Evaluation of an Augmented Reality Multiplayer Learning Game

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Abstract. Augmented Reality Game-Based Learning (ARGBL) has been proposed as the combination of AR and GBL. Studies show that students increase their motivation in learning when they play ARGBL games. Moreover, ARGBL benefits learning processes by allowing social interaction with digital devices within a multiplayer environment. In order to assess the effects of combining ARGBL and a multiplayer approach, an ARGBL multiplayer video game was built guided by a co-creation method. This paper shows the results in terms of learning after using the ARGBL multiplayer video game as part of a classroom activity.

Keywords: Augmented reality · Multiplayer · Game-Based Learning
Co-creation

1 Introduction

Augmented Reality (AR), defined by Azuma [1], is a combination of virtual and real objects that coexist in the same space. In the last decade, studies have shown that AR provides students with greater motivation for learning during classroom activities [2]. Currently there are numerous applications [3–5] that integrate Augmented Reality which are built specifically for the educational environment. Game-Based Learning allows students to learn by new and playful means through video games created for this purpose. Many of the game experiences found in the state of the art [6–8] include AR for learning; nonetheless, they fail to effectively take advantage of the social interaction that Augmented Reality provides [9].

Section 3 describes the video game developed under the Co-CreARGBL method. Section 4 describes the evaluation and analysis process carried out in this study. Finally, Sect. 5 outlines the conclusions and future work.

2 Related Work

The video game showed in this study, named "TerraExplora", was built in context of the SmartSchool project (a project of the University of Cauca, Colombia) following the method Co-CreARGBL [10]. The game aimed to take advantage of AR with social interaction benefitting teaching and learning processes.

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The design and development process of "TerraExplora" was described deeply in [10]. Also, that study showed the lessons learned during the process. This paper describes the evaluation and analysis of "TerraExplora" which was conducted in a naturalistic environment setting in a real classroom during a Geography lecture in a rural school in the Colombia's southwest.

3 The Game

"TerraExplora" is an educational video game built using a co-creation method [8] which integrates AR and social interaction. The AR role was the visualization of graphic game elements over a marker-based map of Colombia (Colombian regions, position mark, characters, Colombian resources and climatic events). This video game aims to support learning activities about the Departments (regions) of Colombia and their economic resources, which are the main learning objectives set by primary school teachers. Thanks to the co-creation integrated during each stage of the development process, "TerraExplora" was built and improved considering the input of the teachers trying to fulfill their expectations related to learning and motivation. The game storyline is presented as a competition in which aliens from different planets come to earth looking to know about the Colombian resources. The video game uses marker-based AR which makes the students focusing onto the map as a learning object. The device running "TerraExplora" should be equipped with a webcam with enough resolution to perform marker detection and the Android Operative System.

During the game session, two players face each other to achieve the main objective of the game: fulfill missions. Missions consist of finding natural resources produced in different Departments (regions) of Colombia. Each player has the ability to move through the departments of Colombia, explore them and collect the resources found. These actions can be performed through buttons on a main interface (Fig. 1A). Likewise, these actions have an energy cost and the game is played turn by turn. Players will be affected by several obstacles, such as the opponent player's decisions. For example, players may use cards which can be used to benefit their own game or affect their opponent.

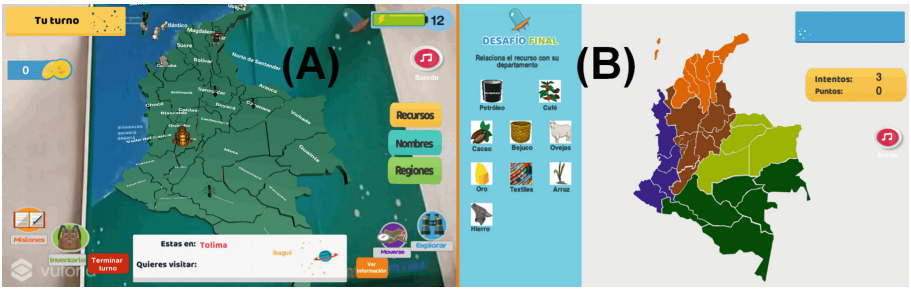

Fig. 1. (A). Main interface of the game. (B). Final challenge interface.

Lastly, a final challenge begins when the missions have been completed. This challenge consists in placing the resources of the missions, with their respective Department. The winner will be the one with the highest total score. Figure 1(B) shows the interface of the final challenge.

For more information, we recommend reviewing the paper "Developing an Augmented Reality Multiplayer Learning Game: Lessons Learned" [10], which deeply describe the design and development process of "TerraExplora".

