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Multimedia application with animated cartoons for teaching science in elementary education

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ABSTRACT

This study reports research findings on the use of animated cartoons in a multimedia application meant to evaluate their effectiveness in supporting teaching and learning in science. The researchers have developed a cartoon-style multimedia application whereas animated cartoons where designed from scratch using appropriate programs. The study was carried out in various elementary schools of Athens, Greece, and 179 pupils aged 10–11 years participated in it. The research results provide evidence that the use of animated cartoons significantly increases the young students' knowledge and understanding of specific science concepts, which are normally difficult to comprehend and often cause misconceptions to them.

1. Introduction

The presentation of ideas in visual form has been proven to be particularly important as it helps the educational process in a critical way. Many writers have already pointed out the importance of visual communication in the instructive practice (Arnheim, 1969; Barlex & Carré, 1985; Fisher, 1990). Bliss, Ogborn and Whitelock (1989), in particular, noted the motivating factor of cartoon-style material in their research.

Cartoons represent a form of art that has been promoted into an important visual language, which influences the human sentiments and transmits messages using symbols and pictures. They constitute a combination of humour, exaggeration, and symbols, while presenting a subject using the simplest lines possible. Eulie (1969) pointed out very successfully that cartoons contain messages and, when they are selected carefully, they can easily provide information via the symbols and the exaggeration. Most important is that they use familiar pictures and objects from daily life.

Wright (1979) argued that cartoons could be successful in integrating cognitive processes with the psychomotor domain because of the integration of visual, auditory, and kinesthetic learning modalities. According to Horn (1980) "cartoons have the ability to make a point without the semantic ambiguities inherent in the written words". It is a universal language (Horn, 1980; Muse, 1984) that it allows readers to develop their imagination. Philippe (1980) indicated that using cartoons is effective because they are familiar, can exaggerate events, and can reveal many facts at a glance.

In addition, cartoons can be used effectively in the teaching process when they provide information with regard to concretely instructive objects. They were used by many researchers in the classroom in order to promote learning, both in children and adolescents (e.g. Ball, 1982; De Fren, 1988; Demetrulias, 1982; Eulie, 1969; Madden, Chung, & Dawson, 2008; Peacock, 1995; Tsou, Wang, & Tzeng, 2006). Surprisingly enough, the most innovative use in the instructive practice is that they initially capture the students' attention and, then, they allow them to travel with their mind in a world of imagination and amusement while they are learning.

The importance of cartoons in science education has been recognized in recent years, as they received an increasing amount of research attention. Perales and Vilchez (2002), Perales and Vilchez (2005), Perales and Vilchez (2006) have studied among children and teenagers the influence of well known television cartoons' programmes. They have defined the ways that cartoons stimulate the active involvement of the students in the learning of physics, in the development of the curriculum in secondary education. Research evidence indicates that cartoons are already used as innovative and supporting tools in science teaching. Purely concept cartoons have rapidly proven to be a popular teaching

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and learning approach that is applicable in a variety of settings. Keogh and Naylor (1999), the creators of the "concept cartoon" strategy, have used them increasingly in both primary and secondary science education. Concept cartoons appear to offer an innovative approach to gaining access to children's ideas in science and to providing possible starting points for relevant scientific investigations. They appear to provide a possible means of offering opportunities for learning at a variety of levels and of enhancing children's motivation. Such concept cartoons have been used in various ways and in diverse situations to teach science, to assess pupils' (and student teachers') levels of understanding of scientific matters or as a mean to scaffold students' argumentation in the case of formative assessment (Chin & Teou 2008), to engage students in scientific discussion, to promote childrens' argumentation in primary science (Naylor, Keogh, & Downing, 2007), and to stimulate interest in science questions in museums and other exhibition centres. Development has taken place over the last years in the light of extensive research into their effectiveness (Keogh & Naylor, 1997a; Naylor & Keogh, 1999). Moreover, an identifiable strength of the concept cartoons is a similar presentation of competing theories or ideas in which the learners' notions are challenged by the 'multiple lines of data that are provided' (Chinn & Brewer, 1993). In this respect, there are similarities between the utilization of concept cartoons and other active learning techniques which endeavour to promote conceptual change (e.g. Chinn & Brewer, 1993; Roth & Anderson, 1988; White & Gunstone, 1992).

