Creative Education, 2016, 7, 1270-1291
Published Online June 2016 in SciRes. http://www.scirp.org/journal/ce
http://dx.doi.org/10.4236/ce.2016.79134

Production and Evaluation of Educational Material Using Augmented Reality for Teaching the Module of "Representation of the Information on Computers" in Junior High School

Stefanos Giasiranis[1], Loizos Sofos[2]

[1]Department of Primary Education-Postgraduate Studies Programme in Education Sciences-Education with the Use of New Technologies, University of the Aegean, Rhodes, Greece
[2]Department of Primary Education, University of the Aegean, Rhodes, Greece
Email: giasiranisst@gmail.com, lsofos@rhodes.aegean.gr

Received 11 May 2016; accepted 19 June 2016; published 22 June 2016

Abstract

The purpose of this study was the investigation of the added value of technology of Augmented Reality in education and, particularly, whether this contributes to both student performance improvement, as well as the appearance of the psychological condition of Flow, which, according to research, has had a positive effect on their performance when experienced during learning process. The research involved a total of 42 students in their second year of junior high school who were taught the module "representation of the information on computers" using two different technologies, those of Augmented Reality and the Web. Research data showed that both technologies contributed to student performance improvement and to the appearance of Flow to pupils, with apparently better results with the student group who utilized the technology of Augmented Reality, though.

Keywords

Augmented Reality, Flow, Interactive Learning Environments, Secondary Education

1. Introduction

Although learning is not something new, educational technology is. Only a few decades ago, few people had the

How to cite this paper: Giasiranis, S., & Sofos, L. (2016). Production and Evaluation of Educational Material Using Augmented Reality for Teaching the Module of "Representation of the Information on Computers" in Junior High School. *Creative Education, 7,* 1270-1291. http://dx.doi.org/10.4236/ce.2016.79134

privilege to have the availability of technology that could help them learn. Nowadays, technology in general and educational technology in particular has been rapidly evolving as well as being utilized in both formal and informal education. Computers, mobile phones, interactive whiteboards, videos, multimedia applications, educational games and learning platforms, simulations, virtual reality, Internet and Web 2.0 applications are just some technology examples, which have been effectively used by teachers and students in educational environments (Dror, 2008).

Nowadays, the new technology of Augmented Reality has emerged in the field of education and up-to-date research shows that its use can have very positive learning outcomes. Such examples constitute research projects by Kerawalla, Luckin, Seljeflot and Woolard (2006), who searched the potential of Augmented Reality in teaching the Earth-Sun interaction and day-night consecution, the research programme Learning Physics through Play (Enyedy, Danish, Delacruz, & Kumar, 2012) concerning a series of scientific research on the teaching of Newtonian force and motion, the EcoMobile programme (Kamarainen et al., 2013) concerning the use of the particular technology in environmental education and a large number of research games in open spaces, such as Outbreak at MIT, Environmental Detectives, Gray Anatomy etc. (Dunleavy & Dede, 2014).

In Greece, Augmented Reality has been slightly used in education. The majority of applications concerned its use in open spaces of archaeological interest or inner museum and technology park spaces (Gialouri, 2011; Grigoraki, Politi, & Tsolakos, 2013; Siampanopoulou 2014; Sintoris, 2014). However, cases where Augmented Reality is used in the classroom, such as the case of Dimitriou (2009) who created an Augmented Reality application for the teaching of electrical circuits to high school students, almost do not exist.

Thus, the research on the use of Augmented Reality in a classroom and the total absence of its applications for the subject of Information Technology is relatively small scale, at least in Greek reality. The present research was carried out in order to fill in both gaps, contributing to the further investigation of its pedagogical value. The answers to be given upon its completion, can highlight a different aspect of the use of Augmented Reality in the educational process, encourage more researchers to explore its educational value, not only for the subject of IT in junior high school but also for other subjects and educational levels and, finally, inform teaching practitioners about the new technology and motivate them to start using it more often during their teaching sessions.

2. Review of Relevant Research Projects

Through an expanded bibliographical review, 31 relevant research projects were identified. All of them had Augmented Reality as their application field, posed pedagogical aims and were held within or/and outside the classroom, with the participation of pupils or students. The following paragraphs summarize the most important results of these research projects.

Students, coming in contact with the technology of Augmented Reality for the first time, are impressed by the way virtual elements are incorporated into the environment they are located, and, as a result, **they are motivated and actively participate** in course activities (Klopfer et al., 2005; Seo, Kim, & Kim, 2006; Freitas & Campos, 2008; Dunleavy, Dede, & Mitchell, 2009; Liu & Chu, 2010; Wijers, Jonker, & Drijvers, 2010; Cai, Wang, Gao, & Yu, 2012; Dünser, Walker, Horner, & Bentall, 2012; Salvador-Herranz et al., 2013; Cai, Chiang, & Wang, 2013; Chen, Liu, & Lu, 2013; Di Serio, Ibáñez, & Kloos, 2013; Fleck & Simon, 2013; Kamarainen et al., 2013; Wojciechowski & Cellary, 2013; Cai, Wang, & Chiang, 2014; Ibáñez, Di Serio, Villarán, & Kloos, 2014; Ahn & Choi, 2015; Tarng, Ou, Yu, Liou, & Liou, 2015).

During teaching sessions, **they express their enthusiasm** for what they do (Klopfer et al., 2005; Kerawalla et al., 2006; Freitas & Campos, 2008; Liarokapis & Anderson, 2010; Wijers et al., 2010; Cai et al., 2014), **collaborate on a great degree** with one another in order to achieve their objective (Klopfer et al., 2005; Dunleavy et al., 2009; Liu & Chu, 2010; Fleck & Simon, 2013; Kamarainen et al., 2013; Lin, Duh, Li, Wang, & Tsai, 2013; Ahn & Choi, 2015) and, in a lot of cases, **are absorbed in what they do** in such a degree that they sense a modification of time or decreased reflex (Dunleavy et al., 2009; Liu & Chu, 2010; Cai et al., 2012; Salvador-Herranz et al., 2013; Fleck & Simon, 2013; Ibáñez et al., 2014).

At the end of the teaching session, they have a positive attitude towards the technology used and claim to be **eager to use it again** (Núñez, Quirós, Núñez, Carda, & Camahort, 2008; Juan, Toffetti, Abad, & Cano, 2010; Cai et al., 2012; Salvador-Herranz et al., 2013; Cai et al., 2013; Wojciechowski & Cellary, 2013; Cai et al., 2014; Tarng et al., 2015). They consider it **easy to handle** (Shelton & Hedley, 2002; Sin & Zaman, 2010; Liarokapis & Anderson, 2010; Liu & Chu, 2010; Wijers et al., 2010; Salvador-Herranz et al., 2013; Wojciechowski & Cellary, 2013; Tarng et al., 2015), **effective** because it helped them learn (Liu & Chu, 2010; Wojciechowski & Cellary, 2013; Tarng et al., 2015) and **apt to help them learn more** (Sin & Zaman, 2010; Liu & Chu, 2010; Salvador-Herranz et al., 2013; Wojciechowski & Cellary, 2013), although do not hide their **satisfaction** for what they have achieved by using it (Liu & Chu, 2010; Salvador-Herranz et al., 2013; Di Serio et al., 2013; Wojciechowski & Cellary, 2013).

The accuracy of the students' views seems to reflect on their learning outcomes. After the use of technology, they have **better performance** than before (Shelton & Hedley, 2002; Seo et al., 2006; Nischelwitzer, Lenz, Searle, & Holzinger, 2007; Juan et al., 2010; Sin & Zaman, 2010; Liu & Chu, 2010; Wijers et al., 2010; Pasaréti et al., 2011; Cai et al., 2012; Dünser et al., 2012; Salvador-Herranz et al., 2013; Chen et al., 2013; Fleck & Simon, 2013; Kamarainen et al., 2013; Lin et al., 2013; Cai et al., 2014; Ibáñez et al., 2014; Ahn & Choi, 2015; Tarng et al., 2015), however, not when they do not handle the application themselves (Cheng & Tsai, 2014), **they improve the spatial perception** (Shelton & Hedley, 2002; Núñez et al., 2008) **they are able to observe objects, which, under normal circumstances, they are not able to**, either because of their size (too big or too small) or because they are not visible in the environment (Dunser et al., 2012; Fleck & Simon, 2013; Kamarainen et al., 2013; Ibáñez et al., 2014), **they retain their knowledge for longer periods** (Cai et al., 2012; Cai et al., 2013) and it seems that **students of low or medium initial performance benefit more**, on the basis of their knowledge test results before the use of Augmented Reality, whereas students with very good initial performance did not show expected improvement (Shelton & Hedley, 2002; Freitas & Campos, 2008; Cai et al., 2013; Cai et al., 2014).

3. Theoretical Framework

The term Augmented Reality refers to such technology which increases the sense of reality, allowing the coexistence of digital and factual information in the same environment (Azuma, 1997). Unlike Virtual Reality which completely substitutes real world, the user is capable of not only simply seeing digital elements but also communicating and exchanging data, interacting with them.