4 Evaluation

In this section we present the results of the evaluation process conducted on the use of ARGBL and the multiplayer approach through the analysis of "TerraExplora" in a real educational environment. An evaluation based on mixed methods [11] was carried out. The game was deployed in Samsung Galaxy Note 10.1 tablets, with 4.1 Jelly Bean Android Operating System, 3 GB of RAM. In this section we show the problem statement, research design, sampling, data collection and analysis of the results.

4.1 Problem Statement

This stage begins with the definition of the evaluation question. The question that was raised for this project was the following:

Did the students benefit from to the use of ARGBL multiplayer videogames as "TerraExplora"?

4.2 Research Design

The methodology of Mixed Methods [11] provides a number of research designs depending on the characteristics of the research work. That is why the chosen research design in this project was the Concurrent Triangulation Design (DITRIAC) [11], due to the evaluation's aim to corroborate results and carry out a cross-validation between quantitative and qualitative data. On the one hand quantitative approach used an experimental design with the aim of comparing the results of two student groups. On the other hand, the qualitative approach used a case study with the purpose of determining the effect of the video game in terms of learning outcomes.

4.3 Sampling

The sample for this project consisted of 31 sixth grade students from the rural town of "La Cabaña", Department of Cauca, Colombia aged 11 years old on average and a standard deviation of 1.4. A process of simple random probability sampling was carried out, which involved taking the population and divide it into two groups (experimental and control) by selecting their members at random through a table of random numbers without considering any preference of the students.

4.4 Data Collection

To find how the game impacted the learning process, students in the experimental group were asked to interact with the video game during the class. In turn students in the control group took a class activity as they do in their normal school days. The experiment was divided in three stages: (i) test of learning styles, (ii) class activity or gaming activity and (iv) interviews. For the quantitative approach, information was obtained by the participants through questionnaires. The qualitative approach used observations, interviews, audio recordings and photographs. Table 1 shows different activities addressed on the class activities and game activity. Note that the main difference is on activity Book Reading and VideoGame.

Table 1. Summary of stages during the class activity

Activities	Class Activity	Game Activity
Didactic activity	✓	✓
Map	✓	✓
Video	✓	✓
Book reading	✓	–
VideoGame	–	✓
Conclusions and statement	✓	✓

(i) **Test of learning styles**

Based on the study carried out by Chen [12], competition mechanisms are related to the skill of students. The study concluded that the design of competitive learning activities can be improved by considering the preferences of students and their abilities to achieve a more efficient learning process. For this reason, in this project, a test of learning styles was used with the aim of analyzing how the preferences of the students influenced their learning.

We used a test adapted from the "CAPSOL Style Of Learning Assessment" [13], with the objective of determining the learning styles from the students profile ranging low to high preference. In this case we chose the learning styles related to the influential skills in the project, which are: visual, auditory, bodily-kinesthetic, individual, group and written expression.

The test consists of 18 questions whose answers have a numerical value (1–4). Once the test is completed, the respective analysis of the answers is carried out to determine the student's preference for learning styles.

(ii) **Class activity**

The class activity was solely used with the control group. The teacher guided a class carefully observing that the educational content was the same as the content integrated in "TerraExplora". The teacher began with a didactic activity which motivated the students to participate in the class considering their previous knowledge about the topic of interest: Departments of Colombia. The teacher subsequently used a video

projector to show the map of Colombia and indicate its regions, as show in Fig. 2. Also, the teacher showed a video explaining the regions of Colombia and its characteristics. At the end of the video the teacher gave the information related to Colombian resources with a document that students transcribed to their notebooks.

Fig. 2. Teacher imparting the class activity to the control group.

A questionnaire designed by the teacher was conducted to assess students' learning, which had questions related to the educational content presented during the class activity.

(iii) **Gaming activity**

The gaming activity was conducted with the experimental group, the teacher used an instructional activity to guide this session, which was designed to introduce the topics of the educational content and explain the game mechanics. During this activity, the teacher carried out the same traditional didactic activity as well as the presentation of the map of Colombia and the same video explaining the regions of Colombia and their characteristics.

After the video was played, the gaming session began with the support of the teacher, as shown in Fig. 3. The gaming session lasted approximately 25 to 30 min.

