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New Strategies Using Handheld Augmented Reality and Mobile Learning-teaching Methodologies, in Architecture and Building Engineering degrees

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Abstract

In this paper we present “ML-AR” Practice Modules, in the field of Architecture and Building Engineering. They are alternative to traditional courses which are taught over a semester, and adapted to the student learning flow. In this case we used a particular technology such as Hand Held Augmented Reality (HHAR), to overlap virtual models on real scenes. Experience was limited to specific groups within four areas of undergraduate and master. In each case, specific Mobile Learning (ML) practices have been carried out. Each experimental group (EG) has been able to visualize a virtual model created by them or their teachers, in order to evaluate an architectural proposal or a construction detail, on site, as part of their own learning process. Students without the required devices, still in the ordinary course, configured the control group, (CG). Virtual models generation and augmented scenes preview on site, provided evaluation tools for better assessment and knowledge of student’s proposals prior to any intervention. In addition, tangible interaction and the ability to modify and share their views also provided social skills and helped to create a self-formative process. Mobile devices and AR technology were used close to the students who show greater motivation and commitment in their didactic contents generation. Evaluation is based on academic performance improvement through study cases, by comparing the achievement of the overall objectives between the two groups (EG & GC). Relationship between performance and usability is also assessed. The experiments carried out confirmed our initial hypothesis, where Information and Communication Technologies (ICT) used in the web 3.0 environments, allow improving learning processes and reducing its temporality without previous experience at a very low cost. AR Technology in this area combined with Cloud computing development, creates a new paradigm of continuous training and self-learning through the use of AR technology.

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1. Introduction

The experience described, that we will name in abbreviated form ML Modules is based on the use of Augmented Reality (AR) independent to the original contents of a traditional course taught over a semester. AR technology allows collaborative experiences in a real scene. So users can work with computer-generated objects as if they were real objects in a real environment, and in real time. In addition, AR allows a Tangible Interaction. By superimposing virtual objects in a real environment, through fiducial 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 the classroom.

Due to the impossibility that all students have mobile phones or tablets to carry it out, we decided to refine our experience to practice modules, where 3G phones or WiFi tablets (Hand Held devices) are used with specific applications to view virtual models in real space. We have chosen to incorporate them at specific parts of regular subjects of Architecture, Building Engineering and master's degree. Students, who had advanced mobile devices, formed up the experimental group (EG), or scenario S2. Students from the ordinary course configured the control group (CG), or scenario S1, and they didn't use AR technology.

We used this strategy multiple times, to evaluate an architectural proposal, or a construction detail on site, in order to get new inputs from the learning process and to involve students in the creation of virtual models as a prelude to actually build, view and / or take notes, and capture the place of study. This allowed to involve students in the learning process by the use of mobile devices and technologies that motivate them because they are part of their living environment and natural. The comparison between the achievement of the overall objectives between the two groups (EG and CG), and academic performance improvement of EG, are the basis of our project.

Experiences were carried out within the framework of compulsory subjects of the degrees of Architecture ETSAB-UPC, Building Engineering EPSEB-UPC, Master in Urban Management and Valuation UPC and Architecture and Building Engineering in "La Salle" -URL. Several experiments have been tested using different software and technologies, from the use of QR codes to display multimedia content and to download AR content, to virtual models registration using image recognition or geolocation.

The experience starts from the premise that the new tools ICT (Information and Communication) used in the web 3.0 environment allow at very low cost (we use free commercial applications, educational licenses or self developed apps) to improve learning processes and reduce its temporality. All without prior experience thanks to intuitive tangible interfaces and capabilities of new mobile devices. At the same time, the cloud computing technology development (applications and services sharing through ubiquitous internet and service availability 24h/365days/year), makes possible to approach this hypothesis.

To prove our hypothesis we set a first reference knowledge level before the modules. All students (EG&CG) have completed a PRE-Test, and once EG is defined and AR course is finished, we used usability questionnaires and a POST-test to evaluate the academic performance improvement. In short we can say that higher gain is achieved by EG students. They also show a higher degree of satisfaction by the use of AR technology, and commitment and motivation is improved. So it seems that the correct use of these technologies has improved student's learning process.

