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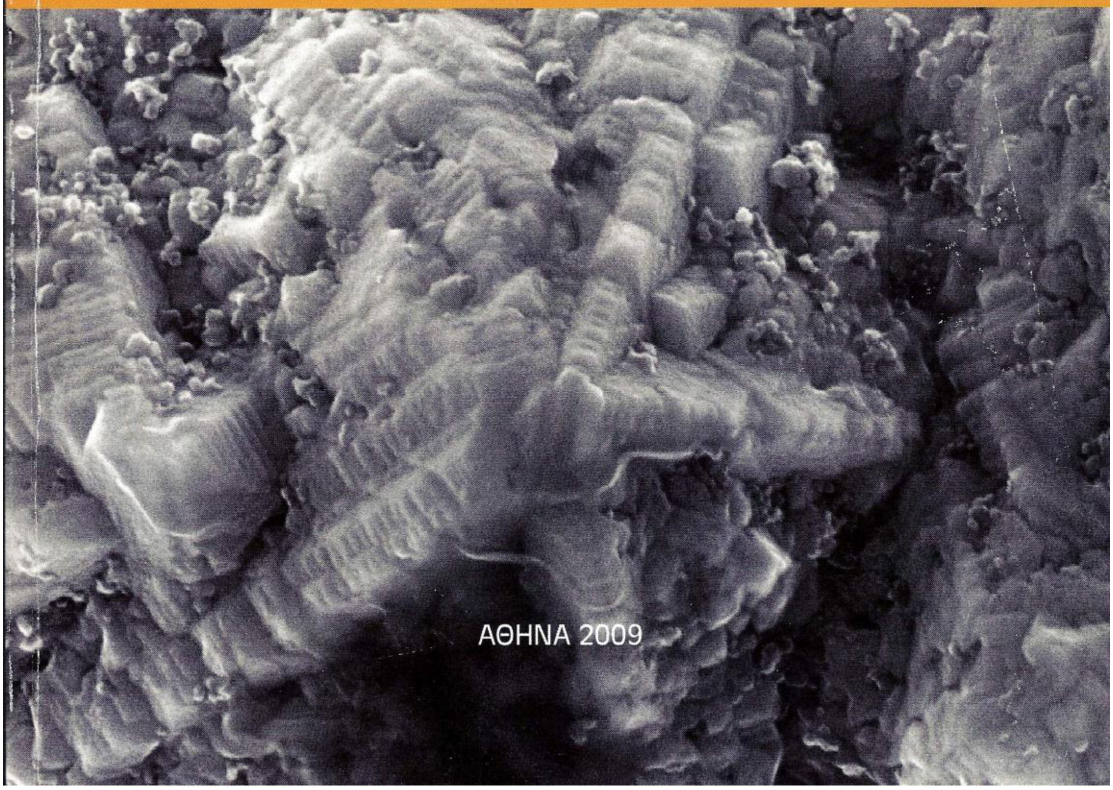

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THE IMPACT OF 3D VISUALIZATION TYPES IN EDUCATIONAL MULTIMEDIA FOR 12TH GRADE SCIENCE COURSES

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ABSTRACT
This study reports research findings on whether the use of interactive 3D animations, plain 3D animations and 3D illustrations, combined with narration and text, contributes to the learning process of 12th grade students in science courses. The research was carried out in various public high schools of Greece, and 111 students aged 17-18 years participated in it. Three different versions of an interactive multimedia application called “Atomic Orbitals” were utilized, each one differing from the other two in the types of visuals. All the rest of the application components (narration, text, navigation, auxiliary tools, interface, etc.) were common in all three versions. The research results prove that interactive 3D animations have a greater contribution to the learning process than the other two types of visualization. In addition, all three versions of the multimedia application increased the students’ interest, making the instructional material more appealing to them. Moreover, the success rates of the students exposed to the interactive 3D animations suggested that 17-18 years old students overcome possible conginitive overload problems.

KEYWORDS
Secondary education; Media in education; Multimedia/hypermedia systems; Interactive learning environments; 3D visualizations

INTRODUCTION
In recent days educational science has not yet been able to provide a clear and coherent collection of guidelines for designing effectively instructional multimedia. In most cases, designers' intuitions on what might work and aesthetic considerations are the main driving forces behind the development of these kinds of learning materials [1].