Finally, we must take into consideration that in the learning process, attention gaining is an important initial event of instruction (Gagné, 1985). Animation provides a good way to gain the attention of a student and also to cue a student to focus on the most critical features of a screen display (in the case of a multimedia application). The most direct application of animation in instruction is using it to present lesson content. Certainly, animation affords many practical methods of gaining and cueing attention, such as special effects during transitions between screens and, mainly, moving icons or characters, including cartoons and text/narration. There is some evidence suggesting that the effect of animation on comprehension is dependent on the user's age. In the case of children, however, animation may have an effect, at least under certain conditions, such as when dealing with material that is neither too difficult nor too simple, which requires motion or trajectory attributes to be visualized, and where explicit links are made between the text/narration and the animation (Rieber, 1990). In the case of motion concepts, Rieber (1989, 1991) found that students viewing animations on Newton's laws of motion were better able to retain, retrieve, and apply the content material.

2. Cartoon-style multimedia application

For the construction of the cartoon-style multimedia application, cartoons where designed from scratch using appropriate programs. Therefore the application was enriched with narration, dialogues, static graphics, and animation, and was addressed to the fifth grade of elementary school students. The narrations, texts and questions of the multimedia application were based on the books of science that are used in the 5th grade of the Greek elementary school.

The cartoon-style multimedia application that was created consists of two major parts. In the first part, the presentation and the analytic explanation of the involved basic science concepts of volume, mass, and density was attempted via animated cartoons and hearing dialogues, thus aiming at both the comprehension and the assimilation of the above concepts. In particular, a fifteen-minute story with animation and narration was presented. The story takes place in the interior of a house, with basic heroes the wise old male-owl Aristides and the young female rabbit Chloe. A specific script was followed whereas Aristides answers Chloe's questions, grabs the opportunity to explain the meaning of mass, volume, and density and, at eventually, he resolves Chloe's indirect queries. Chloe asks questions and, through the answers that she gets, her misconceptions regarding the aforementioned basic science concepts are corrected. Nevertheless, specific animated cartoons have been drawn for the needs of the story presented so that, in combination with narration and dialogues, are functioning as auxiliary material for the user-student. In the second part of the application, a series of seven closed-type questions are presented. The questions are of the multiple choice type, and each student has three choices and one attempt to make in order to give his/her answers to each question.

Due to the fact that the cartoon-style application was addressed to the age of eleven, it was built in such a way in order to be easy in use and navigation by the novices – i.e. the young pupils. For this reason, the main screen (Fig. 1) is very simple. In particular, the screen consists of: a bar, with the known three choices of diminution, enlargement, and exit, as well as two buttons (in the form of animals), i.e. one monkey for the exit and one rabbit which correspond to the thematic unit that is currently examined. When the user places the mouse pointer on a button, he/she observes three changes: the change of colour in each button, the appearance of a figure, and, last but not least, the appearance of the familiar cartoon 'cloud' in the upper part of the screen, where an explanation of the operation of the corresponding button is given.

Because the cartoon application was designed to be used as a didactic tool, it was obvious that, in addition to the pedagogical aspect, it had to be friendly and interesting enough for the young children to watch it. Indicatively, a small part of the cartoon animation is presented in Fig. 2 whereas four key frames are presented in which the rabbit shows through animation the measurement of the volume of water. At the same time, the narrations and dialogues which are heard, explain in detail the procedure of the liquid volume measurement.

In the second part of the cartoon application, i.e. in the questions section, the same simple cartoon-style is used and the answers that each student gives are recorded. Each question takes advantage of the processing partnership between visual and verbal information, which is well-established theoretically – e.g., Paivio's dual-coding theory Paivio, 1990. For example, in the question of Fig. 3, the student is called to study carefully the table that is given and then to answer the question by selecting one of the three answers provided.

Then the student is led to the next screen, Fig. 4 where he/she hears via the narration, whether he/she has chosen the right answer, the right explanation is given and, in addition, the opportunity to visualise the correctness of the answer via the animations that he/she watches. In each one of the animations the balance operates and, at the end, the mass of ball of all three materials is recorded.

