Giasiranis, S., & Sofos, L. (2017). Flow Experience and Educational Effectiveness of Teaching Informatics using AR. *Educational Technology & Society, 20* (4), 78–88.

Flow Experience and Educational Effectiveness of Teaching Informatics using AR

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(Submitted May 21, 2016; Revised October 25, 2016; Accepted October 31, 2016)

ABSTRACT

The purpose of this study was the investigation of the added value of technology of augmented reality (AR) 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 AR 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 AR, though.

Keywords

Augmented reality, Flow, Interactive learning environments, Secondary education

Introduction

Only a few decades ago, few people had the 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, simulations, virtual reality 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 AR 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 AR in teaching the Earth-Sun interaction and day-night consecution, 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, AR 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 AR is used in the classroom, such as the case of Dimitriou (2009) who created an AR application for the teaching of electrical circuits to high school students, almost do not exist.

Thus, the research on the use of AR 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 AR 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.

Review of relevant research projects

Students, coming in contact with the technology of AR 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 (see Table 1).

During teaching sessions, they express their enthusiasm for what they do, collaborate on a great degree with one another in order to achieve their objective 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.

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. They consider it effective because it helped them learn and apt to help them learn more, although do not hide their satisfaction for what they have achieved by using it.

The accuracy of the students' views seems to reflect on their learning outcomes. After the use of technology, they have better performance than before, 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, they retain their knowledge for longer periods.

Table 1. Relevant research projects

Study	Before teaching	During teaching			At the end of teaching						
	Impressed and motivated	Enthusiastic	Collaborate	Absorbed	Eager to use AR again	Consider AR as effective	Apt to help them learn more	Satisfied	Perform better	Able to observe objects	Retain knowledge
Ahn, and Choi, 2015	✓		✓						✓		
Cai, Chiang and Wang, 2013	✓				✓						✓
Cai, Wang, and Chiang, 2014	✓	✓			✓				✓		
Cai, Wang, Gao, and Yu, 2012	✓			✓	✓				✓		✓
Chen, Liu, and Lu, 2013	✓								✓		
Di Serio, Ibáñez and Kloos, 2013	✓							✓			
Dunleavy, Dede, and Mitchell, 2009	✓		✓	✓							
Dünser et al., 2012	✓								✓	✓	
Fleck, and Simon, 2013	✓		✓	✓					✓	✓	
Freitas and Campos, 2008	✓	✓									
Ibáñez et al., 2014	✓			✓					✓	✓	
Juan, Toffetti, Abad and Cano, 2010					✓				✓		
Kamarainen et al., 2013	✓		✓						✓	✓	
Kerawalla et al., 2006		✓									
Klopfer, Perry, Squire, Jan, and Steinkuehler, 2005	✓	✓	✓								
Liarokapis and Anderson, 2010		✓									
Lin, Duh, Li, Wang and Tsai, 2013			✓						✓		
Liu, and Chu, 2010	✓		✓	✓		✓	✓	✓	✓		
Nischelwitzer et al., 2007									✓		
Pasaréti et al., 2011									✓		
Salvador-Herranz et al., 2013	✓			✓	✓		✓	✓	✓		
Seo, Kim and Kim, 2006	✓								✓		
Shelton and Hedley, 2002									✓		
Sin and Zaman, 2010							✓		✓		
Tarng, Ou, Yu, Liou, and Liou, 2015	✓				✓	✓			✓		
Wijers, Jonker, and Drijvers, 2010	✓	✓							✓		
Wojciechowski, and Cellary, 2013	✓				✓	✓	✓	✓			

Theoretical framework

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

Research in web environments (Liao, 2006; Shin, 2006; Webster, Trevino and Ryan, 1993), in games and in virtual reality environments (Faiola, Newlon, Pfaff and Smyslova, 2013; Papastergiou, 2009) have showed that students' learning outcomes can be enhanced if students experience the psychological condition of Flow during teaching. AR 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 themselves, 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: (a) the perceived by them, difficulty of challenge they have to face, and (b) the 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 and Csikszentmihalyi, 1999): (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 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.

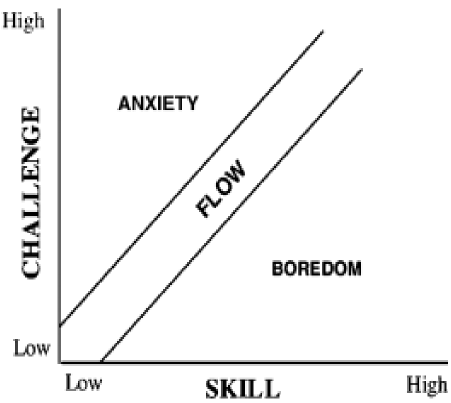

Figure 1. Initial model of flow (Csikszentmihalyi, 1975)

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 (Oosterhof, 2010; Rellos, 2006).

