Augmented Reality in Architecture Degree New Approaches in Scene Illumination and User Evaluation

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Abstract- **In this paper we report our experience in designing, developing and evaluating new didactic methods, in order to help students to improve their spatial and graphical skills. Specifically, in this educational research investigation, the goal is to evaluate the use of Augmented Reality (AR) in architecture, urbanism, to build construction and interior design of undergraduate, and to master students learning processes. We have used mobile phones, laptops, as well as low cost AR applications.**

Keywords- ***Augmented Reality; Education Research; Architectural Graphic Representation; User Experience; Technology in Education***

I. INTRODUCTION

The main objective of this study is to assess the degree of satisfaction and integration of students using new visual technologies associated with mobile devices in the process of architectural design. To evaluate our objectives, we reviewed the state of the art related to the use of surveys to describe the user profile and to evaluate their satisfaction using new technologies, and the application of new technologies in the educational framework, as well as the degree of implementation of a specific technology such AR in heterogeneous frameworks and professional training.

II. STATE OF THE ART

A. Advanced Technology in Teaching Experiences

The emergence of new communications technologies in all areas of society has created a new situation in the specific framework of the education and how we can integrate these technologies into the dynamic role of teaching. The constantly development of these digital technologies allows new models of information and requires user's skills improvement to manage all type of data in digital environments. These types of skills are often referred as “digital literacy” [1, 2]. As described [3], we can find a detailed description of the main skills ranging from cognitive to motor, sociological, and emotional. Some tasks required in this framework include the interaction with different displays and user interfaces, using digital reproductions or hyper-textual navigation to obtain a better mastering and experience with computer programs and navigation [4].

We can begin to find solutions implemented in pre-university education that relate to higher education, especially in areas where the use of visual information is very important such as in the frameworks of multimedia, design, communication, or architecture and in any other area of higher education [5]. Some examples are the use of whiteboards, interactive books, social media and other eLearning resources [6], and more advanced systems in the visualization of 3D models, buildings and spaces in the architecture education, as interactive models, spatial analysis or new 3D mobile interactions [7] using AR, one technology with a great development in the last years [8].

The introduction of more user-friendly technology (such as mobile phones, tablet, social networks, etc.), in the learning process is an educational strategy that removes the traditional and bored lectures. With these new methodologies the teacher achieves greater motivation in the monitoring of contents, a new interface to share educational material that allows a work timeless and adaptation to the professional technologies by the students.

B. Designing User Test

A basic topic in the experimentation and research of scientific hypotheses based on the user's response lies in the adequate design and use of different “test of user” or “survey of profile” that allows the extraction of data to study.

A common mistake is to simplify these studies to the concept of “usability”. We could understand it as the interaction of a physical or virtual device with a user and his basic human capabilities [9]. Therefore, we can state the difficulty in establishing proper ways and adapt the study to test, measure, evaluate and compare measurable results that depend on the user experience. These processes require defining methods, metrics, processes and tools to measure how to fit each experiment [10].

In the teaching framework, the type of test to use is usually the main objective to determine usability of new learning processes of the training project. This approach means that the type of questions should be directed to the teaching methodology and not the project itself, since the project evaluation is carried out with specific questionnaires related to it. In this way, by depending on the training method and the results, it will be possible to question the initial assumptions and review a more effective implementation of how teaching methods can incorporate new technologies favorably.

In the survey design, to model the response of implementing new technologies in university teaching resources, there are prominent surveys, based on user profile, which focuses on the efficiency and effectiveness of the course, and on the level of satisfaction and student preferences. [11].

The most common parameters that we must consider in evaluating a new approach in teaching technology are the degree of knowledge of new technologies, the use made of social networks, computer known applications, and knowledge of the theoretical content of the course under the program. In our case we have focused on the application of augmented reality to improve teaching, the work is documented in all applications and modes of implementation. [12, 13, 14, 15].

C. Augmented Reality (AR)

The creators [16] define AR as a virtual reality variation, where the user can see the real world with virtual objects, mixed or superimposed. In contrast to virtual reality, AR does not replace the real environment, but uses it as a background to be registered. The final result is a dynamic image of a 3D virtual model superimposed to a real time video of the environment. This scene is shown to the user in a computer screen or other devices, as projectors, digital board, special glasses, or in a 3G cell phone. This sensitive experience is essential for the rising of this technology. The main problem in architecture and building construction is to solve virtual objects and real images integration. Overlap must be accurate and at the right scale, in order to achieve its hypothetical situation and size matching in real scene.