During the gaming activity, information was gathered through observations which focused on identifying how multiplayer mechanics and AR cause an increase in student interest and motivation, and consequently better learning. The observation was based on the analysis key factors such as participation, mood, respond timing and amount of accurate answers. Also, it was observed the duration of each turn, the need for help from students and the errors presented in the video game. Once the game activity was

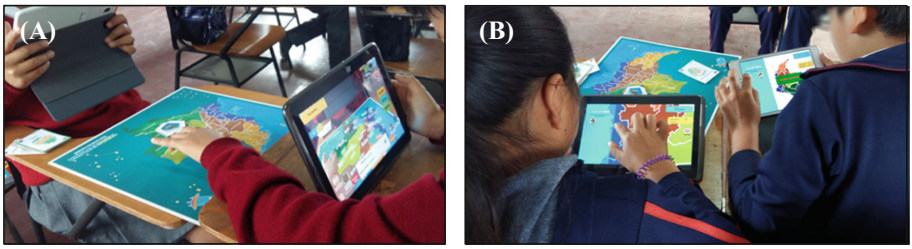

Fig. 3. (A) Gaming activity. (B) Final challenge.

completed, students in the experimental group took a questionnaire to evaluate their learning. This questionnaire is the same one used with the control group.

(iv) **Interviews**

After the class and gaming activity, students were randomly selected from each group to interview them. A third interview was conducted to the teachers in order to know their opinion/perception related to the integration of video games, such as "TerraExplora", in their classes and its influence on the teaching and learning processes.

4.5 Analysis of Results

Learning. The questionnaire was one of the instruments used in the assessment of learning, which was applied to both the control and experimental group. The results were entered into the software for statistical analysis STATA [14], which allowed to analyze the data and gather conclusions. We were not able to find statistical significance probably because of the small sample size. The questionnaire was composed of 7 questions, which were related to the learning objectives set by the teachers. Table 2 shows the results of the questions related to the learning objectives (regions, Departments and resources).

The first question of the questionnaire was related to the Departments of Colombia. The results showed that 75% of the students belonging to the experimental group got good answers against 63.2% of the students belonging to control group. This positive result is considered to be attributed to the gaming mechanics because, in the game, the students had to travel through Colombia and are able to virtually visit the departments.

The sixth question was related to the regions of Colombia. The results showed that 58.3% of the students belonging to experimental group were successful in the response, while no student in the control group was fully successful. It should be noted that no student from the experimental group missed the answer which suggests that they identified at least one region of Colombia. This positive result is considered to be attributed to AR and the gaming mechanics included in "TerraExplora" which allowed the students to visualize the regions of Colombia and foster their learning because the information is presented in a visual and entertaining way capturing their attention and avoiding boredom. The students who recognized the regions of Colombia got an

Table 2. Results of the analysis by group

Question	Group	Scale		
		Good	Regular	Wrong
1	Control	63.2%	36.6%	0%
	Experimental	75%	25%	0%
2	Control	26.3%	36.8%	36.8%
	Experimental	16.7%	16.7%	66.7%
3	Control	31.6%	36.8%	31.6%
	Experimental	50%	25%	25%
4	Control	57.9%	0%	42.1%
	Experimental	75%	0%	25%
5	Control	78.9%	0%	21.1%
	Experimental	91.7%	0%	8.3%
6	Control	0%	68.4%	31.6%
	Experimental	58.3%	41.7%	0%
7	Control	36.8%	21.1%	42.1%
	Experimental	83.3%	0%	16.7%

advantage over their opponent because the game has a set of "clues" which are always related to the regions of the country.

Question seven was related to the resources and its producing Department. The results showed that "TerraExplora" influenced a high number of students (83.3%) form the experimental group. These students were able to relate a resource with the corresponding producing Department. While in the control group most students (42.1%) responded erroneously, this could be related to the lack of motivation during the class. In support of the above, the observations during the game activity indicated that several students struggled to remember the Department where they knew that a specific resource was produced to fulfill a certain mission motivated by competition.

Generally, the result showed that the experimental group was characterized by having a greater number of good answers compared to the control group, as shown in Table 3, suggesting that elements included in "TerraExplora" (AR and social interaction) influenced those results.

Table 3. Overall results related to student learning.

Group	Good	Regular	Wrong
Control	42.1%	28.6%	29.3%
Experimental	64.3%	15.5%	20.2%

The results obtained in the questionnaire were analyzed in order to understand the differences between the control and experimental groups. As shown in Figs. 4(A) and (B).