Two research lines that seem to be more promising are Sweller's cognitive load theory [2], and Mayer's generative theory of multimedia learning [3]. Nevertheless, most 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 [4]. At the same time, a strong argument is arising 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 [5]. Multimedia research has recently focused on dynamic media and is searching for didactical settings where animations consistently support learning. However, static visual presentations continue to have educational benefits that are comparable to those of considerable animations [6].

PROCESS AND EXPERIMENTAL DESIGN

2.1 Presentation of the experimental research

Our research aims at finding out whether specific types of visualization (3D illustration, 3D plain animation and interactive 3D animation) combined with narration and text, contribute to the learning process of 17 and 18 year-old students in sciences. Based on the latest educationally acceptable theories and researches in various multimedia visualizations, an interactive multimedia application titled "Atomic Orbitals" was created. The application is addressed to 12th grade students in Greece and three different versions were created, each one differing from the other two with regard to the type of visualization.

In particular, the first version involves interactive 3D animations, the second one utilizes 3D plain animations, and the third one employs 3D illustrations. All the rest of the application components (narration, text, navigation, auxiliary tools, interface, etc.) are common in all three versions. It is worth to mention that four scenes with 3D plain animations concerning the thematic unit of energy are common in the first and second version of the application, since it was considered that the use of interactive 3D animations will not contribute to the learning process.

A statistical research study then followed, which aimed at finding out whether the three factors, i.e. interactive 3D animations, 3D plain animations and 3D illustrations, as well as combinations of the three, make learning more efficient and, 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:

- The factor "3D static colour illustration" predominates over the other two factors.
- The factor "plain 3D animation" predominates over the other two factors.
- The factor "interactive 3D animation" predominates over the other two factors.
- The aforementioned 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 aforementioned 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 Presentation of the multimedia application

It should be noticed that in order to achieve specific goals 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 plain 3D animations, and interactive 3D animations using appropriate programming,
- the elaboration of the text and sound speech and, finally,
- 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 “Atomic orbitals”, explains in detail material in the current school book of Chemistry, for the 12th grade students. The text material has been enriched with elements from the international bibliography [7-10]. Overall, the application includes the following thematic units: Historical Retrospection, Introduction, Quantum numbers, Energy, Periodic Table.

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 plain 3D animation or interactive 3D animation). In addition, three auxiliary windows are presented: the navigator bar, the window “text” (which is displayed whenever the user wishes to read it), and the window “window”. These are floating windows, as they can be moved to any part of the screen (Fig. 1).

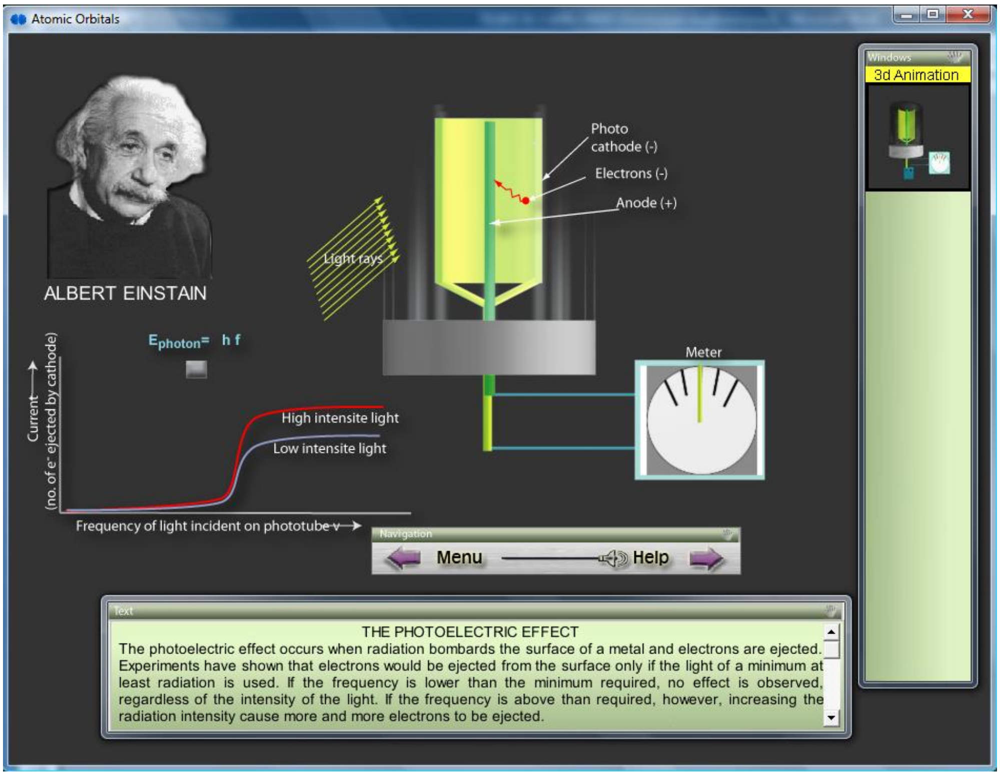

Fig.1: Auxiliaries’ windows in one of the main scenes (filtering, in particular).

