentioned before. Finally, the high degree of conceptive and cognitive processes that are required during learning with animation could cause, according to Lowe (2004), the "overwhelming" effect. The cost in cognitive level is sometimes so high, that the students do decide not to use animation (Lowe, 2003; Pane, Corbett, & John, 1996). This is observed when a large amount of information is provided to the students in order to process it. Contrary to this, Lowe (2003) develops an opposite argument. An underwhelming effect is observed when the students are guided by the dynamic presentation of subject and, in reality; do not deal with its comprehension. It is not essential for participants to presume the time order of presentation of subject sections and, potentially, they do not deal with it. The result is the misunderstanding with regard to the comprehension of information that depends on the complexity of elements and relative interactions. Also it is remarkable that when the students are examined, they present low results of progress.

In the case of the time allocated by the students in order to answer questions, no differentiation emerges in any of the three versions. A possible explanation is that the time that students allocated was limited, in order to run all the applications. If there was a possibility of extra time perhaps the present result could be different.

The presentation of interactive 3D animation or 3D animation has a fixed duration (Ainsworth & Van Labeke, 2004). In combination with the increased interest that the students show (Chang T. & Chang D., 2004; Weiss et al., 2002), we were led to the result that the students hear the narration that has duration similar or slightly more than the time duration of the above representations. Also due to the fact that in the version with interactive 3D there is a possibility to study a change or a development of phenomenon from different viewing angles, the time of narration was increased. So it can be easily explained why the students listened to all the narration or read all the text only in the versions with interactive 3D animations and 3D animations. On the other hand, in the version with static illustrations, students did not listen to all the narration or did not read all the text. The above occurred in most of the scenes.

The narration or the text that accompanies each scene does not determine how much time a student will spend in each scene. It was observed that the students do not listen to the entire narration (and, consequently, do not read all the text that accompanies it) when the time duration is long. So the narration does not determine how much time is spent by each student in a scene. Yet, most of the students did not watch Scene 11 till the end, where the duration of narration was long (and, in consequence, so was the extent of text).

A positive relation was found between the time that students allocated to watching the multimedia application and the time that they used to answer the questions. Thus, it was observed that as the time that students allocated to the multimedia application was increased, the time to answer the questions was increased as well. A possible explanation is that students who study the application thoroughly, they also study the questions thoroughly before they answer them. Another possible explanation is that the students, who have a difficulty and hesitancy to use the PCs, dedicate more time in the follow-up of the application and in the answering of questions.

It was also observed that as the number of scenes that the students watched was increased, the time of watching the multimedia application was also increased. Specifically, there is a positive relation between the time that students allocated to watching the multimedia application and the number of different scenes that each student watched (excluding the questions). This positive relation implies that the students did not dedicate time to individual scenes but their interest was extended uniformly over all the scenes. This observation was especially true in the third version.

Students with an increased percentage of correct answers to the questions obviously took the trouble to check their answers. There is a positive relation between the percentage of correct answers that students gave and the check of correctness of their answers. It is notable that the statistically significant relation was observed in all three versions. This is due to the fact that the students that were sure for their answer checked its correctness. Moreover, the check of certain questions gave the possibility for one more try in case of a wrong answer. This second effort probably led to the correct answer and, thus, increased the percentage of correct answers.

It became apparent in the first two versions that as students allocated more time to watch the scenes, the percentage of correct answers decreased. It was found that there is a negative relation between the percentage of correct answers to the questions and the time that each student allocated to watching the multimedia application. The increased time of watching the scenes in these two versions is due to the fact that the students studied interactive 3D as well as 3D animations with the help of the interactive controls that they possess. The above negative relation can be explained by the fact that the effect of the first two versions was to increase the cognitive load of the students. This wore out the students and reduced temporarily their learning capacity. In general, the increase of extraneous cognitive load during the presentation of a way of learning has as a consequence the reduction of effectiveness in the resolution of problems by the students (Hegarty, Narayanan, & Freitas, 2002; Sweller 1988), as well as the reduction of success in tests of maintenance of knowledge (Mayer 2001) for this way of learning. In static illustrations, overloading of cognitive load is not observed (Mayer et al., 2005).

Finally, it was observed in the third version that, as the time that students allocated to answering the questions increased, the percentage of correct answers also increased. A possible explanation is that because the time that the students had at their disposal to "run" all the application was limited, and since there is evidence that in the first two versions a lot of time was allocated in watching the scenes, the time that remained for the answering of questions was much shorter than the corresponding that the students allocated to the third version.

5. Conclusions

The most important conclusion of this exploratory study is that the contribution of all three types of visualization is differentiated in a multimedia application. In particular, both interactive 3D animations and 3D animations dominate the 3D illustrations regarding the increase of the study interest for the thematic unit that is presented, while the last ones are the least attractive to the students. On the other hand, the third type dominates the first two regarding the reduction of cognitive load, as it is found that the interactive or the dynamic 3D models may lead to cognitive overload problems, in multimedia-learning environments in particular, as such environments are assumed to generate a heavy cognitive load.

In summing up, the combination of all three types of visualizations in a multimedia application for the sciences is recommended. The unilateral use of one of the three types of visualizations does not improve the effectiveness of learning process. This research aims mainly at assessing the contribution to the learning process of interactive 3D animations, 3D animations and 3D illustrations, comparing the individual contributions of the respective visual means.

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