2. Objectives.

We seek to encourage a greater interest in the use of ICT in several disciplines integrated in architectural scope in order to improve student's academic performance. To do that, Human-mobile interaction study in teaching processes was addressed, as well as the Visualization capabilities of architectural virtual models on handheld devices, mostly with small screen size and insufficient processors to correctly render architectural 3d

models. In this area, mixed scenes visualization, and the use of travel notes or sketches on site, by using mobile devices, might be considered as the current version of photomontage, widely used throughout the 20th century.

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:

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

On the first 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, 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, as we said before, we compared final results between EG and CG.

3. Background

Briefly, ML early works addressed from a scientific point of view are COMTEXT [1], understood as a virtual environment for learning using mobile devices. Other experiences [2], extend the same idea in a virtual university based on the use of Internet and mobile devices, by developing a ML platform called WELcome (Wireless E -Learning). This educational expertise has already been claimed as basic by several authors [3], [4]. In our experience we are talking about a concept that straddles the ML and Ubiquitous Learning (UL) where the data are stored in the cloud and are consulted on any place by all kinds of educational programs and social networks.

Meanwhile, the use of AR in the field of architecture has been previously presented and discussed [5] and is the most obvious example of ICT progress, and of student's affinity towards these technologies. Defined as a variation of Virtual Reality (VR) in which the user sees the real world mixed with virtual objects superimposed. AR does not replace real world but rather complements it. The result is a composed scene where a virtual 3D model is displayed overlapped to real objects on the used device screen (computer, projector, whiteboard, special glasses, Smartphone or cell type). In the field of education specific applications have been studied for mathematics and geometry teaching [6]. More recently some work focused on teaching and 3D models visualization [7], [8] can be found.

In the case of architecture, we find occasional contributions covering different specific fields such as building rehabilitation [9] to evaluate an architectural proposal final appearance, in planning [10], or in urban design [11], [12], [13]. Qualitative leap and the technology diffusion has been possible since the popularization of smartphones and through the work of [14], ARToolkitPlus © libraries, which has resulted in multiple commercial applications. It is in this context ML attached to the RA is set as a new teaching option.

4. Work description

The first day of the course, all students answered a test (PRE) that was used to determine prior knowledge on the subject. It was based on previous years used tests. It was useful to verify that all students groups were similar before start the experience. EG Students received specific training in RA. Practices had a duration of two sessions of two hours each. First session, is dedicated to receive general information on the exercise, and to get familiar with AR applications. In the second session, visualization of 3d models imported from Moodle-Athena (intranet used) is tested. Specific Apps interaction is also assessed (U-AR, ARPlayer and Layar). Virtual models adjustment and appearance evaluation is addressed, outdoor, in a third session of four hours.

Finally, to parameterize these experiences, a final usability questionnaire and a POST test have been carried out on each study case.

4.1. Case Study 1. ML-AR Practices in Computer Applications course (3 ECTS) Degree of Architecture ETSAB 2012.

The first case study is identified as a course of Housing and Urban Landscape. The subject goal is to model urban complexes to design architectural proposals as sculptural elements. Two main thematic areas are addressed: the use of digital image processing and the use of agile tools to create 3D virtual sets. In this case, we focused on the study of interventions in the urban landscape of Barcelona, the place of intervention was the Flassaders square recently remodeled to complete Picasso Museum extension in 2009. Sculptures artist reference was V. Vasarely. The working group was 25 students divided into three groups: a 8 members control group, who had no 3G phones or incompatible with AR applications, and two Experimental groups who followed the traditional course, named iOS (9 students) and Android (8 students). Android users used the U-AR self developed application. iOS group used Armedia © viewer. Experimental group focused on evaluating on site the best fit in size and location of the proposed models according to the dimensions of the square (Figure 1). High differences were found on this basic aspect of the exercise between EG and CG who did not properly adjust their proposal to the proposed site. [15]