The window menu, which is presented when the button “menu” is pressed on the navigator bar, consists of the collapsible sub-menus: “file”, “units”, “exercises”, “bibliography”, and “authors”. In the collapsible sub-menu “units”, the user can return in any individual unit of the multimedia application. The plain 3D animations and interactive 3D animations have an operation of “pause, play”, which make easier the comprehension of the phenomenon or the concept that they describe. In addition, the interactive 3D animations (Fig. 2) feature the operation of rotation with the mouse and keyboard. The operations of zoom, minimize, reset can be turned around as follows:

Left click: x-axis rotation.
Left click + Shift: y-axis rotation.
Left click + Ctrl: z-axis rotation.
Left click + Shift + Ctrl: free rotation.
Selecting Plane (if it exists) the symmetry levels are presented or disappeared.

The brightness is regulated via the “brightness” option.

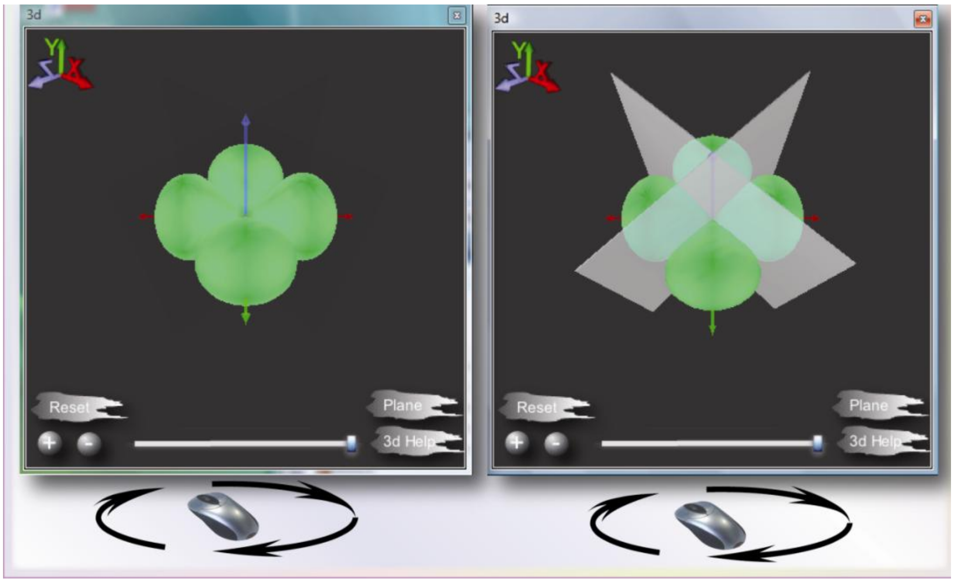

Fig.2: Interactive 3D animation

2.4 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 9 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 visualised. The percentage of correct answers is recorded and presented at the end of the 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.

2.5 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.

2.6 Research Methodology

Sample: A total of 111 students participated in the main research (37 in the first sample, 34 in the second, and 41 in the third one). The sample was selected randomly in clusters, 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 15 students from each sample were used.

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 0.459 and, according to the values of the Total Item Correlation, five of the questions are considered to be inadequate, two of them are marginally suitable, another one suitable, while one question is perfectly suitable. For the sample with plain 3D animation the Cronbach's Alpha indicator was 0.528. According to the above, five questions were considered to be inadequate, two marginally suitable, and two perfectly suitable. Finally, for the sample with 3D illustrations the Cronbach's Alpha indicator was 0.808. Thus, two questions were found to be marginally suitable and all the other questions were found to be perfectly suitable. Thus, after completion of the checks in all questions, it was found that five of them needed changes.