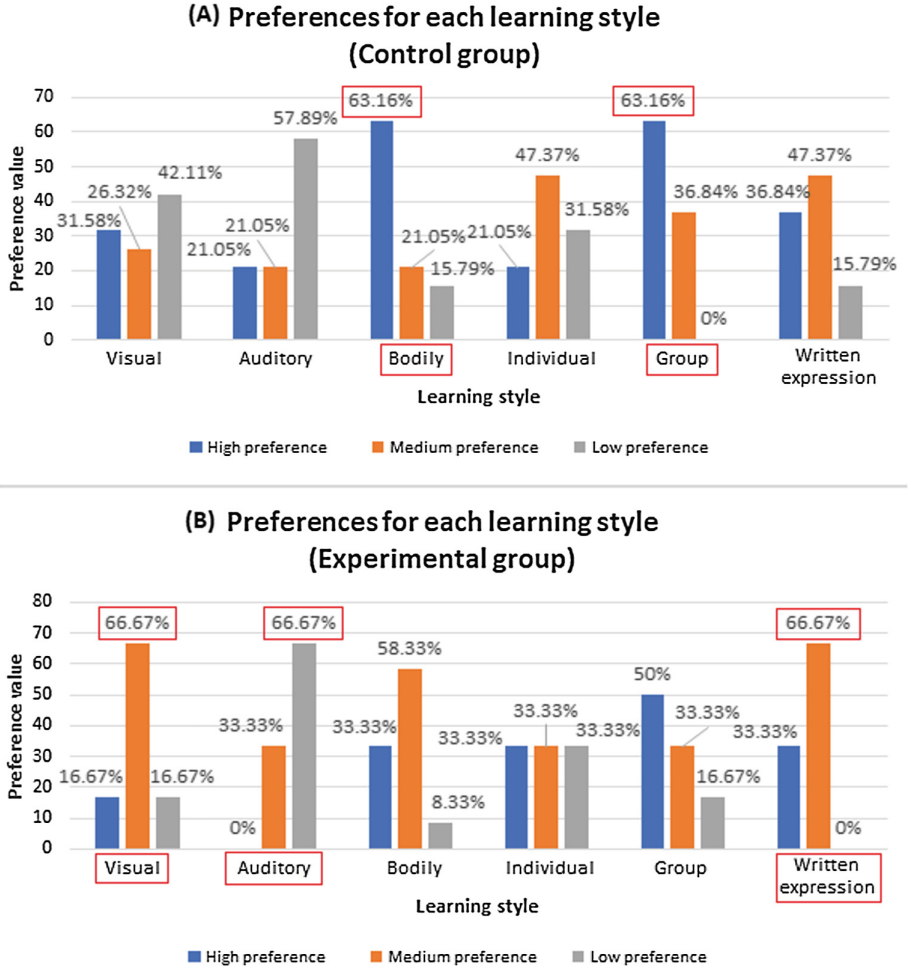

Fig. 4. Preferences for each learning style in control and experimental group

The analysis showed that most students belonging to the control group were inclined towards a bodily-kinesthetic and group learning styles. Regarding the experimental group, the students were inclined towards visual, bodily-kinesthetic, group and written expression learning styles. This suggests that most of the failures in the control group may be due to the fact that a traditional class does not promote their maximum performance because their preferences are inclined to group learning and socialization which are not present in a traditional teacher-to-students lecture. In contrast, the learning styles of the experimental group are more aligned with the game characteristics. The gaming mechanics set in "TerraExplora" are focused on promoting learning by association based on the benefits that provides the AR and social interaction in order to obtain a better student learning. It is considered that students belonging to the control group would obtain better results if they had use "TerraExplora" as the experimental

group did, because the physical interaction with the gaming elements helps them remembering and processing information, and the multiplayer mechanics included in the game fits the student's learning styles.

5 Conclusions and Future Work

In this paper, the evaluation of a multiplayer AR Game-Based Learning game has been shown. Regarding the influence of the video game in the learning process, students gave a greater value to the educational content they have to accomplish a game mission. The teaching strategy of Learning by Association played an important role to fulfill the missions in the game. This causes the learning to take place indirectly motivated by the use of components such as AR and social interaction.

As for the influence of learning styles in the results obtained in the questionnaire, it is considered that students belonging to the experimental group obtained a good performance in learning with a 64.3%, compared with the control group with a 42.1%. This may be because most students showed an inclination to a learning style that benefits from the social interaction included in "TerraExplora". On the other hand, it is considered that the students belonging to control group would obtain better results if they will experience with "TerraExplora", because the interaction with the physical elements would help them to remember and process information. Also, the multiplayer mechanics included in the video game benefit this because of the students' high preference for group and bodily-kinesthetic learning styles.

By observing the results, it is concluded that competition integrated in "TerraExplora" allowed students to learn the educational content in a fun way as they looked to get advantage over their opponent, however some students preferred to play in a collaborative way.

Finally, teachers expressed that "TerraExplora" is a support tool to the classes because the students perform the practical part reinforcing the knowledge acquired in class. Teachers emphasized that the use of "TerraExplora" supports learning by association, provides a fun experience that captures the attention of children, increases the motivation and manages an interesting game mechanics for students.

As future work of this research, we propose to include a collaborative experience in the video game, i.e. the possibility of choosing between collaborative or competitive game because some of the students showed preference toward collaboration in their quest to fulfill the missions. Also, the game may be improved to a continuous pace (not turn-based) in order to minimize the gaming time and possible boredom.

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