Developing an Augmented Reality Application in the Framework of Architecture Degree

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ABSTRACT

We describe the development, implementation and evaluation of an augmented reality (AR) application for mobile devices. It has been particularly intended to be used in educational environments. This application has been called U-AR, and is based on optical image recognition from real environment images, to act as markers. Once they are associated with virtual information (3D architectural models, in our case), the application allows viewing, scaling, and positioning it interactively and in real time. Some improvements have been implemented compared to existing commercial ones, such as the ability to view different models consecutively with a single marker and the possibility to move these computer-generated objects around the scene.

The main objective was to assess the feasibility of using AR on mobile devices in educational environments. In addition we evaluated academic performance improvement using this technology. Validation was done through a case of study. It was carried out by Architecture students of the ETSAB, (UPC-Barcelona-Tech) outdoor. Results obtained by student's architectural proposals, after using this technology, and by questionnaires responses, demonstrated the application suitability as a new tool to be used in learning processes.

Categories and Subject Descriptors

H.5.1. [Multimedia Information Systems]: Artificial, augmented, and virtual realities; Evaluation/methodology. K.3.1. [Computer Uses in Education]: Collaborative learning, Distance learning.

General Terms

Design, Experimentation, Human Factors.

Keywords

Augmented reality, mobile devices, learning processes.

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1. INTRODUCTION

Specific application development for educational purposes, using augmented reality technology (AR), is an educational research project that arises from the Interest Group for Logistics and Education in Architecture, GILDA. It is an interuniversity group centered in the architectural field, assigned to the Project RIMA, (Research and Innovation in learning methodologies) from ICE, (Institute of Education Sciences at the Polytechnic University of Catalonia, UPC), which is specialized in the field of education technological disciplines.

This project aims to respond to the growing need of new technologies incorporation in learning processes. They are alternative to traditional ones, and provide new tools to improve motivation and student academic performance, enabling a greater acquisition of skills by the student and, as we'll see, reverting in better academic performance. To evaluate its feasibility, a case study was assessed. It was conducted on a Computer Applications (APF) course at the UPC.

Which aims to complete student's training and technical resources to design, analyze, develop and present architectural projects under the overall theme of the course of Housing and Urban environment. This is embodied in two main directions: the utilization of digital image processing and the use of agile tools to create 3D virtual scenes. Results demonstrated that better results are achieved when students use AR technologies on mobile devices (running on Android and iOS software).

2. THEORETICAL, PEDAGOGICAL AND DIDACTIC FOUNDATIONS

Learning, by definition, is the process by which memories are built, while memory is the result of learning [1]. In recent years, the desire of learning process improvement has led a transition to a technologically enhanced classroom, where computers, media players, interactive whiteboards, internet, web 2.0 tools, and games have been incorporated. The emergence of the World Wide Web revolutionized how to access, share and encode information, playing a key role in learning. E-mail and mobile phones have transformed the way we communicate, and the list of technologies that can be useful in learning processes is huge and constantly growing, not being simple to define which may be suitable for learning and which are not [2].

More recently, immersive technologies in virtual and augmented reality worlds have been used. Its usefulness has been assessed by

By designing an AR mobile tool we will give students control ownership of their learning process. Besides that, experience will be a challenge when student confronted with it, in a new way. Then learning will be more effective. Finally, we can say that the AR implementation effort will not help, if student don't make a commitment effort to complete the exercise. As we see commitment

The process has been divided into two parts. On the one hand, there's a virtual-contents manager program that runs on student's desktop computers, and lets them to create and manage content channels. User can associate one or several models to one marker choosing initial visualization scale, and channel and 3d models name (fig.1). The programming language we decided to use is Java. One of the biggest advantages of Java is that it runs on a virtual machine, so that a Java application is independent of the operating system in which is executed. So it could be used on any computer, whether Mac, Windows or Linux.

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On the other hand we have the mobile device application, which recognize markers using the device camera, register them, and shows virtual information overlapped to the real scene. Application allows student to alternate easily its own generated content, and also to move and to scale in an intuitive and tactile interface.

Fig. 2.- Logo, installation and application on mobile device.

When students finished this process, a folder is generated. It contains an *.xml (Extensible Markup Language) file that has all channel generated structure, 3dmodels (*.obj and *.mtl) and texture files, organized in subfolders. This information is needed to be loaded on application in order to read channel information.

Fig. 3.- Sample Loading and Displaying generated channel.

Xml file is widely used to describe data structures and allows communication between different applications. In our case, the content manager creates an XML file and mobile application interprets the document to load and display correctly virtual model (Fig.4).

Fig.4.- XML document structure sample.

For rendering we use OpenGL (Open Graphics Library), as a standard specification defining a cross-language, multi-platform API (Application Programming Interface) widely used for writing applications and simulating physics.

