Construction Processes Using Mobile Augmented Reality: A Study Case in Building Engineering Degree

Albert Sánchez Riera[1], Ernesrt Redondo[2], David Fonseca[3], and Isidro Navarro[2]

[1] EPSEB, Universitat Politècnica de Catalunya Barcelona Tech,
Avd. Gregorio Marañon 44, 08028, Barcelona, Spain
albert.sanchez.riera@upc.edu
[2] ETSAB, Universitat Politècnica de Catalunya Barcelona Tech,
Avda. Diagonal, 649, 08028, Barcelona, Spain
{ernesto.redondo,isidro.navarro}@upc.edu
[3]Arquitectura La Salle, Universitat Ramon Llull,
C/. Quatre Camins 2. 08031, Barcelona, Spain
fonsi@salle.url.edu

Abstract. In this paper we describe the implementation and evaluation of an augmented reality (AR) application, on mobile devices. It's based on optical images recognition from real environment, and it has been particularly intended to be used in educational environments. Some improvements have been implemented compared to existing commercial ones, such as the ability to compare and move different models consecutively with a single marker. The 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 where students were able to see a virtual construction process overlapped to real environments. It was carried out by Building Engineering students of the EPSEB (UPC-Barcelona-Tech). Results obtained by student's PRE and POST test, and by questionnaires responses, demonstrated the application suitability as a new tool to be used in learning processes.

Keywords: Augmented Reality, Construction processes, educational research, Human-Computer Interaction, mobile learning.

1 Introduction

Beyond the superimposition of virtual objects on real environments, AR features are usable in a wide range of applications in the field of engineering and construction, offering potential advantages in all stages of a construction process [1], from conceptual design, to building systems management and maintenance throughout its servicetime. Virtual models, once overlapped to real space, can provide additional information for a better understanding of the building, thus contributing to a greater efficiency in construction processes, rehabilitation or building maintenance.

In this case we focused on the implementation of new digital technologies in building construction and maintenance learning processes, within the course of

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Technical Projects II in the School of Building Construction (EPSEB) (UPC-Barcelona-Tech). In general, a synergy between traditional methodologies and AR new technology was proposed, to visually build up hybrid (virtual and real) construction processes. In this case, we tested the process of opening a void in a load-bearing wall. The Study case was held with 146 students divided in a control and an experimental group. Students blend the physical and virtual worlds, so that, real objects (markers) were used to interact with three-dimensional digital content and to increase shared understanding. We used light maps in textures to incorporate lighting conditions from surroundings, and introduced *occluders* for a better integration of the scene in its real location.[2].

The objective was twofold. First, to evaluate the feasibility of using AR technology on mobile devices, in educational environments, and secondly, to assess the student's academic performance improvement. To do that we compared two scenarios: S1 (based on slides and traditional methodologies) and S2 (based on augmented reality technology on mobile devices). The research questions were:

1. What's the student's degree of satisfaction and motivation using this new methodology?
2. Are there any differences in academic results depending on which of the two teaching scenarios proposed are used?

On the first case, some experiences have been done to evaluate Virtual Environments (VE) usability [3, 4]. In our case we were based on ISO 9241-11 which provides usability guidelines: 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.

On the second case, to evaluate academic performance improvement, we compared final results between control and experimental groups. Results obtained by student's PRE and POST test, and by questionnaires responses, demonstrated that combining an attractive technology, and by the user-machine interaction that involves the AR, students feel more motivated, their graphic competences and space skills are increased in shorter learning periods, and their academic performance is highly improved. The experiment can be seen in: http://youtu.be/8UEs8T6vSPI

2 Theoretical, Pedagogical and Didactic Foundations

Learning, by definition, is the process by which memories are built, while memory is the result of learning [5]. 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. 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 [6].