Nowadays, teachers have been offered two different types of Augmented Reality applications. Those based on the user's location (location-based) and exclusively use portable devices to project augmented information on screen and the ones based on the existence of an object or an image (image-based) and are able to use either a portable device (Dunleavy & Dede, 2014) or a personal computer (PC) with a camera (Cheng & Tsai, 2013), or even a Head Mounted device (HMD) (Yuen, Yaoyuneyong, & Johnson, 2011). The first type of applications is suitable for exploratory activities outside the classroom, such as games, visits to archaeological sites and museums, while the second, is suitable for skills-building and knowledge acquisition activities inside the classroom (Cheng & Tsai, 2013).

Research in web environments (Webster, Trevino, & Ryan, 1993; Liao, 2006; Shin, 2006), in games and in virtual reality environments (Papastergiou, 2009; Faiola, Newlon, Pfaff, & Smyslova, 2013) have showed that students' learning outcomes can be enhanced if students experience the psychological condition of Flow during teaching and several researchers have already recognized that this positively supports their learning (Pearce, Ainley & Howard, 2005; Kye & Kim, 2008; Choi & Baek, 2011). Augmented Reality as a means which shares common features with virtual reality, is expected to help students develop Flow.

The state of "Flow" can be described as the psychological situation of someone who is involved in a pleasant and enjoyable, for himself, activity in the course of which they appear to be totally preoccupied in what they do. In order to be found in such a psychological situation, they have to meet two factors which play the most important role: (1) the, perceived by them, difficulty of challenge they have to face and (2) their, perceived by them, skill to deal with this challenge. Therefore, even a low difficulty activity is able to induce Flow state when there is balance between these two factors. In the case of imbalance, a person can feel Anxiety when they consider that they have a lower degree of skills than those needed to complete the activity and Boredom when the opposite happens. The relation between these two factors has been represented on a model (**Figure 1**), where the psychological state of Flow constitutes a channel (Csikszentmihalyi, 1975).

Generally speaking, nine factors relate to the appearance of "Flow" (Jackson & Csikszentmihalyi, 1999), without excluding the existence of others (Finneran & Zhang, 2005): (1) challenge-skill balance, when both are at a high level and in balance with one another, (2) action-awareness merging, when everything occurs spontaneously and automatically, (3) clear goals, when the person knows what to do, (4) unambiguous feedback, when the person immediately knows whether they have achieved their goals, (5) concentration on task at hand, when

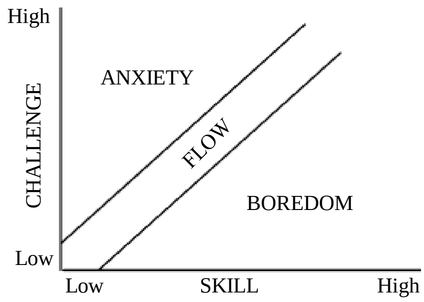


Figure 1. Initial model of "Flow".

the person is fully concentrated on and preoccupied with what they do, (6) sense of control, when the person feels they have their actions under control and can cope with anything which may occur (7) loss of self-consciousness, when the person loses their sense of self, (8) transformation of time, when the person feels that time has passed very quickly, or has lasted for centuries and (9) autotelic experience, when the person considers that the effort made was worth it.

A necessary condition to make the use of each and every form of technology effective in an educational framework is its proper teaching use (Sofos, 2011). What is important is not technology itself, but the way it is used to support learning (Bronack, 2011).

A teaching session is characterized successful by the degree of achievement of learning outcomes expected by the teacher at the end of each session. The existing objective difficulty in this kind of control is the way in which what the student has learned will be reliably tested, since the biggest part of his thought is not visible to others. To overcome this difficulty, the teaching practitioner resorts to search for clues that will certainly indicate knowledge acquisition. These clues become visible through an expected behaviour determined during lesson planning and described with the learning objectives and performance objectives. The learning objectives are more generally set in relation to the performance objectives. Therefore, there may be the case where a learning objective may be equivalent to a set of performance objectives. However, both describe an action or behaviour which can be observed and thus be controlled (Rellos, 2006; Oosterhof, 2010).

What must be ensured during objectives description is that a student's performance constitutes a representative indicator of the skill being tested. What can help at this stage is the knowledge of the skills types as proposed by Bloom (1956) and formed the basis for two out of the three categories used by modern cognitive psychologists, that is the declarative and procedural knowledge (the third is problem solution) (Oosterhof, 2010).

Declarative knowledge corresponds to the first step of Bloom's objectives taxonomy, Knowledge (Oosterhof, 2010). The purpose of learning happening here is the storage of information in the student's memory and its recall and presentation later, almost in their original form. Procedural knowledge, on the other hand, corresponds to the remaining steps of Bloom's taxonomy, Understanding, Implementation, Analysis, Synthesis and Evaluation. It is the form of knowledge to be acquired by a student in order to be able to complete an activity and often involves motor skills and cognitive strategies. To evaluate procedural knowledge it is useful to subdivide it into discriminations, concepts/notions and rules and follow a different technique for each one of them. Discriminations refer to students' reaction to stimuli perceived by their senses and their evaluation is done by asking them to identify the stimulus which is different to the rest. Concepts/Notions refer to examples with particular characteristics which the students are again invited to locate. Finally, rules refer to the principles implementation and ask students to apply them to unknown examples (Oosterhof, 2010).

4. Purpose and Research Questions

The aim of this study was to investigate the contribution of Augmented Reality technology to the improvement of student performance and the emergence of the psychological state of Flow through a teaching intervention to junior high school second-year students. These students would be taught the "Representation of the information inside a computer" module which is suggested in the curriculum using a digital implementation of Augmented Reality. The results would be compared to the results of a second, equivalent, group of students who would be taught the same module using a different kind of technology, in particular the Web technology.

In order to achieve the goal of this research, the following research questions were posed:

1. Did the use of the Web contribute to the improvement of the learning outcomes of the control group, to what extent and in which knowledge categories?

2. Did the use of Augmented Reality contribute to the improvement of learning outcomes of the experimental group, to what extent and in which knowledge categories?

3. What kind of differences appear between the two groups after the teaching intervention, as far as their overall learning level and the individual categories of knowledge are concerned?

4. Did students in each group experience the psychological state of Flow using their digital applications and which group appeared the strongest state?

5. Did the groups show differences in each of the nine factors related to the psychological state of Flow and how big they were?

5. Method

The research was conducted in the Junior High School of Massari, a regional school on the island of Rhodes. The school was chosen for several reasons such as adequate technological equipment, the willingness and enthusiasm expressed by the students to learn using their tablets and the good cooperation with the school administration.

The second-year class had a total of 42 students divided into two parties, initially equivalent to each other as shown by their performance in the positive subjects of the previous school year. The students of the first party (B1) were 20 and there was equivalence in terms of their gender. Their school performance in the positive subjects of the previous school year curriculum (Mathematics, Physics, and Computer Science) was 14.7 on average. The second party (B2) had 22 students, 10 boys and 12 girls. The corresponding average of their in the positive subjects of previous year curriculum was 15.0.

It should be noted here that the previous year marks of the students were used as a criterion of assessment of students' initial school performance because the research was conducted at the beginning of the school year (October), during which they had not yet received their marks for the second year class.

The first party constituted the control group, while the second, the experimental group. The selection of the B2 party as the experimental group was according to the sole criterion of the number of students who owned tablets and were eager to bring them to school and use them during sessions. The students of both groups were taught "Unit 1-Digital World" of the school book for the subject of I.T. in Junior High School, following a constructive approach and specifically a teaching scenario of Anchored instruction. Anchored instruction is based on the existence of an "anchor" which usually takes the form of a video. The video-anchor sets a problem and gives students the initial information in order to start solving it. The difference in the teaching approach is identified in the digital tool for the collection of extra information used by each group. The control group used the computer lab computers to collect information from the website http://diadiko.weebly.com in order to solve the problem set by the anchor, while the experimental group used tablets to collect information from an application of Augmented Reality. Both the website and the application of Augmented Reality were created for the research purposes with Weebly and Layar (basic version) tools, respectively, and their contents did not differ.

The first three research questions referred to the investigation of the pedagogical value of the technology of Augmented Reality compared to Web technology and their research data was collected through a quiz given to students beforehand and one week after the teaching intervention. The quiz was developed by the researcher for research purposes and numbered a total of 21 questions, 9 of which related to declarative knowledge and the remaining 12 related to procedural knowledge, of which 4 questions referred to Concepts/Notions and 8 to Rules. Each correct question was given 1 point and every wrong one was given 0.

The last two research questions investigated the occurrence of the psychological state of Flow and the estimation of its intensity degree. The research data was collected using two different questionnaires developed by other researchers. Both were translated and adapted to the knowledge level of the students.

The first one (intermediate Flow questionnaire) was developed by Pearce et al. (2005) and its purpose was to assess more accurately the fluctuation of the Flow, which is more difficult to assess with one and only questionnaire given to students at the end of the research, especially in small-scale surveys such as this. This questionnaire was given to the students in two different teaching phases. It contained two questions of the 5rank Likert scale and investigated the existence of balance between the difficulty of the activity completed by the students using their digital applications and their skills.