Finally, in order to get a better integration of virtual models in the scene we were focused on occluders recognition and lighting

simulation. Because most of the times, the virtual model lacks realism and are not integrated sufficiently into the scene to be credible. This problem takes on special significance to visualize architectural proposals, because a non-integrated scene may seem unlikely and unattractive (Fig. 5).

To solve the problem of lighting conditions differences between real environment and virtual objects superimposed, student's generated models had to be single meshes, and they incorporated textured maps simulating lighting conditions from real environment. For occluders implementation we followed the concept of phantoms suggested by [19]. The main idea is to generate a model identical to real-world one, that produces an effect of occlusion on the virtual object.

Fig. 5. Sample images from the same 3dmodel, using occluders and lighting integration modeling techniques.

4. Case Study

In this case, we focused on the study of interventions in the urban landscape of Barcelona with ICT help. Following these premises, we worked on the Plaza Flassaders (Fig. 6), who recently completed the construction of the extension of the Picasso Museum in 2009.

Fig. 6. Case study location.

The working group is composed of 25 students divided into three groups: a control group, consisting of 8 users who do not have smartphones or AR technology is not supported (No_AR). They will follow the traditional course based on slides; and two experimental groups, which we call iOs (9 students) and Android (8 students) both will be involved in AR specific training. Android users will use the U-AR application and iphone users will use Armedia.

4.1 Research questions

In order to investigate the impact of two technologies implementation scenarios: S1 (based on slides) and S2 (based on augmented reality technology on mobile devices), on student academic performance. The research questions were:

1. Are there any differences in academic results depending on which of the two teaching scenarios proposed are used?
2. Is there any difference in student's degree of satisfaction and motivation depending on which of the two teaching scenarios proposed they used?

The study also included a quantitative analysis to determine usability of U-AR application. Some experiences have been done to evaluate Virtual Environments (VE) usability.

Stanney [20], used a multi-criteria assessment technique to design and evaluate Virtual environments. In our case we were based on ISO 9241-11 which provides usability guidelines [21];

- Effectiveness, defined as the user's ability to complete tasks during the course, in relation to the "accuracy and integrity" that it had been made.
- Efficiency, on the assigned resources, they asked questions related to the expenditure of time and effort for solving the proposed exercise.
- Satisfaction, understood as subjective reactions of users about the course.

4.2 Procedure

The whole course was performed in three phases. Augmented reality experience was conducted on the second one.

4.2.1 First Phase:

In summary, this phase involved the use of all digital architectural tools knowledge acquired by students throughout their training in previous courses to model existing environment, to select an artistic reference, and to generate a virtual scene incorporating their proposals. Students captured site information through digital photography and vectorial cartography.

Specialized applications as Photomatch, Ptlens, Sketchup were used to rectify images, in order to get basic dimensions and measurements from the environment. They chose an artistic reference, and modeled their proposals using AutoCAD, Rhino, or SketchUp. Student's models were incorporated to the virtual generated scene. They were required to define scale and location, and to render preliminary proposals.

Fig 7. Preliminary student's proposals.

4.2.2 Second Phase:

We called this: Visual analysis and adjustments "in site", of their sculpture and urban design proposals using both traditional processes and AR.

In this phase we defined experimental and control groups between the different students of the course. Students were asked about their availability to participate in the experiment. 8 students continue the ordinary course (NO_AR) and the other 17 are divided into two experimental groups. Android (8) and IOS group (9).

Once they visited the site, control group continued developing their proposals in traditional way. They used for that 3dsmax Sketchup, and other 3dmodeling tools. They made metric analysis of the scale, position and orientation of sculptural models proposed in order to adjust their proposals.

AR groups used U-AR, they generated their own content channels and were able to see their proposals "in site", overlapped to the real environment. They also were able to see different models with the same marker and to verify scale, size, and position comparing different proposals¹.

Fig 8. Sample images using U-AR application "in site".

4.2.3 Third phase: Final Project Presentation

In this last phase, both groups were required to reconsider their proposals. Reformulation of their project was done. Scale and dimensions of the sculpture, points of view and areas of impact were changed according with "in site" information obtained using traditional an AR scenarios.

Fig 9. Final presentation results, once student's proposals were reformulated.

5. EVALUATION

To evaluate this exercise all students made an architectural proposal in a conventional manner, as we said in point 4.2.1 (first phase). In this case, as mentioned, they designed a sculpture, furniture, or some kind of intervention for a real space choosing an artistic reference. After visiting the site, control group and experimental groups (using AR) reformulate their proposals. Pre and post proposals were evaluated using the following criteria:

- 30%: Quality of the model presented (textures, light immersion, no. Of polygons, and no. Of textures used).
- 40%: Integration into the site (scale, position, viability of the proposal...)
- 30%: Subjective opinion about proposal quality (through other users rating).