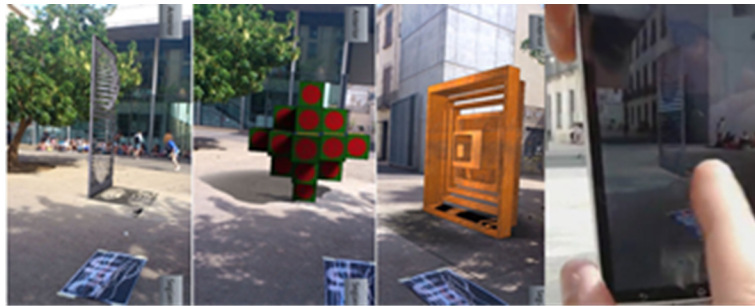


Fig. 1. Images samples of virtual models visualization from the designed sculptures and their on site adjustment.

4.2. Case Study 2. ML-AR Practices in the subject of the Technical Project II (3 ECTS), Degree of Building Sciences and Technology, EPSEB, 2012.

In this case, the object of study was focused on the application of ICT in construction and maintenance learning processes. Students, with prior training in ICT, mostly unknown AR uses in education. The experience was performed in three stages. PRE-Test, Lectures, and POST-Test. In this case, we tested the process of opening a void in a load-bearing wall. The Study case was held with 146 students. They were divided into 4 groups. 3 control groups (1M, 2M, and 3T) and 1 experimental group (4T). 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 lighting maps in textures to incorporate lighting conditions from surroundings, and introduced *occluders* for a better integration of the scene in its real location. The details of the experiment can be found described in [16] (Sanchez, A. et al. 2013).



Fig. 2. Construction process visualization on site.

4.3. Case Study 3. ML-AR Practices in ICT applied to spatial analysis (60h) course, Master in Urban Management and Valuation, ETSAB-UPC 2012.

The experience was placed on the Barcelona Knowledge Campus (BKC). It was carried out by 11 students in a single experimental group, taken as control group students from last year who made the same project. ML-AR module lasted two sessions of three hours. We constructed a database to integrate modeled buildings data (textures, size, position, links, etc..) with graphical information, similar to a GIS (Geographic Information System). In this case we used Layar, free application that allows geo-referencing both alphanumeric and digital content for integrated viewing on mobile devices. See Figure 3. In addition an specific Information Channel was created to allow filtering content. The details of the experiment can be found described in [17].

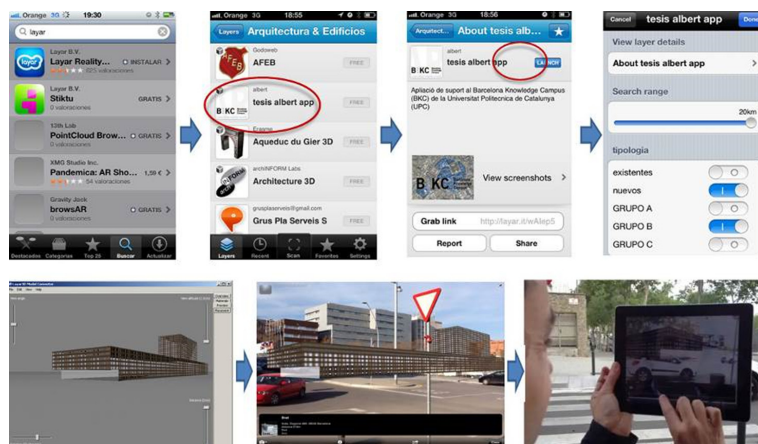


Fig. 3. Download process and visualization sequence of geo-referenced models.

4.4. Case Study 4. ML-AR Practices in the Representation Systems II course (9 cr.). Architecture Degree, La Salle Barcelona, URL, 2011-12.

The project was conducted by 57 students. Students from previous year were taken as the control group. In this case we integrated various ML-AR strategies for students proposals presentation. We used for that QR codes that linked to various multimedia content, from video to 3d models, to be viewed on their mobile devices using AR technology, web pages, etc.. The results of the surveys and academic developments may be found in [8].