3. Process and experimental design

In sciences mass, volume, and density are often considered to be obscured notions, causing not only difficulties in the learning process but also misconceptions to the fifth grade students. Researchers (Adey & Shayer, 1988; Smith et al,1985) have already pointed out the problems

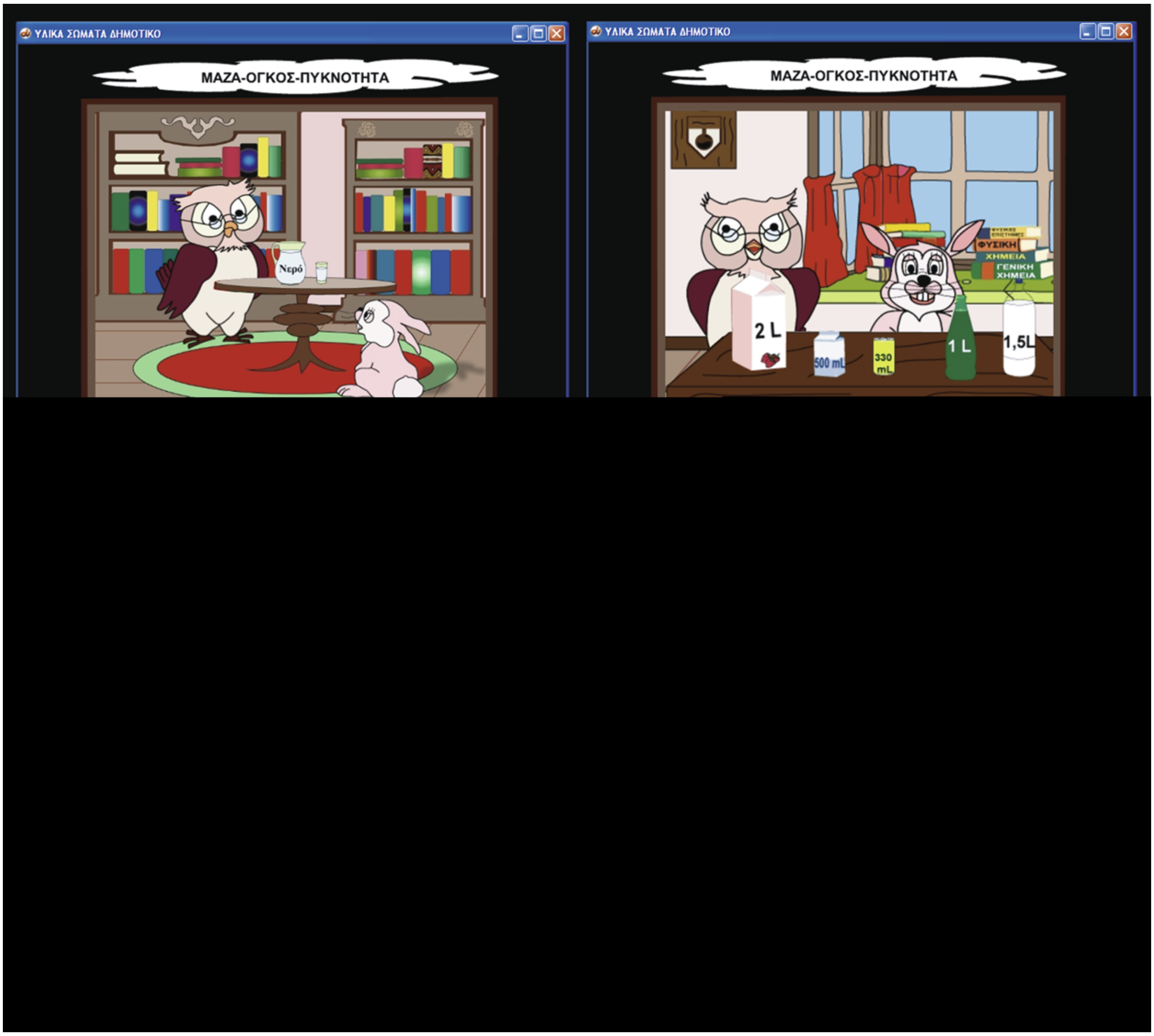

Fig. 1. Screens of the application presenting the concepts of mass, volume, and density.

that students at that age confront as they find it difficult to differentiated the concepts of size, weight, mass, volume and lastly density. A difficulty with the concept of density is that there is no direct way of measuring it. Although children from nine years old may get a global notion of 'heaviness', the quantification of density does require that two variables (mass and volume) are first differentiated and then related to each other. Basically in the fifth grade they attempt to calculate densities numerically or realize that there is a unique number which defines the density of a substance under standard conditions.