3.2 Main research

As far as concerning the questions, after the correction and the modification of them, the check of their reliability and validity was repeated for all nine questions. The results could be summarised as follows:

- In the version with interactive 3D animation Cronbach's Alpha was equal to 0.743 and Pearson's correlation was greater than 0.3 for all the questions,

- in the version with plain 3D animation Cronbach's Alpha was equal to 0.719 and the correlation of Pearson was higher than 0.3 for all questions, and
- in the version with 3D illustrations Cronbach's Alpha was equal to 0.858 and the correlation of Pearson was higher than 0.4 for all questions.

Therefore, the above results showed that all questions can be considered as suitable.

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 the first version of the multimedia application, the mean time that students allocated to each scene (without the questions) was found to be longer compared to the other two versions of the application. Specifically, the Kruskal Wallis test gave H=19.041 df=2 p<0,05 indicating that a statistically significant difference appeared. Then, the performing tests of Mann-Whitney-U gave statistically significant differences between the versions with: interactive 3D animation and plain 3D animation (U=334.500, N_1=37, N_2=34, p<0.017), and also interactive 3D animation and 3D illustrations (U=351.000, N_1=37, N_3=40, p<0.017). Finally, the version with plain 3D animation and 3D illustrations gave no statistically significant difference (U=579.500, N_2=34, N_3=40, p=0.276>0.017).

No statistically significant difference was also observed between the three versions of the application regarding the number of scenes that each student watched as the Kruskal-Wallis gave H=2.341, df=2 p=0.310>0.05.

Additionally, the biggest success rates in answering the questions were observed in the version with the interactive 3D animation. In particular, as the Kruskal-Wallis gave H=9.837, df=2, p=0.007<0.05, it was evident that statistically significant differences appeared. Then, the performing tests of Mann-Whitney-U gave statistically significant differences between the versions with: interactive 3D animation and plain 3D animation (U=419.500, N_1=38, N_2=35, p<0.017), and also interactive 3D animation and 3D illustrations (U=463.500, N_1=38, N_3=41, p<0.017). Moreover, the version with 3D animation and 3D illustrations gave no statistically significant difference (U=618.500, N_2=35, N_3=41, p>0.017).

Regarding the total time that student needed to answer questions, it was found that no statistically significant differences exist between the three versions of the multimedia application (H=0.307 df=2 p=0.858>0.05).

Finally, Table 1 demonstrates the basic correlations between the dependent variables for each version of the main research.

Correlations	**Version 1**	**Version 2**	**Version 3**
Between the number of the questions that the students had checked and the success rates	ρ=0.348 * df=35 p=0.035	ρ=0.376* df=32 p=.029	ρ=0.667** df=38 p=0.135
Between the percentage of success	ρ=0.380 *	ρ=0.342 *	ρ=0.195

and the time allocated by the students to watch the multimedia application	df=35 p=0.020	df=32 p=0.048	df=38 p=0.229
Between the percentage of success and the time that they used in answering the questions	ρ=0.075 df=35 p=0.658	ρ=-0.080 df=32 p=0.653	ρ=524** df=38 p=0.001
Between the time allocated by the students to the questions and the time allocated to watch the multimedia application	ρ=-0.004 df=35 p=0.980	ρ=-0.073 df=32 p=0.680	ρ=0.199 df=38 p=0.229
Between the number/total of scenes that the students watched and the number/total of questions that they checked their answers	ρ=0.019* df=35 p=0.912	ρ=0.424* df=32 p=0.012	ρ=0.443** df=38 p=0.004

**Correlation is significant at the 0.01 level (2-tailed).

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

Table 1: Basic correlations between dependent variables.

CONCLUSIONS

In this research study the most essential conclusion is that interactive 3D animations in science multimedia applications contribute more effectively to the learning process compare to plain 3D animations and 3D illustrations. This can be enhanced by the fact that 12th grade students have sufficiently developed the necessary metacognitive abilities [11] as well as the spatial ability [12]. Thus, they can conceive and understand interactive 3D animations passing possible cognitive overload problems, as it is well known that such multimedia-learning environments generate a heavy cognitive load for younger students. Also, the 17-18 years old students’ interest towards the science application was not affected by the version they had watched, while in smaller ages (13-14 years old) interactive 3D animations and plain 3D animations dominate the 3D illustrations.

In concluding, the results of this research demonstrate that the use of interactive 3D animations in a science multimedia application addressed to 17-18 years old students is definitely recommended. This type of visualization generally improves the students’ learning process, as proved by the evaluation of the students in comparison to plain 3D animations and 3D illustrations and thus, educational multimedia applications using interactive 3D animations could act as a supporting teaching and learning tool for science courses.

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