Fig. 4. Different project presentation strategies through the use of QR codes

5. Methodology.

As we mentioned before, to evaluate usability of AR technology on mobile devices and to assess student's academic performance improvement, experiences were performed in three stages: PRE-Test, Lectures, and POST-Test (Figure 9). In each case, 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). Control groups followed the traditional course based on slides (Scenario 1), and experimental groups were involved in AR specific training (Scenario 2).

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 the experience started.

During two 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 experiental groups, however, received an additional lecture which taught the application operation, and how to manage distributed contents to be visualized through AR. In addition, they got detailed instructions of the assay to be performed through their devices, and 3d virtual content to be visualized was explained and distributed.

Once the course is finished, experimental group students were 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.

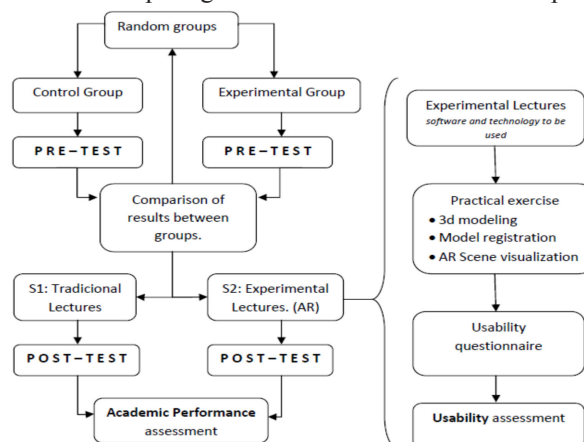


Fig. 5. Methodological process General scheme.

We have used both paper and on-line questionnaires. They were designed to be answered using Likert scales (ratings from 1: disagree to 5: strongly agree). From Pre-Test responses we obtained user's profile and the degree of knowledge / motivation for various technologies. Post-Test was used for final evaluation and to get student's usability assessment. Particularly noteworthy has been the exercise using Layar (study case 3), where the ability to respond to certain questions on site was incorporated. Students opinion about their proposals was collected on site, and real time. We used for that google docs Questionnaires (Figure 6).



Fig. 6. 3d model visualization and questionnaire responses on site.

6. Results and Discussion

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. The overall assessment of the courses was rated 3.51 points out of 5, 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.

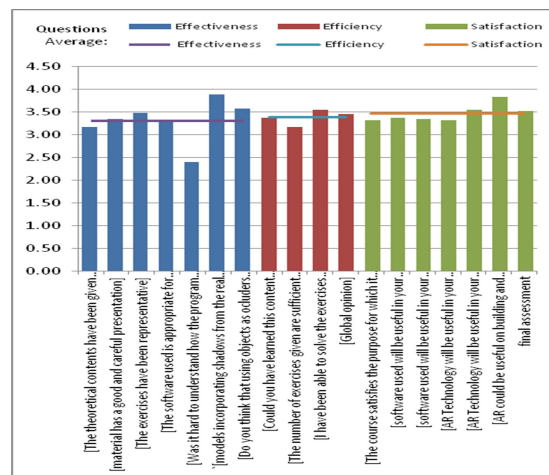


Fig. 7. Student's responses to the Usability questionnaire.

Quality indicators of Efficiency, effectiveness, satisfaction, and previous training, were constructed from an expression that weights each variable from its value and the percentage of variance explained [18]. The value obtained illustrated the situation of each student compared to the other participants in the questionnaire for each of these indices. It was useful to correlate every indicator with another and with the student's academic performance. The following table (Table 1) illustrates the results obtained by five students who made the experiments, comparing the average of their scores directly with the index of usability constructed.

Table 1. Results of five students relating the mean responses with usability ratings.