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

[7], [8], [9], [10], [11], [12], [13], [14]. These experiences, that used augmented reality in the area of entertainment and education, demonstrated the great potential of this technology. But in education, it may still be considered as a new tool, and further investigation is necessary, paying special attention to user experience and learning processes [15]. Because, despite the ongoing effort to technology implementation, there is also the need to immerse students in new learning environments, these in turn, continuously changing [16]. Teachers, meanwhile, face the challenge of constantly be updated to provide new forms of teaching, focusing on the acquisition of generic skills in which students must construct their own knowledge through constructivism, proposed by Piaget [17] and meaningful learning proposed by Ausubel [18]. In contrast, we can frequently find situations in the classroom where educational contents are simply exposed and presented without any interaction by the student, that receive passively new concepts and content to be memorized, getting bored easily and consequently minimizing their learning. Student motivation is essential to reverse this situation [14].

There is where AR can helps to improve the learning process performance [14], [19]. AR and virtual reality (VR) share some common features such as immersion, navigation and interaction [20]. However, AR has two main advantages over VR: Allow collaborative experiences in a real scene. So users can work with computer-generated objects as if they were real objects in a real environment, in real time; and Tangible Interaction. By superimposing virtual objects in a real environment through markers, user can modify and manipulate the scale, position and location of virtual objects. So we could say that AR technology, by providing new interaction possibilities, promote active student participation in its own knowledge construction. Thus, it becomes a suitable medium to be used in schools [21].

In our field of study, construction processes, AR technology features would allow to show a "completed" reality, superimposed to the real. It could create an impossible image of what does not exist, as a result of the analysis of existing building systems (structural, facilities, envelope ...). It would facilitate rehabilitation and maintenance tasks, as well as systems verification, update and interactivity in the same place, and in real time, promoting more efficient management and control processes of building constructive elements. During the case of Study, described below, we implemented AR technology applying these principles to future construction engineers, with the purpose of increasing their learning, getting greater efficiency performing these tasks, traditionally handcrafted and little technified.

3 Case of Study

Technical Projects II is a subject which is intended mainly to provide students with technical capacity enough to tackle construction and execution issues of a technical project. They acquire the ability to apply advanced tools needed to solve all problems involved in technical project management, as well as, the ability to write technical projects and construction works and to draft documents which are part of them. In summary, at the end of the whole course they should be able to analyze technically project performance and its translation to the execution of works, and get the capacity to integrate into a work team.

The course is divided in three blocks: Structural falsework, Building Facilities, and building envelope. As we said, we worked on the first one, focused on the process of opening a void in a load-bearing wall. At the end of this practice, the student should be able to: Identify different ways to implement this construction process; analyze the structure of a building and quantify their loads to replace a structural element; and calculate and design all the elements in a practical case.

3.1 Procedure

In order to evaluate usability of AR technology on mobile devices and to assess the student's academic performance improvement, the experience was performed in three stages. PRE-Test, Lectures, and POST-Test. The total number of students enrolled in the course was 183. At the end of this first block, after students evaluation, we excluded those students who had not performed any of the tasks required for assessment (PRE-Test, practical exercises, or Final test), so the final number of students who participated in the experiment was 146. They were divided into 4 groups. 3 control groups (1M, 2M, and 3T) and 1 experimental group (4T). Control groups followed the traditional course based on slides (Scenario 1), and the experimental group was involved in AR specific training (Scenario 2). They used a self-developed application (U-AR) under Android platform.