The second (final Flow questionnaire) given to students at the end of the research was developed by Jackson & Marsh and had a Cronbach's reliability indicator a=0.83 (Jackson & Marsh, 1996). It included a total of 36 questions of the 5rank Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = neither disagree nor agree, 4 = agree, 5 = strongly agree). These questions tried to seek the nine factors which the appearance of Flow is related to and every factor corresponded to four questions which were repeated, differently formulated, every nine questions.

Each question of the final Flow questionnaire was rated from 1 - 5. The total score for each student could range from 36 (total absence of Flow) to 180 (high Flow intensity). Also, the average of each factor could range from 4 (complete absence of Flow) to 20 (high Flow intensity).

In order to answer the research questions of the present study, the research data were analyzed both descriptively using the Microsoft Excel 2010 programme and inductively using the statistical programme SPSS 19.

More, specifically, as far as the inductive analysis is concerned, there was initially a regularity control of the variables through the Shapiro-Wilk test and then, for those variables presenting regularity, depending on the research question, what was chosen was either a parametric t-test of either dependent or independent samples. For the rest of the variables, we selected the corresponding non-parametric test, either the Wilcoxon one or the Mann-Whitney one.

6. Results

6.1. Research Question 1

Initially, there had been regularity control of every variable using the Shapiro-Wilk test, as the sample of the control group (N = 20) was fewer than 50 people. It was found that five variables presented regularity: the variable Procedural knowledge-rules, both before and after teaching intervention, with a significance level of p = 0.054 and 0.070 respectively, the variable Sum of procedural knowledge afterwards with a significance level of p = 0.290 and the variable Total score both before and after teaching intervention, with a significance level of p = 0.193 and 0.142 respectively.

Variable pairs before-after exhibiting regularity, underwent a parametric t-test of dependent samples (paired samples t-test). The results showed a high correlation between the variables Total score before and Total score after (r = 0.654, $p < 0.05$) and a marginal correlation between the variables Procedural knowledge-rules before and Procedural knowledge-rules after (r = 0.244, $p > 0.05$) (**Table 1**). Also, there was a statistically significant difference in the average values of these two variable pairs, at a significance level of $p < 0.05$ (Procedural knowledge-rules [t(19) = −10.782, p = 0.00], Total Score [t(19) = −10.357, p = 0.00]) (**Table 2**).

All other pairs of variables (before, after) as well as the variable Sum of procedural knowledge after, whose corresponding variable (Sum of procedural knowledge before) showed no regularity, were analyzed by the non-parametric Wilcoxon test. What became apparent from the results of this analysis was that all three pairs of variables showed a statistically significant difference on significance level $p < 0.05$ (Declarative knowledge [Z(20) = −3.741, p = 0.00], Procedural knowledge-concepts [Z(20) = −3.926, p = 0.00], Total procedural knowledge [Z(20) = −3.947, p = 0.00]) (**Table 3**). Moreover, the overall student performance increased by 3.50 points

Table 1. Correlation table of the dependent samples.

Variables' pairs	N	r	p
Procedural knowledge-rules before & Procedural knowledge-rules after	20	0.244	0.300
Total score before & Total score after	20	0.654	0.002

Table 2. Control group: Results of the t-test for dependent samples.

Variables	Before		After		Differences				
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	t	df	p
Procedural knowledge-rules	2.00	1.026	5.80	1.473	3.80	1.576	−10.782	19	0.00
Total score	3.50	1.573	11.95	4.478	8.45	3.649	−10.357	19	0.00

Table 3. Control group: Results of the Wilcoxon non-parametric test.

Variables	Before		After		Rank					
	Mean	Standard deviation	Mean	Standard deviation	↓	=	↑	Z	df	p
Declarative knowledge	0.75	0.851	3.90	2.511	0	2	18	−3.741	20	0.00
Procedural knowledge-concepts	0.75	0.910	2.25	1.118	0	1	19	−3.926	20	0.00
Total procedural knowledge	2.75	1.209	8.05	2.328	0	0	20	−3.947	20	0.00

(SD = 1.573) to 11.95 (SD = 4.478) i.e., 8.45 points on average (**Table 2**).

Finally, the variations in students' answers were calculated as well as the minimum and maximum number of correct answers in each category aiming at the reflection of the degree of their performance improvement after the teaching intervention. The results showed that, while before teaching intervention there were students who had not given a proper answer to any question of each category (Min = 0), after the teaching intervention all students replied properly to at least one (Min = 1). There even were students who had given a correct answer to all Procedural knowledge questions (Concepts Max = 4, Rules Max = 8) or had come very close to the optimum result (Declarative knowledge, Max = 8).

Moreover, there was no student to have given a wrong answer to a question of the final test while in the initial test had given a correct answer to the same question (Change to False = 0). The majority of students changed their answers to the better, giving correct answers in the final test. More specifically, 18 students improved their responses to Declarative knowledge questions, 19 students improved their responses to Procedural knowledge-concepts questions and Procedural knowledge-rules questions, while all students (100%) showed improvement in the total of Procedural knowledge questions as well as the general total of the test questions (Total score). Only two students (10.0%) in a Declarative knowledge question, a student (5.0%) in a Procedural knowledge-concepts question and another one in a Procedural knowledge-rules question, maintained their initial response, whether it was right or wrong.

6.2. Research Question 2

Following a similar analysis procedure to the one followed in the research question 1 there was first regularity control of every variable using the Shapiro–Wilk test, as the sample of the control group (N = 22) was fewer than 50 people. Through the particular control, it was found that two variables presented regularity: the variable Sum of procedural knowledge before and the variable Total score before with a significance level of $p = 0.182$ and 0.155 respectively. Despite their regularity, however, these two variables were analyzed following the non-parametric Wilcoxon test since their respective variables (after teaching intervention), showed no regularity.

The test results (**Table 4**) showed a statistically significant difference on a significance level of $p < 0.05$ for all variable pairs before-after (Total Score [Z(22) = −4.110, $p = 0.00$], Declarative knowledge [Z(22) = −4.121, p = 0,00], Procedural knowledge-concepts [Z(22) = −4.146, $p = 0.00$] Procedural knowledge-rules [Z(22) = −4.041, $p = 0.00$], Procedural knowledge-total [Z(22) = −4.128, $p = 0.00$]). In addition, the overall learning student level increased on average by 10.64 points [before (M = 3.36 SD = 1.989), after (M = 14.00 SD = 4.461)].

After that, the variations in students' answers were calculated as well as the minimum and maximum number of correct answers in each category. The results showed that, while before teaching intervention there were students who had not given a proper answer to any question of each category (Min = 0), after the teaching intervention all students replied properly to at least one (Min = 1). There even were students who had given a correct answer to all Procedural knowledge questions (Concepts Max = 4, Rules Max = 8) or had come very close to the optimum result (Declarative knowledge, Max = 7).

Finally, there was no student to have given a wrong answer to a question of the final test while in the initial test had given a correct answer to the same question (Change to False = 0). All students, apart from one (4.5%) who did not change his answer to a question of Procedural knowledge-rules, changed their answers, giving correct answers to all knowledge categories of the final test.

6.3. Research Question 3

To determine the difference in the learning level of the two groups, their research data in the quiz after the teaching intervention was used. Initially, there was a variables regularity control through the Shapiro-Wilk test,

Table 4. Experimental group: Results of the Wilcoxon non-parametric.

Variables	Before		After		Rank					
	Mean	Standard deviation	Mean	Standard deviation	↓	=	↑	Z	df	p
Declarative knowledge	1.05	0.950	4.82	1.763	0	0	22	−4.121	22	0.00
Procedural knowledge-concepts	0.86	0.889	3.32	0.945	0	0	22	−4.146	22	0.00
Procedural knowledge-rules	1.45	0.912	5.86	2.232	0	1	21	−4.041	22	0.00
Procedural knowledge-total	2.31	1.460	9.18	2.970	0	0	22	−4.128	22	0.00
Total Score	3.36	1.989	14.00	4.461	0	0	22	−4.110	22	0.00

since the sample (N = 42) was smaller than the limit of 50 people. Results pointed out that no variable showed regularity.

What followed was a variable control through the non-parametric Mann-Whitney test (**Table 5**), which showed that between the groups there was a statistically important difference on a significance level $p < 0.05$, hence heterogeneity between the two groups, only as far as the variable Procedural knowledge-concepts [U(42) = 104.00, $p = 0.02$] is concerned. In the other categories of questions and on the overall test performance, despite the fact that the experimental group had better results, the groups showed no significant difference between them.

The two groups showed their smallest difference in the category Procedural knowledge-rules, with just 0.06 points in favour of the experimental group, whereas in the category Procedural knowledge-concepts as well as in the variable Total Procedural knowledge, presented their biggest difference with 1.07 and 1.13 points respectively, again in favour of the experimental group. Furthermore, they showed 0.92 points difference in favour of the experimental group in Declarative knowledge and 2.05 points difference in Total score, again in favour of the experimental group (**Table 6**).

It is worth noting that, while initially the control group showed better performance results in the categories Procedural knowledge–rules, Total Procedural knowledge and total Score of the initial quiz, after teaching intervention, the experimental group covered the difference.