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).

Purpose and research questions

The aim of this study was to investigate the contribution of AR 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 AR. 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:

- 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?
- Did students in each group experience the psychological state of Flow using their digital applications and which group appeared the strongest state?
- Did the groups show differences in each of the nine factors related to the psychological state of Flow and how big they were?

Method

The research was conducted in the Junior High School of Massari, a regional school on the island of Rhodes. 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 while the second party (B2) had 22 students.

The first party constituted the control group, while the second, the experimental group. The students of both groups were taught "Unit 1-Digital World" of the school book for the subject of Informatics Technology 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 AR. Both the website and the application of AR were created for the research purposes with Weebly and Layar (basic version) tools, respectively, and their contents did not differ.

The AR application which was created recognized five different images. The first one, regarded general information about the Binary system, the next three regarded the codification of the text, the numbers and the images respectively and the last one, the process of decoding of the text, the numbers and the images. In order an image of those five to be recognized and the augmented information to be displayed on the screen of the tablet that a student was using, he/she had to enable both the wifi of the tablet and the Layar browser and then to focus with the camera of the tablet on the image. After the recognition the student could interact with the application by tapping with his/her finger the parts of the application in order to collect the necessary information.

The first research question referred to the investigation of the pedagogical value of the technology of AR 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, nine of which related to declarative knowledge and the remaining 12 related to procedural knowledge, of which four questions referred to Concepts and 8 to Rules.

The other 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, Ainley and Howard (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 (i.e., (a) How difficult have you found this activity? (b) How do you judge your skills during this activity?) of the 5 rank 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 and Marsh (1996) had a Cronbach's reliability indicator $a = 0.83$. It included a total of 36 questions of the 5 rank 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.

In order to answer the research questions of the present study, the research data were analysed 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.

Results

Research question 1

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, 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 2), which showed that between the groups there was a statistically important difference on a significance level $p < .05$, hence heterogeneity between the two groups, only as far as the variable Procedural knowledge-concepts [$U(42) = 104.00$, $p < .05$] 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.

Table 2. Group comparison: Results of the Mann Whitney test

	Control group		Experimental group				
	Mean	*SD*	Mean	*SD*	*U*	*df*	*p*
Declarative knowledge	3.90	2.511	4.82	1.763	165.50	20/22	0.165
Procedural knowledge-concepts	2.25	1.118	3.32	.945	104.00	20/22	0.002^*
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

Note. $^*p < .05$.

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.

Research question 2

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). 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 psychological state of Flow after the end of the second similar activity.

At the end of the first activity, most students of the control group (Figure 2A) 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, two seem to worry less than the others and were very close to the state of Flow, six 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, two 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, four appreciated that they were slightly bored and very close to pass to the state of Flow, two in a medium state of Boredom and the other two at a large state of it.

At the end of the second activity (Figure 2B), 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, two 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, six felt a low degree of boredom and very close to the state of Flow, while only one student experienced Boredom of a medium degree.

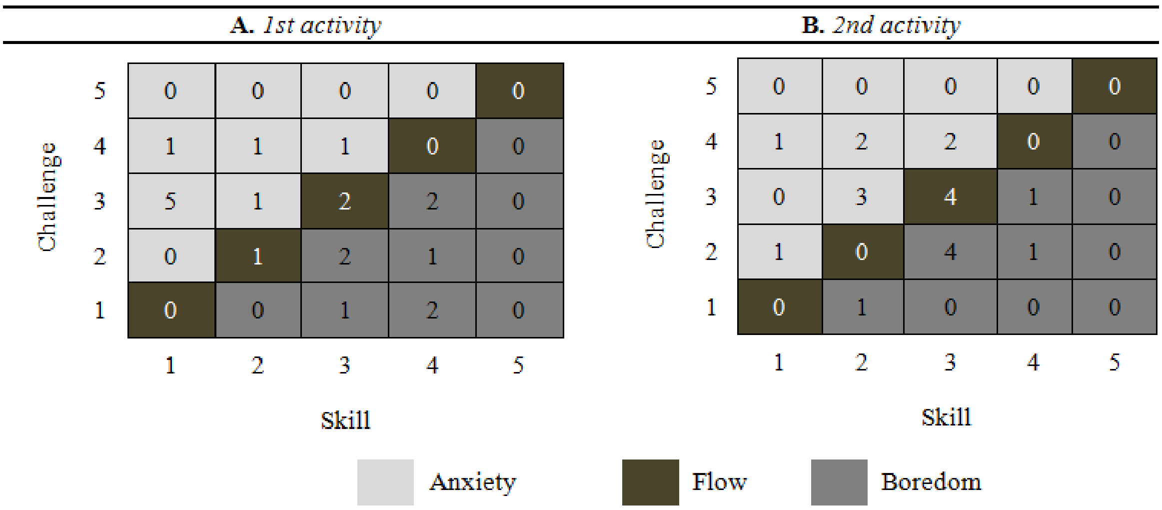

Figure 2. Control group: Estimation of its students' challenge – Skill

For the experimental group, at the end of the first activity (Figure 3A), 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, five worried to a lower extent than others and were very close to the state of Flow, two 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, three out of the four students who were, according to their estimation, in the state of Flow, experienced it at a medium degree and one of them at a low degree.