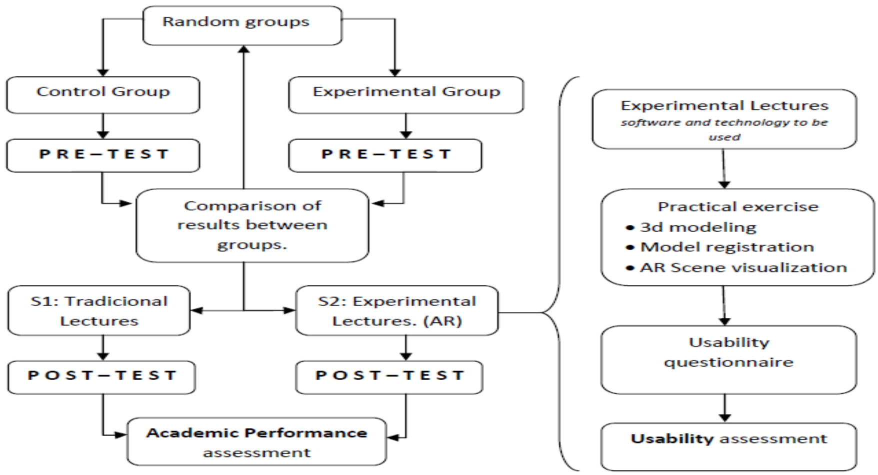

Fig. 1. General Scheme of the methodological process

So, the first day of the course, all students answered a test (PRE) that was used to determine prior knowledge on the subject. It is based on previous years used tests. It was useful to verify that all students groups were similar before start the experience.

During three sessions, they all received a conventional class, based on lectures and practical exercises. Participants, divided into small working groups of 5 or 6 students, consulted and clarified doubts with the teacher. Students from 4T group (experimental) , however, received an additional lecture which taught the application operation, and how to manage distributed contents to be visualized through augmented reality. In addition, they got detailed instructions of the assay to be performed through their devices, and 3d virtual construction process to be visualized was explained and distributed.

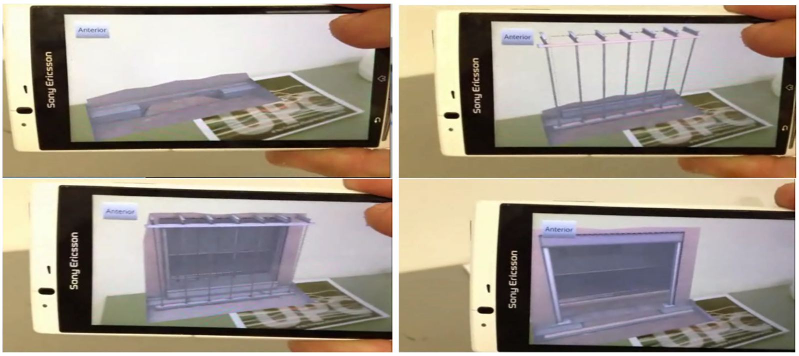

Fig. 2. Images of the construction process to open a void in a load-bearing wall, using AR on mobile devices

In short, they should select a place in the school, and through their mobile devices, they should watch "in situ" the five steps we had divided the construction process: Reinforcement of existing foundations; falsework for shoring and temporary support loads; Demolition of the brick wall; placement of columns and beam to support final loads; and falsework removal and final state.

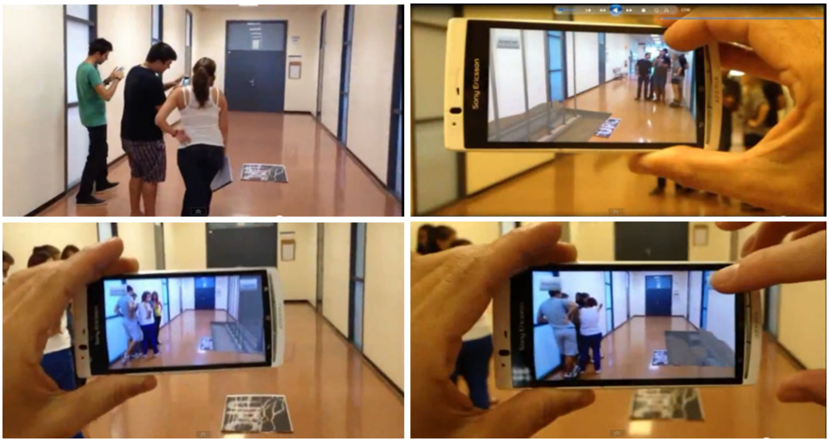

Fig. 3. Images of experimental group students viewing a construction process using their mobile devices

Once they finished, experimental group students were also required to answer a usability questionnaire in order to get their opinion related to efficiency, effectiveness and satisfaction opinion about the experience.