6.4. Research Question 4

The answers of each student group in the intermediate Flow questionnaire were used to simulate, through the use of a table, the original Flow model (**Figure 1**) of Csikszentmihalyi (1975). According to this model, the values on the diagonal of the table show a state of Flow, those above the diagonal indicate Anxiety, while the rest of them below the diagonal show Boredom. Moreover, in order to assess the intensity of each situation, it was considered that the closer to a Flow state (diagonal) students find themselves, the smaller the degree of Anxiety or boredom they experience and respectively, the farther away from the Flow State they are, the greater the Anxiety they experience.

Two different tables for each group were created. The first concerned the psychological condition of students after the end of the first activity in which they used their digital applications, and the second concerned the psychologicalstate of Flow after the end of the second similar activity.

At the end of the first activity, most students of the control group (**Table 7(A)**) were in a state of Anxiety (N = 9, f = 45.0%), then to a state of Boredom (N = 8, f = 40.0%) and less to a state of Flow (N = 3, f = 15.0%). Of the students who were in the state of Anxiety, 2 seem to worry less than the others and were very close to the state of Flow, 6 were in a medium state of Anxiety and one was in a great state of it. Of the students who were in the state of Flow, 2 estimated that they were in a medium state of it and one in a small state of it. Finally, of students who were in the state of Boredom, 4 appreciated that they were slightly bored and very close to pass to the state of Flow, 2 in a medium state of Boredom and the other two at a large state of it.

At the end of the second activity (**Table 7(B)**), there was an increase of students' skills who were in the state of Anxiety, without however, a change in their total number (N = 9, f = 45.0%). Six of them experienced a low degree of Anxiety and very close to the state of Flow, 2 of them experienced medium Anxiety and one felt great Anxiety. The number of students who found themselves in a state of Flow had increased (N = 4, f = 20.0%) and all of them felt a great degree of Flow. Finally, the state of Boredom was experienced by a student fewer than in the previous activity (N = 7, f = 35.0%). Of the aforementioned students, 6 felt a low degree of boredom and

Table 5. Group comparison: Results of the Mann Whitney non-parametric test.

Variables	Control group		Experimental group				
	Mean	Standard deviation	Mean	Standard deviation	U	df	p
Procedural knowledge-concepts	2.25	1.118	3.32	0.945	104.00	20/22	0.002
Declarative knowledge	3.90	2.511	4.82	1.763	165.50	20/22	0.165
Procedural knowledge-rules	5.80	1.473	5.86	2.232	197.50	20/22	0.565
Procedural knowledge-total	8.05	2.328	9.18	2.970	163.50	20/22	0.150
Total Score	11.95	4.478	14.00	4.461	165.00	20/22	0.164

Table 6. Group comparison: Differences on averages per knowledge category.

Variables	Before the teaching intervention			After the teaching intervention			Total difference
	Experimental group	Control group	Difference	Experimental group	Control group	Difference	
Declarative knowledge	1.05	0.75	0.30	4.82	3.90	0.92	0.62
Procedural knowledge-concepts	0.86	0.75	0.11	3.32	2.25	1.07	0.96
Procedural knowledge-rules	1.45	2.00	-0.55	5.86	5.80	0.06	0.61
Procedural knowledge-total	2.31	2.75	-0.43	9.18	8.05	1.13	1.56
Total Score	3.36	3.50	-0.14	14.00	11.95	2.05	2.19

Table7. Control group: Estimation of students' challenge-skill.

A. 1*st activity*

Challenge \ Skill	1	2	3	4	5
5	0	0	0	0	0
4	1	1	1	0	0
3	5	1	2	2	0
2	0	1	2	1	0
1	0	0	1	2	0

B. 2*nd activity*

Challenge \ Skill	1	2	3	4	5
5	0	0	0	0	0
4	1	2	2	0	0
3	0	3	4	1	0
2	1	0	4	1	0
1	0	1	0	0	0

Anxiety   Flow   Boredom

very close to the state of Flow, while only one student experienced Boredom of a medium degree.

For the experimental group, at the end of the first activity (**Table 8(A)**), there seemed to be a balance between the number of students who were in the state of Anxiety and Boredom (N = 9, f = 40.91%), while the minority of students were as well in the state of Flow (N = 4, f = 18.18%). Of the students who were in state of Anxiety, 5 worried to a lower extent than others and were very close to the state of Flow, 2 worried a bit more and experienced Anxiety of a medium degree, while the other two worried even more and were in a great Anxiety State. Of the nine students who were in the state of Boredom, six experienced it at a lower degree and were very close to the state of Flow, one experienced it at a medium degree and the other two students felt a medium grade of Boredom. Finally, 3 out of the 4 students who were, according to their estimation, in the state of Flow, experienced it at a medium degree and 1 of them at a low degree.

At the end of the second activity (**Table 8(B)**), there was a change in student estimation, but the balance between Anxiety and Boredom still maintained to a lower degree than before (N = 8, f = 36.36%), though. The number of students who estimated that they were in a state of balance between activity difficulty and their skill (Flow) had increased to six (N = 6, f = 27.27%) but were still fewer than the others. Students, who experienced a

Table 8. Experimental group: Estimation of students' challenge-skill.

A. 1*st activity*

Challenge \ Skill	1	2	3	4	5
5	0	0	0	0	0
4	2	2	1	0	0
3	0	3	3	1	0
2	1	1	5	1	0
1	0	0	0	2	0

B. 2*nd activity*

Challenge \ Skill	1	2	3	4	5
5	0	0	0	0	0
4	1	1	1	2	0
3	0	5	4	3	0
2	0	0	3	1	0
1	0	1	0	0	0

Anxiety Flow Boredom

low degree of Boredom and very close to the state of Flow, had increased by one. Moreover, the number of students who believed that their skills had improved but they were still in a state of Boredom had increased as well. Finally, only one (1) student remained at a medium degree of the state of Boredom, while two students, who were at a high degree in the state of Boredom towards the end of the first activity, had changed estimate. Similarly, the number of students who experienced a low degree of Anxiety and were very close to the state of Flow had increased by one (1), one (1) student fewer than before was at a state of medium Anxiety, while one (1) was still in a state of high Anxiety. Finally, of the students who were in the state of Flow, 4 estimated that they were in a state of medium Flow and 2 others at a state of high Flow.

Then, what was calculated was the estimation average of each group for each activity (**Table 9**). Thus, it became apparent that the control group students considered both activities easier (1st: 2.65, 2nd: 2.85) than what the experimental group students had considered them (1st: 2.68, 2nd: 2.95). On the other hand, they estimated that their skills were somewhat lower (1st: 2.50, 2nd: 2.60) than the other group estimated theirs (1st: 2.64, 2nd: 2.86). Indeed, the difference of the estimated difficulty and the estimated capacity was lower in the experimental group, a fact, which, to an extent, explains the best psychological situation experienced by the particular students.

Finally, the total score of each group was calculated according to the research data of the final Flow questionnaire. The scores of the control group students ranged from 83 to 140 (M = 111.95 SD = 15.76) and those of the experimental group students from 78 to 146 (M = 123.27 SD = 16.84). More specifically, 9 students from the control group (45.0%) had a total score of less than 108 (neutral state), no student had atotal score of 108, while the remaining 11 students (55.0%) had a total score of more than 108, i.e. they experienced a certain degree of Flow (**Table 10**).

In the experimental group, things were different. Specifically, 2 students (9.09%) had a total score below 108, no student was in a neutral state, while the remaining 20 students (90.91%) experienced a different degree of the state of Flow (**Table 10**).

6.5. Research Question 5

The answers to the questions for each factor for each student were added and their average was calculated. The results showed that the experimental group had bigger averages in all factors and all of them ranged above the limit of 3.0, that is, the limit of neutrality according to the Likert scale of the questionnaire.

More analytically, their averages in each factor were: Balance of challenges-skills (M = 3.44, SD = 0.63), Action-awareness merging (M = 3.02, SD = 0.70), Clear goals (M = 3.57, SD = 0.63), Unambiguous feedback (M = 3.43, SD = 0.56), Concentration on task at hand (M = 3.40, SD = 1.01), Sense of control (M = 3.28, SD = 0.72), Loss of self-consciousness (M = 3.67, SD = 0.75), Transformation of time (M = 3.03, SD = 0.61), Autotelic experience (M = 3.97, SD = 0.72). Therefore, what it emerged was that all students experienced a certain degree of Flow in all factors (**Table 11**).

Table 9. Estimation average of challenge-skill for each activity.

1st activity				2nd activity			
Control group		Experimental group		Control group		Experimental group	
Challenge	Skill	Challenge	Skill	Challenge	Skill	Challenge	Skill
2.65	2.5	2.68	2.64	2.85	2.6	2.95	2.86

Table10. Total score and general average of the final Flow questionnaire.

Total score	Control group				Experimental group			
	N	f	Mean		N	f	Mean	
			Min	Max			Min	Max
Bellow 108	9	45.0%	2.31	2.94	2	9.09%	2.19	2.78
108 (neutral)	0	0.0%	-	-	0	0.0%	-	-
Over 108	11	55.0%	3.08	3.89	20	90.91%	3.06	4.06

Table 11. Average of the factors relating to the appearance of Flow.