In order to shed some light whether fifth grade students are able to comprehend and correlate size, mass, volume with density and solve problems related to the above concepts, the current study was designed. Specifically if animated cartoons help student to finally differentiated the aforementioned concepts and how they connect them in resolving related problems. Also it should be noted that all students were taught the concepts of weight, mass and volume separately in the past years and density prior this year by the current school teachers.

The study was designed to address the questions:

- If animated cartoons help students to differentiate the concepts of mass, volume and density?
- If animated cartoons recall prior knowledge more effectively in fifth grade students?
- If animated cartoons can be used as a supplementary didactical tool for teachers in elementary school?

3.1. Participants

In this study 18 different public schools were randomly selected from Athens metropolitan area. Students of different intellectual ability, gender, economic status, etc constituting one whole classroom from each school took part in the two samples. A total of 179 children participated in the research and specifically 102 in the first sample and 77 in the second one. They all were fifth graders with a mean age of 11 years. The pupils joined the research only after their school teachers, parents and they consented.

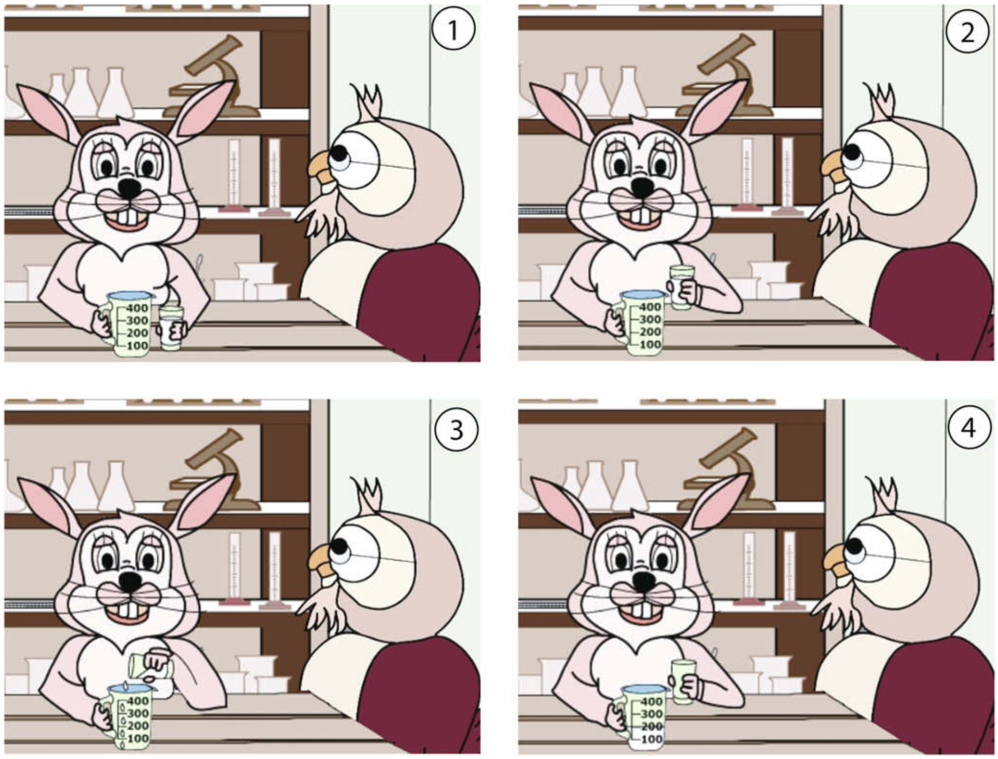

Fig. 2. Four key frames of the animation whereas the rabbit shows how the measurement of the volume of a glass filled with water is made.