Academic performance was assessed comparing results between Control and experimental Groups.

3.2 Usability Assessment

As we mentioned before, we evaluated user's assessment using questionnaires based on ISO 9241-11. Responses average related to effectiveness, efficiency and satisfaction were very similar, ranged from 3.31 to 3.46, out of 5.

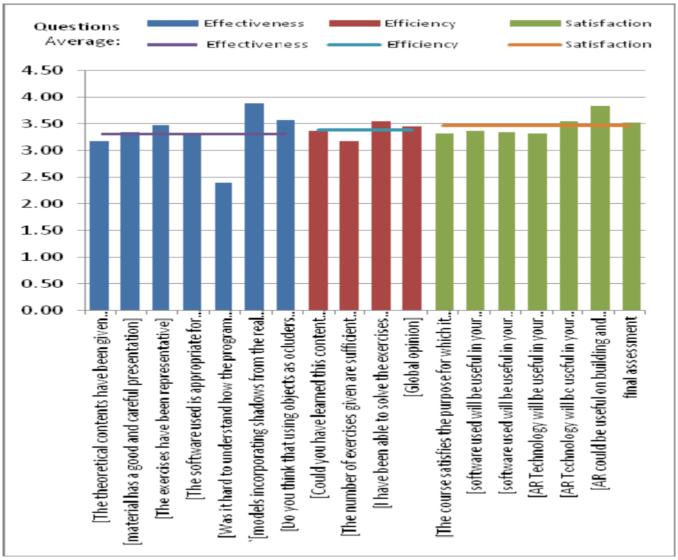

Fig. 4. Student's responses of Usability questionnaire

The overall assessment of the courses was rated 3.51 points out of 5. Similar results were found also in previous studies [22] which confirms the feasibility of using this technology in educational environments.

In a correlation analysis between the course final assessment and the other variables, a high correlation (0.71) was detected with: the representativeness of the exercise and material presentation (0.73). So these variables seem crucial to the success of this kind of teaching experience. On other hand, variables related with the fact of being able to solve the exercises independently (0.09) did not correlate significantly with the course final assessment. No correlations were found between PRE and POST scores, nor with the gain.

Correlations		**PRE_TEST**	**POST_TEST**	**GAIN**	**final**
final	Pearson Correlation	-0.00064	-0.24794	-0.16382	1
assessment	Sig. (2-tailed)	0.99743	0.20333	0.40485	

3.3 Results and Discussion

PRE-TEST mean scores were very similar in all groups. The group that has the highest score was the 2M control group. Experimental group (4T) hovers slightly under the global average of the four groups (Table 1).

Table 1. PRE-Test Results

GROUP	SUBGROUP	N	Mean	Std. Deviation
Control	1M	26	2,52	1,32
	2M	44	3,14	1,45
	3T	38	2,66	1,71
	Total	**108**	**2,82**	**1,53**
Experimental	4T	38	2,62	1,74
	Total	**38**	**2,62**	**1,74**
Total		**146**	**2,77**	**1,58**

To estimate what is the probability that groups are significantly similar, we used Student's t-distribution [23] setting to null hypothesis (H_0) that there are no differences in scores between groups. Statistical significance (2-tailed) was 0.502, higher to 0.05, which means that there is very little chance that the groups are different in their skills, previous training, and therefore the experimental group, who will practice with mobile devices is very similar to the other groups. Null hypothesis is accepted (no significant differences between groups).

Table 2. Independent Samples Test

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
PRE_TEST	Equal variances assumed	,673	144	**,502**	-,06067	,29882

Once students training in this block is finished, they were scored using the following criteria:

- Task 1. 10%: practical exercises at the beginning of each session.
- Task 2. 30%: Theoretical Test.
- Task 3. 60%: Final presentation, which must provide constructive description and graphic of the entire construction process of felling.