	Balance of challenges-skills		Action-awareness merging		Clear goals		Unambiguous feedback		Concentration on task at hand	
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
Mean	2.95	3.44	2.81	3.02	3.05	3.57	3.00	3.43	3.39	3.40
Standard deviation	0.81	0.63	0.82	0.70	0.81	0.63	0.62	0.56	0.75	1.01

	Sense of control		Loss of self-consciousness		Transformation of time		Autotelic experience	
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
Mean	3.14	3.28	3.55	3.67	2.63	3.03	3.48	3.97
Standard deviation	0.49	0.72	0.80	0.75	0.67	0.61	0.71	0.72

On the other hand, the control group did not exceed the neutral threshold (3.0) in all factors and, therefore, students did not experience Flow in these factors (Balance of challenges-skills (M = 2.95, SD = 0.81), Action-awareness merging (M = 2.81, SD = 0.82), Unambiguous feedback (M = 3.00, SD = 0.62), Transformation of time (M = 2.63, SD = 0.67)). In the rest of the factors students showed some degree of Flow, lower than that of the Experimental group, though (Clear goals (M = 3.05, SD = 0.81), Concentration on task at hand (M = 3.39, SD = 0.75), Sense of control (M = 3.14, SD = 0.49), Loss of self-consciousness (M = 3.55 SD = 0.80), Autotelic experience (M = 3.48, SD = 0.71) (**Table 11**).

To determine the existence or non-existence of a statistically significant difference for each factor between the two groups, the average of each factor was initially checked against the Shapiro-Wilk test on whether they fulfilled the regularity criterion, since the sample was lower than 50 (N = 20/22). The test demonstrated that all factors showed regularity in both groups ($p > 0.05$), thus, the parametric t-test of independent samples was chosen, which showed that statistically significant difference between the two groups appears to be in the following factors (**Table 12**): Balance of challenges-skills [$t(40) = -2.226$, $p = 0.32$], Clear goals [$t(40) = -2.330$, $p = 0.25$], Unambiguous feedback [$t(40) = -2.361$, $p = 0.23$], Transformation of time [$t(40) = -2.071$, $p = 0.45$] and Autotelic experience [$t(40) = -2.218$, $p = 0.32$].

Finally, to determine whether the statistically significant differences between the two groups were strong, the effect size indicator d of Cohen (1988) was calculated, only for the particular factors. This indicator showed that the difference between the two groups was great, since, for all factors, it ranged between 0.5 and 0.8 (Balance of challenges-skills: 0.70, Clear goals: 0.74, Unambiguous feedback: 0.75, Transformation of time: 0.65, Autotelic experience: 0.70).

Table 12. Results of the t-test for independent samples.

Flow factors	Levene's test				
	F	p	t	df	p
Balance of challenges-skills	1.807	0.186	−2.226	40	0.032
Action-awareness merging	2.086	0.156	−0.898	40	0.375
Clear goals	2.681	0.109	−2.330	40	0.025
Unambiguous feedback	0.451	0.506	−2.361	40	0.023
Concentration on task at hand	1.301	0.261	−0.037	40	0.971
Sense of control	2.883	0.097	−0.763	40	0.450
Loss of self-consciousness	0.315	0.578	−0.505	40	0.617
Transformation of time	0.014	0.907	−2.071	40	0.045
Autotelic experience	0.148	0.702	−2.218	40	0.032

7. Discussion

7.1. Research Question 1

The analysis of the research data concerning the control group showed a statistically significant difference in their learning results, before and after the teaching intervention. Consequently, the digital Web application used by the students of this group, as an information collection tool, contributed to the positive change of their performance. These students learned new concepts and important information by improving their Declarative knowledge by 3.15 points on average in relation to the knowledge they had before the teaching intervention. Using this knowledge they were able to recognize situations and objects associated with them, improving their Procedural knowledge-concepts by 1.5 points on average and applied this acquired knowledge to decode and encode texts, images and numbers, improving their Procedural knowledge-rules by 3.8 points on average. Overall, the control group students improved their Procedural knowledge by 5.3 points on average, while their overall improvement reached 8.45 points on average.

As far as the change between right and wrong answers is concerned, all students improved their number of correct answers, while there were no students to have changed their knowledge to the worse, in any category of questions after teaching. Finally, the students showed the most significant improvement in the Procedural knowledge questions, where there were students who gave correct answers to all questions of this category, while in the Declarative knowledge questions they approached the optimum result (8 out of 9 correct answers).

7.2. Research Question 2

Similar results to those of the control group were obtained for the experimental group. More specifically, the students learned new concepts and important information by improving their Declarative knowledge by 3.77 points on average in relation to the knowledge they had before the teaching intervention. Using this knowledge they were able to recognize situations and objects associated with them, improving their Procedural knowledge-concepts by 2.46 points on average and they applied this acquired knowledge to decode and encode texts, images and numbers, improving their Procedural knowledge-rules by 4.41 points on average. Overall, their Procedural knowledge improved by 6.87 points on average, while their general improvement reached 10.64 points on average.

All students improved the number of their correct answers and none of them got worsened their knowledge by giving, after teaching, a wrong answer to a question which they had given a correct answer to. There even were students who gave correct answers to all Procedural knowledge questions, while, in the Declarative knowledge questions, they improved the score of their correct answers (7 out of 9 correct answers).

These results concerning student's knowledge improvement are consistent with the results of other relevant studies (Shelton & Hedley, 2002; Seo et al., 2006; Nischelwitzer et al., 2007; Juan et al., 2010; Sin & Zaman, 2010; Liu & Chu, 2010; Wijers et al., 2010; Pasaréti et al., 2011; Cai et al., 2012; Dünser et al., 2012; Salvador-Herranz, et al, 2013; Chen et al., 2013; Fleck & Simon, 2013; Kamarainen et al., 2013; Lin et al., 2013; Cai et al., 2014; Ibáñez et al., 2014; Ahn & Choi, 2015; Tarng et al., 2015).

7.3. Research Question 3

Comparing the results of the two groups it seems that, even though both groups improved their results, the experimental group had better performance in all knowledge categories.

More specifically, the control group improved their average in Declarative knowledge questions by 3.15 points, the Procedural knowledge-concepts questions by 1.5 points, the Procedural knowledge-rules questions by 3.8 points, the total Procedural knowledge by 5.3 points and the Total score by 8.45 points. Similarly, the experimental group improved their average in Declarative knowledge questions by 3.77 points, the Procedural knowledge-concepts questions by 2.46 points, the Procedural knowledge-rules questions by 4.41 points the total Procedural knowledge by 6.87 points and the Total score by 10.64 points.

In fact, although the experimental group had initially showed worse learning outcomes in initial knowledge test, in the questions concerning the Procedural knowledge-rules, the Total of procedural knowledge and the Total score compared to the experimental group, in the final test, not only did they cover the difference but they also surpassed it.

7.4. Research Question 4

At the end of the first activity during which the control group students used their digital application (Web) they seem to be dominated by Anxiety, then Boredom and finally Flow but at a lower degree. Most of them experience Anxiety at a medium degree and Boredom at a low degree.

At the end of the second activity, some changes in the psychological state of students are observed. Although the percentage of students experiencing Anxiety remains the same, the percentage of Flow increases, and, at the same time, the percentage of Boredom decreases. However, if we examine the intensity extent of each state, there emerges both a shift toward the state of Flow (low degree of Anxiety or Boredom) as well as an increase of the number and degree of students who clearly experience Flow.

Moreover, through the final questionnaire of Flow analysis, there seems that several of the control group students experienced Flow, not only during activities but in general as well, achieving a score which reached up to 140 points. The general average of the 11 students who experienced Flow, even though marginally, rated from 3.08 to 3.89, while only one (1) student reached 4 (Strongly agree), with an average 3.89.

Similar results emerged for the experimental group as well, who experience, towards the end of the fist activity, Anxiety and Boredom at the same percentage to the previous one and Flow at a lower degree. As far as student intensity in the states of Anxiety or Boredom is concerned, this is more of low degree whereas Flow mainly appears at medium intensity.

At the end of the second activity, Anxiety and Boredom continue dominating the group members, even though at low intensity, and the psychological state of Flow follows with an increased percentage. As far as the intensity of each state is concerned, low degrees of Anxiety and Boredom dominate as well as medium degree of Flow. However, now, two students experience high degree of Flow, an element which did not appear in the control group. Consequently, the number of students who are close to or already and clearly experience Flow increases, while, at the same time, the number of students who clearly experience Anxiety or Boredom (at medium and low degree) decreases.

The score at the final Flow questionnaire of the experimental group students shows that they experienced as well a state of Flow, not only during activity but also generally, achieving a score which reached 146 points.

7.5. Research Question 5

The analysis of the final Flow questionnaire showed a statistically significant difference between the two groups only in 5 out of 9 factors relating to the psychological state of Flow. These factors were the Balance of challenges-skills, Clear goals, Unambiguous feedback, Transformation of time and Autotelic experience. Moreover, Cohen's (1988) indicator d showed that the difference between the two groups was great.