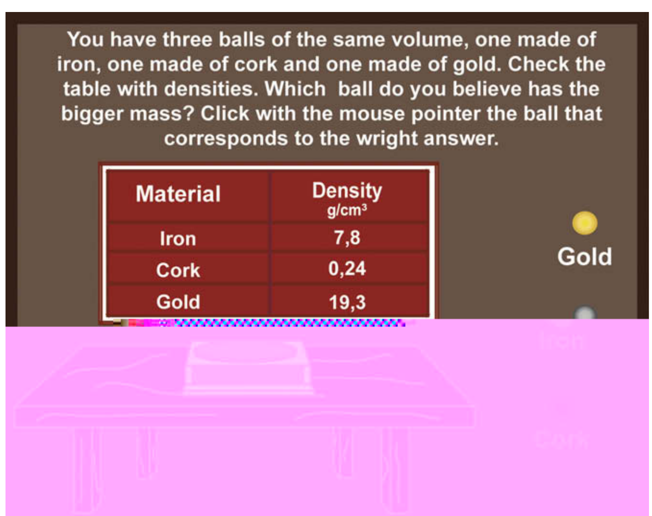

Fig. 3. Question testing the comprehension of the concept of density. The three materials presented are iron, cork, and gold.

3.2. Research methodology

Two groups of students were used in the field study. The research was conducted by the same visitor-investigator, who also is a science teacher and the creator of the cartoons application. Different instructional methods were used in each group but in both groups the same concepts (mass, volume and density) were presented according to the current school book of Science for the 5th grade students. The first group followed the classic instruction method. Specifically, the science teacher/investigator used the teacher's usual methodology, which included the theoretical explanation of the concepts in class with analytical comments regarding qualitative and quantitative examples, the resolving of students' queries that were asked along with problem-solving exercises whereas the students actively participated and, a questionnaire to be answered by the students. In the second group the animated cartoons multimedia application was used only, which included the introductory story, and a questionnaire, all in the form of animated cartoons. It must be noted that questionnaires had exactly the same questions, the same concepts were addressed and they were differentiated only in the way that questions were presented (multimedia cartoon-style versus text-style).

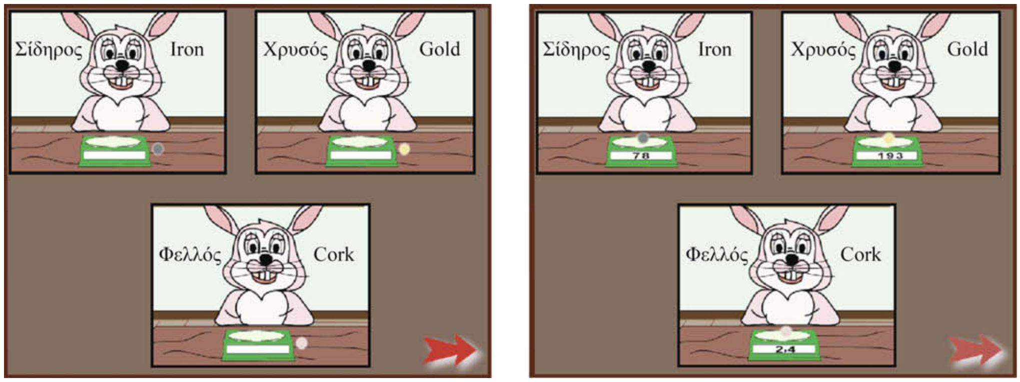

Fig. 4. Indicative frames of animations given during the answering to the question meant to test comprehension of the concept of density.

The post-test multiple choice questions that were used for assessment are of three types, following the post-test of the Chi, Siler, Jeong, Yamauchi, and Hausmann (2001) study: retention, near transfer, and far transfer, that require students to apply the knowledge attained from the computer-based cartoon learning environment or the investigators introductory lesson. Thus, the three levels of questions were used to examine the degree and depth of student learning, such as near or far knowledge transfer. The retention questions simply required the student to recall information. Those questions could be answered directly by referring to a specific hearing sentence(s) in the story or in the introductory lesson. An example of a retention question was "What will you use to measure the volume of a potato? Circle the right answer". For that, students were given three choices: (a) the volumetric jar, (b) the balance, and (c) the volumetric jar on the balance.

The near transfer questions expected students to make inferences. Answers to those questions were indicated in the beginning story but students also had to integrate them across the hearing sentences. A sample of near transfer question (as described and presented in Fig. 3) was "you have three balls of the same volume, one made of iron, one made of cork and one made of gold. Check the table with the densities. Which ball do you believe has the bigger mass? Choose the right answer." The question was followed by three options: (a) ball with gold, (b) ball with cork, and (c) ball with iron.