Means (from 1to 10) and Std. Deviation of the three groups in the first phase, previous AR training ("PRE"), were very similar:

¹ A video can be found at: http://youtu.be/2sJnSv_sgPs

Table 1. Previous results of AR training

grup_2	N	Mean	Std. Deviation
Android	8	6.1200	1.7154
No_AR	8	6.1662	2.2129
ios	9	6.2978	2.0043
Total	25	6.1988	1.9057

To verify that they are equal groups, we used analysis of variance (ANOVA). The null hypothesis (h0) is that the scores match from different groups (no differences).

The analysis of qualifications "PRE" between the three groups (experimental groups ios and Android, and No_AR, control group), shows that there's not significant differences between groups regarding their qualifications before to conduct training ($F_{2, 22} = 0.018$, $p = 0.982$).

Table 2. Anova analysis Between groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.146	2	0.073	0.01	0.982
Within Groups	87.014	22	3.955		
Total	87.160	24			

Upon completion of the proposed course (third phase) students delivered their proposals to be scored as described above. Results showed that experimental groups, which participated in the RA experience, increased their scores.

Table 3. Result of qualifications and gain obtained per group, with PRE and POST presentations:

	grup	nota_pre	nota_post	Gain
Android	Mean	6.1200	7.5112	1.3912
	Std. Deviation	1.7154	0.9918	1.4559
No_AR	Mean	6.1662	6.0762	-0.0900
	Std. Deviation	2.2128	2.0716	3.6307
ios	Mean	6.2977	7.8611	1.5633
	Std. Deviation	2.0043	1.0982	2.0080
Total	Mean	6.1988	7.1780	0.9792
	Std. Deviation	1.9056	1.5992	2.5245

To verify that the observed increase, is statistically significant, it is considered as null hypothesis (Ho), the fact that the mean scores do not vary at the end of the proposed training, that is, after the AR training the experimental groups (ios and Android) and the control group did not increase their results differently.

The obtained values indicate that experimental groups (ios and Android) have significant differences between mean values ($\text{sig} < 0.05$) before and after the course, thus the null hypothesis (Ho) is rejected, and we can affirm that these groups had improved results.

Table 4. Results comparing values obtained in pre-and post-test with the Student t test for paired series.

		Paired Differences					
		Mean	95%Conf. Int. dif		t	df	Sig. (2-
			Lower	Upper			
Pair 1	PRE--POST_NOAR	0.09	-2.94	3.12	0.07	7	0.946
Pair 2	PRE- POST_ios	-1.56	-3.11	-0.19	-2.34	8	0.048
Pair 3	PRE-POST_And	-1.39	-2.60	-0.17	-2.70	7	0.031

However, in the control group, which carried out the activity through conventional training, table shows no significant differences between the mean values i PRE POST, therefore no improvement in the scores is achieved. It is accepted in this case the null hypothesis null (Ho).

5.1 U-AR application usability

As we mentioned before, we evaluated user's assessment using questionnaires based on ISO 9241-11, which provides usability guidelines (effectiveness, efficiency and satisfaction). Responses average were very similar, ranged from 3.59 to 3.73, out of 5.

Fig. 10. Final average rating

The overall assessment of the courses was rated 4.18 points out of 5. This gives an idea of the degree of satisfaction achieved.

In a correlation analysis between the course global opinion and the other variables, a high correlation (0.68) was detected with: the representativeness of the exercise. So this variable seems crucial to the success of this kind of teaching experience. Global opinion was not so correlated with the fact of being able to solve the exercises independently. The strongest correlation (0.89), however, was with obtained gain variable. Students with little gain between pre and post qualifications rated worse than student from experimental groups (with higher gains). On other hand, variables related to prior knowledge of technology and to the use of different software and operating systems did not correlate significantly with the course global opinion.

6. Conclusions

In relation to U-AR, and the use of new technology on learning processes with mobile devices, some advantages have been found over other commercial applications such as: the possibility to

display several 3Dmodels without changing the marker (which allows to compare different architectural proposals and hypotheses); and the ability to move objects in the scene. These benefits were crucial to the viability of the study outdoors, helping to minimize the problem of stability in the scene of that kind of AR systems, based on optical recognition.

Related to research questions, we found significant differences in academic results depending on which of the two teaching scenarios were used. (Research question 1). And results show significant differences in student's satisfaction and motivation depending on which of the two teaching scenarios were proposed (research question 2). However, similar experiences with larger groups must be repeated to compare these results.

Results suggest that combination of an attractive technology and the user-machine interaction that involves the AR, make students feel more motivated. They created dynamic photomontage and architectural proposals, for visual evaluation in a real environment, getting involved on their own knowledge construction, and consequently, development and evolution of graphic competences and space skills were increased in a shorter learning periods, and their academic performance was significantly improved.

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