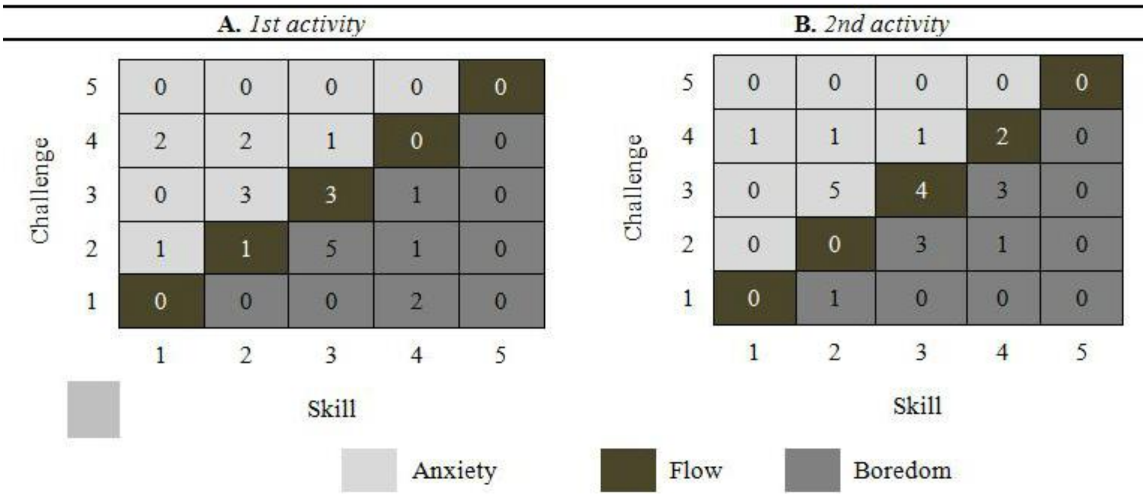

Figure 3. Experimental group: Estimation of its students' challenge – Skill

At the end of the second activity (Figure 3B), 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 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 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, one student fewer than before was at a state of medium Anxiety, while one was still in a state of high Anxiety. Finally, of the students who were in the state of Flow, four estimated that they were in a state of medium Flow and two others at a state of high Flow.

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).

Research question 3

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. 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 (Table 3).

Table 3. Factors relating to the appearance of Flow

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

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

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 ($p > .05$), 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: Balance of challenges-skills [$t(40) = -2.226$, $p < .05$], Clear goals [$t(40) = -2.330$, $p < .05$], Unambiguous feedback [$t(40) = -2.361$, $p < .05$], Transformation of time [$t(40) = -2.071$, $p < .05$] and Autotelic experience [$t(40) = -2.218$, $p < .05$].

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).

Discussion

Research question 1

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

Research question 2

At the end of the first activity during which the control group students used their digital application 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 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 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 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.

Research question 3

The analysis of the final Flow questionnaire showed a statistically significant difference between the two groups only in five out of nine factors relating to the psychological state of Flow. The averages of those five factors in which the two groups showed a statistically significant difference, were all greater for the experimental group. Moreover, Cohen's (1988) indicator d showed that the difference between the two groups was great.

Therefore, we can conclude that the implementation of AR 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.

Conclusions

The results enlighten two different potentials of AR, 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.

A possible explanation of these results is that the augmented technology engenders impression and interest to students, which has as a result to motivate them more, to participate more actively and with more enthusiasm in course activities, to be more concentrated and comprehend better anything they are taught.

These results are consistent with the results of other relevant studies (Ahn and Choi, 2015; Cai et al., 2012; Cai et al., 2014; Chen et al., 2013; Dünser et al., 2012; Fleck and Simon, 2013; Ibáñez et al., 2014; Juan et al., 2010; Kamarainen et al., 2013; Lin et al., 2013; Liu and Chu, 2010; Nischelwitzer et al., 2007; Pasaréti et al., 2011; Salvador-Herranz, et al., 2013; Seo et al., 2006; Shelton and Hedley, 2002; Sin and Zaman, 2010; Tarng et al., 2015; Wijers et al., 2010). Although they cannot be used in general, it cannot be refused that they constitute clues of the pedagogical values of AR. Future research, which will surpass the present research restrictions (e.g., the small sample and duration), could certainly prove at a greater extent that these clues are, finally, valid.

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