The far transfer questions tested the ability of students to apply the knowledge in order to solve problems related to the concepts of mass, volume and density – a process that expected the students to analyze, classify, integrate, and relate information which was provided in the beginning story. A sample far transfer question was "A volumetric jar, which weighs 200 g, is placed on an electronic balance. You have one glass filled with water, one filled with alcohol, and one filled with orange juice. A table with the densities of the above liquids is given. Each time you must pour 200 g from one of the above liquids into the jar in order to find out which liquid has the smallest volume. Choose the right answer." Possible answers provided were (a) water, (b) orange juice, and (c) alcohol.

3.3. Procedure

The whole process was conducted in the presence of the current school teacher in every class. A pilot and a main study were performed following exactly the same procedure as it is described below. Each group dedicated 45 min or one school hour to the process. The first group, i.e. the control group, came to class, discussed with the visitor-investigator the concepts for fifteen minutes, and then was asked to fill the questionnaire on paper sheets. The second group, i.e. the experimental group, came to the computer lab and was briefed on the procedure for the "experiment". Each one of the students was seated in front of a computer and was given headphones in order to hear without any interruptions the fifteen-minute introduction of the application. A period of time was given to the students in order questions regarding the functions of the application to be answered by the investigator. And finally, with the headphones each one of the students answered the questions on his/her own. The answers of each student were stored in *.txt form on the hard disk of the respective computer.

4. Results

4.1. Pilot research

The pilot research with a sample of 30 students from both groups was contacted. The assumptions of the pilot research were the same as it were described in the experimental procedure. The assessment was based on the answers that each group gave the total of the seven questions. The questions that were answered by the pupils from both groups were checked for their validity and reliability. Specifically, the indicator Cronbach's Alpha as well as the correlation of Pearson (Total Item Correlation), between all the questions were calculated. In the case of the multimedia animated cartoons, the indicator Cronbach's Alpha was found equal to 0.716 and according to the values of the Total Item Correlation, two questions were found to be marginally suitable and five questions perfectly suitable. In the case with the text sheets, the indicator Cronbach's Alpha was found equal to 0.645 and according to the values of the Total Item Correlation, one question was considered to be inadequate, one question was marginally suitable (this one coincides with one from the two questions that were found to be marginally suitable in the case of the animated cartoons) and five questions were perfectly suitable. It was obvious that three questions needed corrections.

4.2. Main research

In the case of the question that were used for the assessment after the necessary corrections and the modification of three questions, the control of their reliability and validity was repeated and it was found that all seven questions were found suitable. Thus, in the case of the

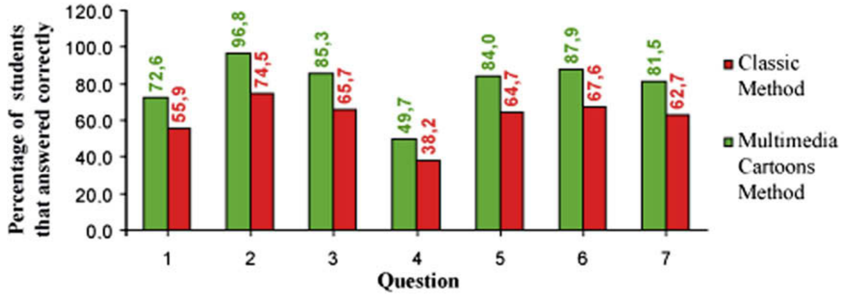

Fig. 5. The mean score of students in each question in both methods.

multimedia cartoons the indicator Cronbach's Alpha was found equal to 0.730 and all the values of the Total Item Correlation were above 0.3 while in the case of the text sheets the indicator Cronbach's Alpha was found equal to 0.726 and the values of the Total Item Correlation were above 0.4.

The Kolmogorov–Smirnov and Shapiro–Wilk tests were conducted and absence of normality was found. Therefore, a non parametric test was used based on the assumptions of the research. The means of corrected answers of students (M_i) were found: for the animated cartoons method $M_{Cartoons} = 80.3\%$ and for the classic method $M_{Classic} = 61.3\%$. It should be noticed that in this research all confidence levels are 95%. The Mann-Whitney U Test was performed and gave: $U = 1515.500$, $N_1 = 77$, $N_2 = 102$, $p = 0.001 < 0.05$. Thus, it became apparent from the comparison of the two methods that a statistically significant difference was observed.