The averages of the 5 factors in which the two groups showed a statistically significant difference, were all greater for the experimental group. Examining their numbers, it was observed that the control group students experienced the factor Clear goals marginally above the Neither agree-nor disagree threshold and reached closer the Agree for the Autotelic experience factor. On the other hand, the experimental group students found themselves marginally over the threshold of Neither agree-nor disagree for the Transformation of time factor, almost at the Agree for the Autotelic experience factor and approximately in the middle, between neutrality and agreement for the remaining three factors.

To sum up, we can conclude that the implementation of Augmented Reality helped students learn what they had to do and when they had achieved their goals, they were concentrated more during activities experiencing balance between challenge and skills and in the end they felt that their effort was worth it, thus being more satisfied. These findings are consistent to those of other individual research projects (Dunleavy et al., 2009; Liu & Chu, 2010; Cai et al., 2012; Salvador-Herranz et al., 2013; Fleck & Simon, 2013; Di Serio et al., 2013; Wojciechowski & Cellary, 2013), since there is not much research testing the appearance of Flow in the way it was tested in the present research except for the research by Ibáñez et al. (2014), whose results converge at a great degree to this one's.

8. Research Restrictions

The essential research restrictions can be initially identified in the small sample as well as the lack of adequate number of portable devices. It is certain that the results would be safer if research implementation involved a greater number of students of even schools, which would have adequate equipment for its needs, so that there would be one digital device for every one or two, at the most, students. This adequacy in portable devices could possibly allow students concentrate more on what they do, reaching the state of Flow more easily.

Other research restrictions are identified in its duration, in the way the digital applications were used and the research data collection tools. As far as the first restriction is concerned, in class research implementation lasted four teaching sessions, during which students used their digital applications in only two out of six phases of the teaching scenario. A longer research, during which students could use the digital applications for longer periods, could lead to safer results. As regards the second restriction, the digital applications were used as information collection tools, while they were not used as instruments for experimentation and investigation. Another teaching approach, with the use of some other development tools or even the full version of the Layar platform which gives far more potential, could investigate these aspects of Augmented Reality technology as well. Finally, as far as the third restriction is concerned, this research used only questionnaires and a knowledge test for the research data collection. These tools could be combined with students' interviews which could better enlighten various research aspects and explain students' answers.

9. Conclusions

Upon research completion, we could say that it has achieved its initial goal, since it gave answers to the research questions. The results enlighten two different potentials of Augmented Reality, which appear here at a greater extent than in Web technology. The first one is that it contributes, to a great extent, to students' performance improvement and the second one is that it helps students experience the psychological state of Flow, which, in turn, helps them improve their performance, since they are absolutely concentrated on what they do, at such a degree that they lose time sense and conscience, they more clearly recognize the objectives they have to achieve and, finally, they are more satisfied by their project.

Although these results cannot be used in general, it cannot be refused that they constitute clues of the pedagogical values of Augmented Reality. Future research, which will surpass the present research restrictions, as these have been described, could certainly prove at a greater extent that these clues are, finally, valid.

References

Ahn, H. S., & Choi, Y. M. (2015). Analysis on the Effects of the Augmented Reality-Based STEAM Program on Education. *Advanced Science and Technology Letters, 92,* 125-130.

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence, 6,* 355-385. http://dx.doi.org/10.1162/pres.1997.6.4.355

Bloom, B. S. (1956). *Taxonomy of Educational Objectives: Handbook 1. Cognitive Domain*. New York: McKay.

Bronack, S. C. (2011). The Role of Immersive Media in Online Education. *The Journal of Continuing Higher Education, 59,* 113-117. http://dx.doi.org/10.1080/07377363.2011.583186

Cai, S., Chiang, F. K., & Wang, X. (2013). Using the Augmented Reality 3D Technique for a Convex Imaging Experiment in a Physics Course. *International Journal of Engineering Education, 29,* 856-865.

Cai, S., Wang, X., & Chiang, F. K. (2014). A Case Study of Augmented Reality Simulation System Application in a Chemistry Course. *Computers in Human Behavior, 37,* 31-40. http://dx.doi.org/10.1016/j.chb.2014.04.018

Cai, S., Wang, X., Gao, M., & Yu, S. (2012). Simulation Teaching in 3D Augmented Reality Environment. *2012 IIAI International Conference on Advanced Applied Informatics (IIAIAAI)*, Fukuoka, 20-22 September 2012, 83-88. http://dx.doi.org/10.1109/IIAI-AAI.2012.25

Chen, J. Y., Liu, C. H., & Lu, K. F. (2013). The Application of Augmented Reality Technology on Gear Instructional Module for Indigenous Culture. *Journal of Information Technology and Application in Education, 2,* 175-178. http://dx.doi.org/10.14355/jitae.2013.0204.09

Cheng, K. H., & Tsai, C. C. (2013). Affordances of Augmented Reality in Science Learning: Suggestions for Future Research. *Journal of Science Education and Technology, 22,* 449-462. http://dx.doi.org/10.1007/s10956-012-9405-9

Cheng, K. H., & Tsai, C. C. (2014). Children and Parents' Reading of an Augmented Reality Picture Book: Analyses of Behavioral Patterns and Cognitive Attainment. *Computers & Education, 72,* 302-312. http://dx.doi.org/10.1016/j.compedu.2013.12.003

Choi, B., & Baek, Y. (2011). Exploring Factors of Media Characteristic Influencing Flow in Learning through Virtual Worlds. *Computers & Education, 57,* 2382-2394. http://dx.doi.org/10.1016/j.compedu.2011.06.019

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Csikszentmihalyi, M. (1975). *Beyond Boredom and Anxiety (The Jossey-Bass Behavioral Science Series)*. San Francisco, CA: Jossey-Bass.

Di Serio, A., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an Augmented Reality System on Students' Motivation for a Visual Art Course. *Computers & Education, 68,* 586-596. http://dx.doi.org/10.1016/j.compedu.2012.03.002

Dimitriou, K. (2009). *The Tangible Augmented Reality in Education: Study and Planning of an Educational Application for Learning of Electrical Circuits for High School Students.* Dissertation, Mytilene: Department of Engineers for the Design of Produce and Systems, University of the Aegean.

Dror, I. E. (2008). Technology Enhanced Learning: The Good, the Bad, and the Ugly. *Pragmatics & Cognition, 16,* 215-223. http://dx.doi.org/10.1075/p&c.16.2.02dro

Dunleavy, M., & Dede, C. (2014). Augmented Reality Teaching and Learning. In J. Michael Spector, M. David Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 735-745). New York: Springer. http://dx.doi.org/10.1007/978-1-4614-3185-5_59

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and Limitations of Immersive Participatory Augmented Reality Simulations for Teaching and Learning. *Journal of Science Education and Technology, 18,* 7-22. http://dx.doi.org/10.1007/s10956-008-9119-1

Dünser, A., Walker, L., Horner, H., & Bentall, D. (2012). Creating Interactive Physics Education Books with Augmented Reality. *Proceedings of the 24th Australian Computer-Human Interaction Conference*, Melbourne, 26-30 November 2012, 107-114. http://dx.doi.org/10.1145/2414536.2414554

Enyedy, N., Danish, J. A., Delacruz, G., & Kumar, M. (2012). Learning Physics through Play in an Augmented Reality Environment. *International Journal of Computer-Supported Collaborative Learning, 7,* 347-378. http://dx.doi.org/10.1007/s11412-012-9150-3

Faiola, A., Newlon, C., Pfaff, M., & Smyslova, O. (2013). Correlating the Effects of Flow and Telepresence in Virtual Worlds: Enhancing Our Understanding of User Behavior in Game-Based Learning. *Computers in Human Behavior, 29,* 1113-1121. http://dx.doi.org/10.1016/j.chb.2012.10.003

Finneran, C. M., & Zhang, P. (2005). Flow in Computer-Mediated Environments: Promises and Challenges. *Communications of the Association for Information Systems, 15,* Article 4.

Fleck, S., & Simon, G. (2013). An Augmented Reality Environment for Astronomy Learning in Elementary Grades: An Exploratory Study. *Proceedings of the 25 ième Conference Francophone on l'Interaction Homme-Machine*, Bordeaux, 13-15 November 2013, 14. http://dx.doi.org/10.1145/2534903.2534907

Freitas, R., & Campos, P. (2008). SMART: A SysteM of Augmented Reality for Teaching 2nd Grade Students. *Proceedings of the 22nd British HCI Group Annual Conference on People and Computers: Culture, Creativity, Interaction, 2,* 27-30.

Gialouri, E. (2011). *Teaching Physics through the Use of Advanced Technological Applications*. Thesis, Athens: National Metsovian Polytechnic School.