The table 3 shows, for groups and subgroups, the results and the gain on the pre-to post course:

Table 3. Results and gain on the pre-to post course

SUBGROUP/GROUP		PRE_TEST	POST_TEST	Gain
1M	Mean (S.D.)	2,52 (1,32)	4,24 (1,13)	1,72 (-0,19)
	N	26	26	
2M	Mean (S.D.)	3,14 (1,45)	4,36 (1,02)	1,22 (-0,43)
	N	44	44	
3T	Mean (S.D.)	2,66 (1,71)	4,80 (0,95)	2,14 (-0,76)
	N	38	38	
Control	**Mean (S.D.)**	**2,82 (1,53)**	**4,49 (1,04)**	**1,67 (-0,49)**
	N	**108**	**108**	
4T	Mean (S.D.)	2,62 (1,74)	4,81 (0,86)	2,19 (-0,88)
	N	38	38	
Experimental	**Mean**	**2,62 (1,74)**	**4,81 (0,86)**	**2,19 (-0,88)**
	N	**38**	**38**	
Total	**Mean (S.D.)**	**2,77 (1,58)**	**4,57 (1,01)**	**1,80 (-0,57)**
	N	**146**	**146**	**0**

The results show that the experimental group (4T) gets better results after training, 0.24 points above the mean of the control groups. Higher gain in relation to the average of the control groups is achieved by experimental group.

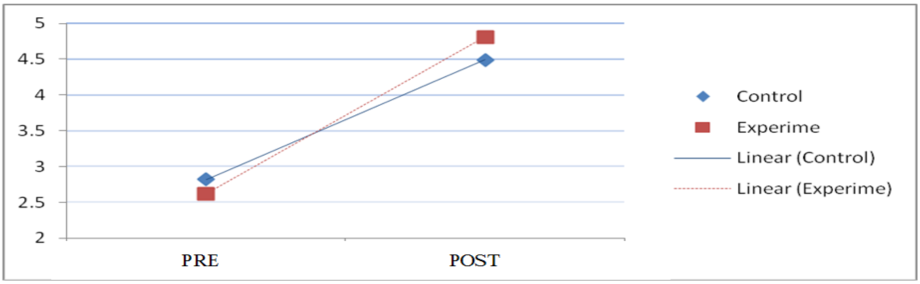

Fig. 5. PRE and POST results evolution

4 Conclusions

In relation to the first question referred as a research question, we may say that outcomes obtained from questionnaires were very positive. The overall assessments about efficiency, effectiveness and satisfaction were all around 3.5 out to 5. So we can affirm that student's felt satisfied and motivated using this new methodology.

In addition, exercises representativeness and material presentation seem to be crucial to the success of this kind of teaching experiences. On other hand, variables related with the fact of being able to solve the exercises independently did not correlate significantly with the course final assessment. There were also no correlations between PRE and POST scores and Final assessment, nor with the gain achieved.

In relation to the second research question, results showed how AR technology, through student's motivation, can help to improve their academic performance. Experimental group achieved best gain and performance results. We tested these strategies in previous case studies [24], and in all of them students felt active and motivated. They engaged, participated, and interacted with 3d virtual content, learning, therefore, was maximized. Despite this, there is a group with similar improvements (3T) and Statistical significance between groups previous training indicated that there are some possibilities that groups were not equal before the course started. Perhaps it was because 3T group was composed of students who traditionally combine study with work. So could be easier for this group to get better results. In next approaches some more AR training and group membership equivalence will be needed to get more significant results.

Finally, we can affirm that AR technology using mobile phones on Building construction area, offers the opportunity of visualizing "in situ" different stages of a constructive process, helping to improve its understanding. This fact allows verifying and comparing different scenarios and virtual proposals, prior to real construction. It could replace, somehow, real interventions. To do that, it's very important the ability of viewing different models with the same marker. In order to show different layers, models, etc… thereby simulating a real constructive process.

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