In Fig. 5 it is obvious that in the questionnaires the percentage of the students who answered correctly in each question is higher in the experimental group (multimedia cartoons) than in the control group (classic method). In all seven questions the Mann–Whitney U Test was performed and statistically significant differences between the two methods were found in questions 1,2,3,5,6, and 7 as $p < 0.05$. However, in the case of question number 4 no statistical difference was observed.

5. Discussion

The present study gives an insight into how students at the age of eleven can better understand and scientific concepts with the help of cartoons and how they approach them during their entanglement with science courses. The principal findings of this study show that students' knowledge and understanding was upgraded through the differentiation of the concepts of mass, volume, and density with the use of animated cartoons. According to Adey and Shayer (1988), the confrontation of exercises which referee to the concept of density is extremely difficult for students of elementary education. Density does not constitute size which can be observed and be measured immediately, but results from the notion of two other sizes: mass and volume. Several of the misconceptions that Greek students in the 5th grade of the elementary school have are of the same types as those reported by researchers in elementary schools of other countries. Smith, Carey, and Wiser (1985), for example, pointed out the misconceptions that are created in the students of elementary education with regard to characteristics of matter, and their difficulty to differentiate the concepts of weight, mass, and density.

In our case study we have attempted to build a learning environment that aimed at fostering problem solving and conceptual development by confronting young learners with their misconceptions. From misconception research, there is widespread agreement that learners construct concepts from prior knowledge (Novak, 1990). Prior knowledge is an important determinant of learning (Johnson & Lawson, 1998) and has been studied extensively in science education. It is evident in fifth grade students that animated cartoons help them recall prior knowledge more effectively, as it is confirmed by the success rates of the students.

We also accept that weight and density undergo differentiation during development according to Piaget's and Inhelder's conclusions. They had placed the development of weight/density concepts not only in the context of theory change but also in the context of more structural changes in cognitive capacity. Moreover, Flavell (1992) related Piaget's developmental stage of formal-operational thinking to the concept of metacognition (Inhelder & Piaget, 1958). At this stage children are capable of hypothetico-deductive reasoning, which requires metacognitive control. Flavell indicated that Piaget would not expect metacognition to show up before the level of formal-operational thinking has been reached (Flavell, 1992, p. 118; Inhelder & Piaget, 1958). 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 years (Veenman & Spaans, 2005). Consequently, in our research children at the age of eleven can understand concepts with the help of cartoons, as their unquestionable strength is the simple lines that they are using. Also, at this age children are familiarized with the figures of the cartoons heroes whom they are watching in TV (e.g. Disney). As Rieber (2000) said animation has greater acceptance in children than adults. All these reasons coincide that perhaps the children's working memory is not overloaded. So, students do not find difficult to add revised and upgraded knowledge to their existing conceptual structure, when it is consistent with the knowledge that is there already even from everyday experience. After all, knowledge acquisition is a gradual process during which existing knowledge structures are revised.

The data results support the supremacy of the cartoons compared to the conventional method. Students' correct answers reached 80.3% in the case with the cartoons application and 61.3% in the classic method. A range of reasons can be given to explain such effectiveness in student learning. Cartoons, in the multimedia application, constitute visual representations of scientific ideas accompanied with narration or minimal text in dialogue form. They are using familiar situations from our daily experience and offer alternative viewpoints on a situation or phenomenon that is being described, including the scientifically acceptable viewpoint among the alternatives that are presented. They are intended primarily as an aid to teaching and learning.

As demonstrated by the results of this study, animated cartoons do in fact help the learning process. In the words of Brocka (1982), "Cartoons are a dynamic combination of visual image and written word, of narrative and dialogue. They have just the cohesive and choreographed imagery we need to reach our students". And the main care of the teacher is to make his/her students see science as interesting, an easy task provided that they engage them in innovative and challenging science learning activities. Thus, well designed multimedia material such as the animated cartoons can be used as a supplementary didactical tool.