Grigoraki, M., Politi, A., & Tsolakos, P. (2013). The Educational Exploitation of Diffuse Calculation Games. An Implementation in History of D' Class of Primary School below the Acropolis. *Proceedings of the 5th Conference on Informatics in Education*, Piraeus, 11-13 October 2013, 1-11. http://195.130.124.90/cie/images/documents13/CIE2013_proceedings/data/cie2013_120.pdf

Ibáñez, M. B., Di Serio, Á., Villarán, D., & Kloos, C. D. (2014). Experimenting with Electromagnetism Using Augmented Reality: Impact on Flow Student Experience and Educational Effectiveness. *Computers & Education, 71,* 1-13.

Jackson, S. A., & Csikszentmihalyi, M. (1999). *Flow in Sports*. Champaign, IL: Human Kinetics.

Jackson, S. A., & Marsh, H. W. (1996). Development and Validation of a Scale to Measure Optimal Experience: The Flow State Scale. *Journal of Sport & Exercise Psychology, 18,* 17-35.

Juan, C., Toffetti, G., Abad, F., & Cano, J. (2010). Tangible Cubes Used as the User Interface in an Augmented Reality Game for Edutainment. *10th International Conference on Advanced Learning Technologies (ICALT)*, Sousse, 5-7 July 2010, 599-603. http://dx.doi.org/10.1109/ICALT.2010.170

Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C. (2013). EcoMOBILE: Integrating Augmented Reality and Probeware with Environmental Education Field Trips. *Computers & Education, 68,* 545-556. http://dx.doi.org/10.1016/j.compedu.2013.02.018

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). "Making It Real": Exploring the Potential of Augmented Reality for Teaching Primary School Science. *Virtual Reality, 10,* 163-174. http://dx.doi.org/10.1007/s10055-006-0036-4

Klopfer, E., Perry, J., Squire, K., Jan, M. F., & Steinkuehler, C. (2005). Mystery at the Museum: A Collaborative Game for Museum Education. *Proceedings of the 2005 Conference on Computer Support for Collaborative Learning: Learning 2005: The Next 10 Years!* Taipei, 30 May-4 June 2005, 316-320.

Kye, B., & Kim, Y. (2008). Investigation of the Relationships between Media Characteristics, Presence, Flow, and Learning Effects in Augmented Reality Based Learning Augmented Reality. *International Journal for Education Media and Technology, 2,* 4-14.

Liao, L. F. (2006). A Flow Theory Perspective on Learner Motivation and Behavior in Distance Education. *Distance Education, 27,* 45-62. http://dx.doi.org/10.1080/01587910600653215

Liarokapis, F., & Anderson, E. F. (2010). Using Augmented Reality as a Medium to Assist Teaching in Higher Education.

Lin, T. J., Duh, H. B. L., Li, N., Wang, H. Y., & Tsai, C. C. (2013). An Investigation of Learners' Collaborative Knowledge Construction Performances and Behavior Patterns in an Augmented Reality Simulation System. *Computers & Education, 68,* 314-321. http://dx.doi.org/10.1016/j.compedu.2013.05.011

Liu, T.-Y., & Chu, Y.-L. (2010). Using Ubiquitous Games in an English Listening and Speaking Course: Impact on Learning Outcomes and Motivation. *Computers & Education, 55,* 630-643. http://dx.doi.org/10.1016/j.compedu.2010.02.023

Nischelwitzer, A., Lenz, F. J., Searle, G., & Holzinger, A. (2007). Some Aspects of the Development of Low-Cost Augmented Reality Learning Environments as Examples for Future Interfaces in Technology Enhanced Learning. In C. Stephanidis (Ed.), *Universal Access in Human-Computer Interaction. Applications and Services* (pp. 728-737). Berlin: Springer.

Núñez, M., Quirós, R., Núñez, I., Carda, J. B., & Camahort, E. (2008). Collaborative Augmented Reality for Inorganic Chemistry Education. In *Proceedings of the* 5*th WSEAS/IASME International Conference on Engineering Education* (pp. 271-277), 22-24 July 2008, Heraklion.

Oosterhof, A. (2010). *Educational Evaluation: From Theory to Practice* (K. Kassimati Ed.). Athens: Ellin.

Papastergiou, M. (2009). Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation. *Computers & Education, 52,* 1-12. http://dx.doi.org/10.1016/j.compedu.2008.06.004

Pasaréti, O., Hajdú, H., Matuszka, T., Jámbori, A., Molnár, I., & Turcsányi-Szabó, M. (2011). Augmented Reality in Education. INFODIDACT Informatics Methodology Conference CD-Publication. (Pasaréti O., Hajdú H., Matuszka T., Jámbori A., Molnár I., Turcsányi-Szabó, M.: Augmented Reality in Education INFODIDACT Informatika Szakmódszertani konferencia cd-kiadvány). http://people.inf.elte.hu/tomintt/infodidact_2011.pdf

Pearce, J. M., Ainley, M., & Howard, S. (2005). The Ebb and Flow of Online Learning. *Computers in Human Behavior, 21,* 745-771. http://dx.doi.org/10.1016/S0747-5632(04)00036-6

Rellos, N. (2006). *Learning Control, Performance Assessment.* Athens: Gutenberg.

Salvador-Herranz, G., Perez-Lopez, D., Ortega, M., Soto, E., Alcaniz, M., & Contero, M. (2013). Manipulating Virtual Objects with Your Hands: A Case Study on Applying Desktop Augmented Reality at the Primary School. *2013 46th Hawaii International Conference on System Sciences (HICSS),* Wailea, 7-10 January 2013, 31-39. http://dx.doi.org/10.1109/HICSS.2013.390

Seo, J., Kim, N., & Kim, G. J. (2006). Designing Interactions for Augmented Reality Based Educational Contents. In Z. Pan, R. Aylett, H. Diener, X. Jin, S. Göbel, & L. Li (Eds.), *Technologies for E-Learning and Digital Entertainment* (pp. 1188-1197). Berlin: Springer. http://dx.doi.org/10.1007/11736639_149

Shelton, B. E., & Hedley, N. R. (2002). Using Augmented Reality for Teaching Earth-Sun Relationships to Undergraduate Geography Students. *The 1st IEEE International Augmented Reality Toolkit Workshop*, Darmstadt, 29 September 2002, 8 p. http://dx.doi.org/10.1109/ART.2002.1106948

Shin, N. (2006). Online Learner's "Flow" Experience: An Empirical Study. *British Journal of Educational Technology, 37,* 705-720. http://dx.doi.org/10.1111/j.1467-8535.2006.00641.x

Siampanopoulou, E. (2014). "Treasure Hunt". A Spatial Game through the Use of Technologies with the Co-Creation of Pre-School Students. *Proceedings of the 3rd Panhellenic Educational Conference of Imathia: Exploitation of Information and Communication Technologies in Teaching Practice,* Naoussa, 4-6 April 2014, 419-431.

Sin, A. K., & Zaman, H. B. (2010). Live Solar System (LSS): Evaluation of an Augmented Reality Book-Based Educational Tool. *2010 International Symposium on Information Technology (ITSim), 1,* 1-6. http://dx.doi.org/10.1109/ITSIM.2010.5561320

Sintoris, Ch. (2014). *Tools for the Design of Space-Sensitive Games for Informal Learning.* Thesis, Patras: Department of Electronic Engineering and Computer Technology, University of Patras.

Sofos, A. (2011). Design Methodology for the Exploitation of New Media in Pedagogic and Educational Activities. *Pedagogic Trends in the Aegean, 5,* 85-98. http://www.rhodes.aegean.gr/ptde/revmata/issue5/Sofos.pdf

Tarng, W., Ou, K., Yu, C., Liou, F., & Liou, H. (2015). Development of a Virtual Butterfly Ecological System Based on Augmented Reality and Mobile Learning Technologies. *Virtual Reality, 19,* 253-266. http://dx.doi.org/10.1007/s10055-015-0265-5

Webster, J., Trevino, L. K., & Ryan, L. (1993). The Dimensionality and Correlates of Flow in Human-Computer Interactions. *Computers in Human Behavior, 9,* 411-426. http://dx.doi.org/10.1016/0747-5632(93)90032-N

Wijers, M., Jonker, V., & Drijvers, P. (2010). MobileMath: Exploring Mathematics outside the Classroom. *Zentralblatt für Didaktik der Mathematik (ZDM), 42,* 789-799. http://dx.doi.org/10.1007/s11858-010-0276-3

Wojciechowski, R., & Cellary, W. (2013). Evaluation of Learners' Attitude toward Learning in ARIES Augmented Reality Environments. *Computers & Education, 68,* 570-585. http://dx.doi.org/10.1016/j.compedu.2013.02.014

Yuen, S., Yaoyuneyong, G., & Johnson, E. (2011). Augmented Reality: An Overview and Five Directions for AR in Education. *Journal of Educational Technology Development and Exchange, 4,* 119-140.

Appendix A: Intermediate Flow Questionnaire

INTERMEDIATE FLOW QUESTIONNAIRE

Full Name:____ Class: ________

You have just completed an activity on your PC or tablet.
Before moving on, please answer the following questions filling the little circle for each answer representing you…

(a) How difficult have you found this activity?

Very easy	Quite easy	Neither easy, nor difficult	Quite difficult	Very difficult
○	○	○	○	○

(b) How do you judge your skills during this activity?