	Student 122	Student 125	Student 48	Student 67	Student 41
W_contents	5	2	2	5	3
W_material	4	2	2	5	4
W_exercises	5	1	2	5	5
W_software	5	2	3	5	5
W_course_purpose	5	2	3	5	5
W_learn_indep	3	3	3	4	5
W_num_exercises	4	2	3	4	5
W_solve	5	3	3	4	5
W_Global_opinion	5	2	1	5	5
T_hard_program	1	2	1	3	1
T_soft_useful_student	5	2	2	5	5
T_soft_useful_engineer	5	3	3	5	5
T_AR_useful_student	5	2	1	5	3
T_AR_useful_engineer	5	3	2	5	3
T_AR_useful_areas	5	2	2	5	4
T_shadows	5	2	2	3	5
T_occluders	5	2	2	3	4
Final_assessment	5	2	2	5	4
AVERAGE	4,56	2,17	2,17	4,50	4,22
EFFICIENCY	0,73	0,03	0,06	0,57	0,89
EFFECTIVENESS	0,96	0,00	0,21	0,66	0,87
SATISFACTION	1,00	0,15	0,13	1,00	0,74
USABILITY	1,00	0,00	0,09	0,82	0,93

Related to Academic performance improvement, PRE-TEST mean scores were very similar in all groups. To estimate the probability that groups are significantly similar, we used Student's t-distribution [19] setting to null hypothesis (H0) that there are no differences in scores between groups. Statistical significance (2-tailed) was higher to 0.05 in all cases, which means that there is very little chance that the groups were different in their skills, previous training, and therefore the experimental groups students, were very similar to the other groups. Null hypothesis were accepted (no significant differences between groups).

Once students training was finished, they were scored. Results show that the experimental groups got better results after training, 0.24 points above the mean of the control groups. Consequently, higher gain in relation to the average of the control groups is achieved by experimental group.

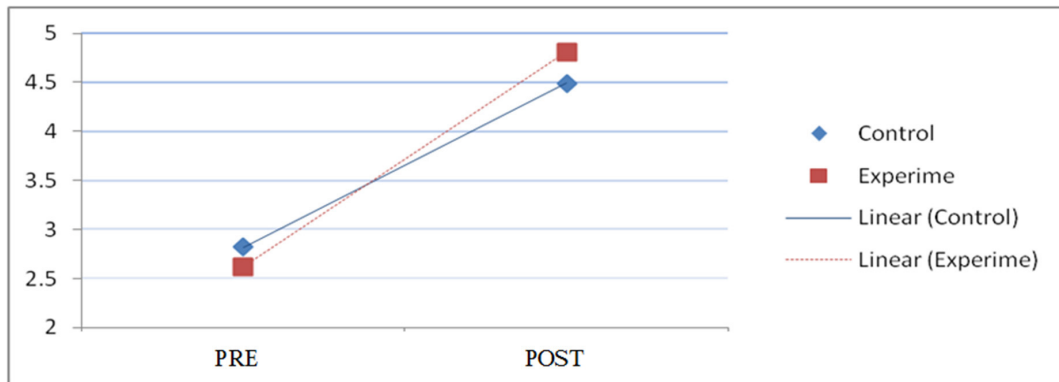


Fig. 8. PRE and POST results evolution

7. Conclusions.

In relation to the first research question, we can say that usability results extracted from questionnaires were very positive. They demonstrated the Technology suitability as a new tool to be used in learning processes. Students have been satisfied and motivated by these new methodologies, in all cases. Regarding the second research question, results showed that AR technology can help to improve student's academic performance. Experimental groups always got higher gain in their post qualifications. So, it seems that by 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. Nevertheless, more exercises should be done to completely confirm this data.

Finally, we can say that the AR technology in combination with the use of mobile phones offers many possibilities to evaluate, on site, architectural projects, urban design, construction processes, and historical heritage studies. AR can help to improve architectural proposals understanding. In addition, AR facilitates social dissemination showing their real scale and position in real time. This allows, at the same time, to check and to compare different scenarios or virtual proposals previous to construction, even opening the door to citizen participation.

As future work, we are developing a new questionnaires that incorporate qualitative aspects, based on personal interviews with individual students, and to repeat the experience in the same subjects. Besides that, we're actually testing Hand Held AR on different fields like rehabilitation, structures, pathologies visualization, facilities management, etc..

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