The animated cartoons which were created and presented and which enriched the multimedia application have much in common with the concept cartoons (Keogh & Naylor, 1999) as well as with some of the strategies used by researchers to explore children' s scientific conceptions (e.g. Nussbaum, 1985; Osborne & Gilbert, 1980; Russell, Harlen, & Watt, 1989; Stavy & Berkovitz, 1980; Stead & Osborne, 1980). In each of these cases, common elements exist which include minimal use of written language or narration, utilization of a visual image and, often, the presentation of alternative concepts or questions relating to one central idea/concept that it is presented. Extensive use has been made of the above strategies as conceptual probes in research. White and Gunstone (1992) discuss the effectiveness of some of these strategies in a classroom context in relation to assessment. As Gunstone (1988: 90) notes: The methods used to probe students' ideas/beliefs are also, almost by definition, excellent teaching/learning strategies.

Furthermore, the present multimedia application with animated cartoons can be granted the status of a successful attempt, as confirmed by the data results, of using audiovisual media as instruments for achieving scientific literacy. Towards that direction we may highlight the use of comic methods (Matthew, 1991; Worner & Romero, 1998), science fiction films (Allday, 2003; Moreno & Pont, 1999). The results were satisfactory in all cases, but especially in the works performed with dynamic images (Shu-Ling, 2000). A possible explanation is that when the animation in cartoons was further elaborated with dynamic visuals, the narration not only drew students' attention toward the dynamic visual, but also explained step by step the visual that helped to build connections between the presented concepts and the animated cartoons.

In addition, consistent with Paivio's dual coding theory learning from animation, the animated cartoons in the present study, like any visual, are best when paired with appropriate verbal support because of the increase to both representational and referential encoding. So these instructional uses of animation could be described as "learning-by-viewing" approaches (Reed, 1985, p. 297–298). Animation, with accompanying text or narration, offers many opportunities for presenting or elaborating facts, concepts, and principles. Also animated cartoons, in contrast with a static background, increase their prominence, as is shown by the data.

An interesting point is that in the case of the questions that were asked to novices students in both cases, all questions were answered successfully in high scores (as it is shown in Fig. 5) except in question number 4 which was difficult to them. It is evident that this far transfer question is considered to be more demanding than the other text based or transfer questions. As confirmed by the data results, the aforementioned question number 4 (sample far transfer question) has no statistical significance as we expected students to answer it in the same way in both methods. One possible reason is that the information needed for answering this particular question had to be encoded, integrated, and inferred from the sentences provided in the first part of the application or in the theoretical introduction of the teacher in the classic method, a complicated process for elementary school students.

The present study had certain limitations, among which the main is that the students had already been taught the concepts of mass, volume and density. Therefore, future research may rely on teaching new concepts in science suitable for elementary school, where it will be tested if the teacher with the help of the animated cartoons will succeed a more effective and deductive lesson. In addition, a pre-test and increased number of teachers could be included in future studies in order to conduct a more comprehensive evaluation of the results.

6. Conclusions

It is important to realize that one of the reasons why science is perceived as difficult by many students in elementary education is that it is a-priori viewed as dealing with concepts which are often difficult to be explained and understood. Some students feel that they have to learn a lot of theory without ever considering how this theory might apply to the real world they are living in. Cartoons represent an attempt to ask some of the questions that students might like to ask, if they would think in terms of everyday life situations/ideas, and actually get some answers. Through these animated cartoon situations science concepts can be given a breath of life and realism. And more important is that animated cartoons attempt to provide learning opportunities such as to facilitate the differentiation of scientific concepts, to recall effectively the prior knowledge and therefore, promote the process of conceptual development.

Furthermore, cartoons in a multimedia application provide evidence that science in a form of a multimedia application in science, provide evidence that science can be discovered even in the most surprising and informal places. The combination of the students' familiarity and acceptance of them, along with careful pedagogical integration, makes this resource an excellent and refreshing complement to learning and teaching. Our research showed that the presentation of cartoons in a multimedia application gave it an obvious advantage as a learning aid, based upon the presentation of specific scientific knowledge in a popular form that is enjoyed by most young students. In teacher's hands, animated cartoons are consider to be an effective supplementary didactical tool that can used for reaching students learning goals inside the classroom. And this is what mainly we are looking for in the modern educational practice in the real school environment.

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