I believe that my skills were …				
Very low	**Low**	**Neither low, nor high**	**High**	**Very high**
○	○	○	○	○

Appendix B: Final Flow Questionnaire

Full Name:____ Class: ________

The following questions refer to the activities you did using your PC or tablet. There is no correct of wrong answer. For each question, please choose the number which represents how you felt during the activities.

Completely disagree 1	Disagree 2	Neither agree, nor disagree 3	Agree 4	Completely agree 5

1.	It was difficult but I believed that my skills would aloow me to manage	1 2 3 4 5
2.	I did the correct actions without thinking that I needed to	1 2 3 4 5
3.	I clearly know what I wanted to do	1 2 3 4 5
4.	It was clear that I was moving on the right path	1 2 3 4 5
5.	I was completely focused on what I was doing	1 2 3 4 5
6.	I felt that I had the total control of what I was doing	1 2 3 4 5
7.	I did not worry about what others might be thinking of me	1 2 3 4 5
8.	The sense of time altered (I felt that it was running either faster or slower)	1 2 3 4 5
9.	I really enjoyed it	1 2 3 4 5
10.	My skills responded to the high difficulty of the activity	1 2 3 4 5
11.	Things seemed to happen automatically	1 2 3 4 5
12.	I felt really well what I wanted to do	1 2 3 4 5
13.	I knew how well I was doing	1 2 3 4 5
14.	It was not difficult to stay focused on what was happening	1 2 3 4 5

Continued

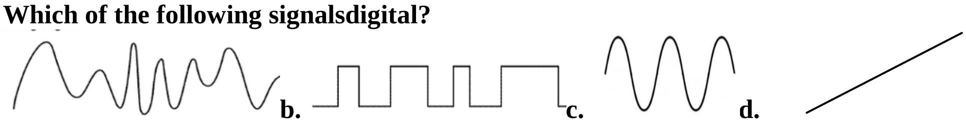
15.	I felt that I could control what I was doing	1	2	3	4	5
16.	I did not worry about my performance during the activity	1	2	3	4	5
17.	The way time was running seemed different to normal	1	2	3	4	5
18.	I liked the particular activity and I would like to do something similar again	1	2	3	4	5
19.	I felt I was quite skilled to deal with the activity demands	1	2	3	4	5
20.	I acted automatically	1	2	3	4	5
21.	I knew what I had to achieve	1	2	3	4	5
22.	During the activities, I knew how well I was going	1	2	3	4	5
23.	I was totally focused	1	2	3	4	5
24.	I had the feeling of total control	1	2	3	4	5
25.	I did not bother with my image towards other	1	2	3	4	5
26.	I felt like time stopped during the activities	1	2	3	4	5
27.	The activity made me feel wonderful	1	2	3	4	5
28.	Activity difficulty and my skills equaled and were of a high level	1	2	3	4	5
29.	I acted spontaneously and automatically without needing to think	1	2	3	4	5
30.	The aims to be achieved were clear	1	2	3	4	5
31.	I was able to know, by the way I performed, how well I was doing	1	2	3	4	5
32.	I was completely focused on what I was doing	1	2	3	4	5
33.	I felt I had total body control	1	2	3	4	5
34.	I did not worry about what the others were thinking of me	1	2	3	4	5
35.	Sometimes, all seemed to happen in slow motion	1	2	3	4	5
36.	The experience I had was worthwhile	1	2	3	4	5

Appendix C: Quiz

FULL NAME :……………………………………CLASS :…………………………………………………

1. **Which of the following signalsdigital?**

a. **b.** **c.** **d.**



2. **Which is the difference between a digital and an analogue apparatus as far as the form of their data is concerned?**

a. in digital apparatuses data is numbers whereas in analogue ones they are texts
b. the rates if their flow data take any rates
c. the rates of their flow data take particular rates
d. they have no difference

3. What kind of apparatus is each one of the following?

Analogue (**A**) or Digital (**D**)?	Apparatus		Function mode
_____		Telephone with selection keys	Pressing a number key, a flow beat is created (e.g. for 1, one beat is created, for 5, five beats, etc.)
_____		Scales	Weighing an item, the scales shows its exact weight in numbers
_____		Clock	Clock hands move passing from all time indications such as the seconds hand which constantly moves among seconds
_____		Radio	The choice of a radio station is immediate after pressing a button without listening to other stations

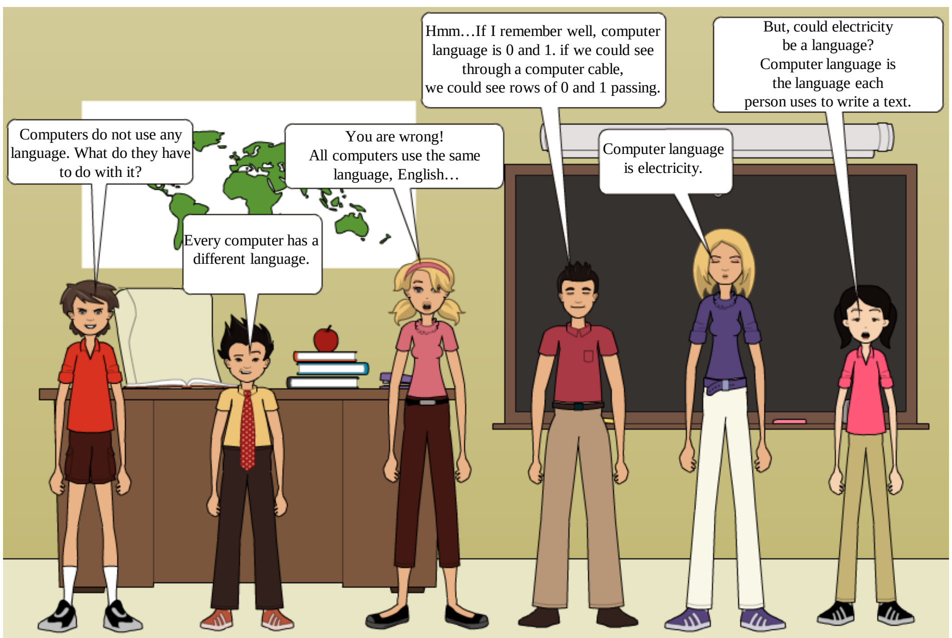
4. Refer to at least two advantages of the use of a digital system

1.____

2.____

3.____

5. Choose the correct answer to the question "Which is the computer language?"



6. **Which are the "letters" of the computer language?**
   a. the English alphabet b. each country's alphabet
   c. numbers from 0 to 9 d. numbers 0 and 1

7. **What do binary digits (bits) symbolize?**
0 symbolizes____
1 symbolizes ____

8. **Which of the following constitutes a byte?**
   a. 01101001 b. 0101010 c. 011010 d. 1210000

9. **Refer to the byte multiples writing them from the smallest to the biggest**
   a. _____________
   b. _____________
   c. _____________
   d. _____________

10. **Originally, we could key in only English characters. Explain in what way this restriction has been overcome.**

____

____

____

11. **Nick wrote a paper on his PC. When he opened it on the school's PC, he discovered that the letters had been jumbled up. When he opened it again on his own PC, the text was normal again. Where seemed to be the problem?**

____

____

____

12. **What is the name of the common code used by computers to code texts?**
   a. XASKI b. ASCII c. Binary d. ABC

13. **How many bytes do we need to code the word "ELLADA" in the computer language?**
   a. 2 b. 4 c. 6 d. 8

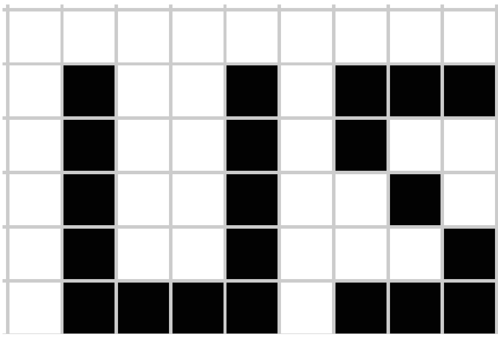
14. **Please code the word AEGEAN using the code given below.**

@	0100	0000
A	0100	0001
B	0100	0010
C	0100	0011
D	0100	0100
E	0100	0101
F	0100	0110
G	0100	0111
H	0100	1000
I	0100	1001
J	0100	1010
K	0100	1011
L	0100	1100
M	0100	1101
N	0100	1110
O	0100	1111

Result:
____
____
____
____

15. Please code number 7 in the computer language.

16. Please code the following picture in the computer language.



17. If the picture of the previous exercise (17) had 5 different colours, how many bits each code would consist of?

a. 1 b. 2 c. 3 d. other: ___________

18. Decode the text 010010100100011001001011

A	0100	0001
B	0100	0010
C	0100	0011
D	0100	0100
E	0100	0101
F	0100	0110
G	0100	0111
H	0100	1000
I	0100	1001
J	0100	1010
K	0100	1011
L	0100	1100
M	0100	1101
N	0100	1110
O	0100	1111

Result: ____

19. Decode the number 01101101 in the decimal numbering system

____

20. Decode the following picture using colours of your choice.

1	0	0	0	0	0	1
0	1	0	0	0	0	0
0	0	1	0	1	0	0
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0