This technology, recently commercialized, covers different areas. If we focus our specific fields of study, we would emphasize the book edition applications, where trackers are added to show additional information, the best example is Magicbook [17]. In the field of the education, specific applications for maths and geometry have been studied [18, 19]. In architecture the use of AR is anecdotic; the precedents in this field are the indoor studies [20, 21].

At Tinmith project, outdoors works have been also done. Other semi-immersive proposals which incorporate AR over screens in the study of urban projects are projects as Arthur [22], the Luminous Table [23] or the Sketchand+Benchworks [24], where different data entry devices are combined in a virtual theatre. More recently [25, 26], different tests on building renovation have been realized. In the urban planning, we may mention [27] and in the infrastructure of the construction enginery [28]. In the architecture teaching stand out [29, 30, 31, 32] devoted to objects design and to other more general teaching applications. There are some baseline surveys about the utility of these technologies on professional architecture companies [33] which had shown a big interest for it.

In our opinion, the quantum leap and dissemination of this technology is due to the fact that it is accessible from mobile phones thanks to the libraries ARToolkitPlus [34]. Mobile Ar software applications appear continuously, we may stand out MARA from Nokia or Layar, the first application of generalist use available both for iPhone and Android Os based phones. In 2010, appears Junaio, the first markerless open-use application. It works with multimedia content (videos, renders, 3D models) registration is based on real environment images recognition, instead of preset patterns. Moreover, low cost AR plug-in for programs as Google SketchUp are generalising the use of this technology, but mostly indoors.

D. Scene Illumination

The problem of virtual models illumination and how it can be integrated into the scene has been also widely discussed. In the first approaches to RA, the virtual object was simply overlapped in the real environment. Major advances in technology focused on the correct calibration and registration of objects, studying the possible effects of occlusion and spatial coherence of objects, regardless of any other adaptation of the object in the scene. In other words, once the object was included in the scene, it was an artificial object, unable to adapt to the changes in environmental light. That kind of configurations lacked realism, and consistency of the scene was based only on geometrical aspects.

The sensation of realism in the scene is obtained primarily through visual interactivity. While it is true that as more senses involved, a greater sense of realism is achieved, a realistic immersion system should be able to create a complete visual simulation or as close as possible to it.

The current level of development of the technology required is still insufficient to achieve correct results in mobile devices. Most of the applications currently available, the realism of the images is sacrificed on behalf of interactivity in “real time”, to increase system operability, or ease of management, and not to the realism of sensory experience. We believe that a non-integrated virtual object in the scene may invalidate any judgment that could be done on it, resulting implausible, unlikely and unattractive.

The first research approach about how to incorporate lighting conditions in virtual objects appeared in the early 1990's, [35, 36, 37, 38] but is in the last 10 years, when the international community has made an effort to provide automated solutions to calculate objects illumination from its environment [39, 40, 41, 42, 43]. And some systems have been designed recently to estimate lighting conditions and apply changes to virtual objects. They are able to cast and receive shadows dynamically and consistently [44].

Some author’s approaches [45] identify three lighting techniques in order to improve the scene quality: common illumination, which are methods that provide some level of mixing, as the addition of shadows projected from real objects into virtual objects, and shadows casted by virtual objects on real ones.

This is the approach that the teaching experience is based on. Although these techniques do not allow any modification of current lighting conditions of the scene we need to take into account for example the “relighting action”, which aims to incorporate dynamically into the scene new lighting effects such as shadows, intensity changes, new lights addition, indirect lighting effects, etc. Also we can find other actions as the “reverse light” or inverse illumination, which contains methods that attempt to recover the photometric properties of all objects in the scene. These methods estimate values of BRDF (Bidirectional Reflectance Distribution Function), as well as the type and position of the light sources in the real scene. The information obtained can be used both for common illumination and relighting techniques.

III. STUDY DESIGN

Based on the theoretical study, we designed two tests, with the first focusing on evaluating the technological and social profile of the student and the second one designed to assess the implementation of AR technology in architectural education. The simplified models of the test (which had additional questions and specific thematic scope and implementation), we can see them in the next two tables:

TABLE 1 INITIAL USER PROFILE TEST

NEW TECHNOLOGIES					
How much interest do you have for the computers and technological advances in general?					
	Nothing	Little	Something	Quite	Much
What technologies are you using from the list below?					
	Mobile	Cam	MP3-MP4	Computer	
	Ladtop	Console	Smartphone	Tablet	
Do you have any of these technologies? Indicates which:					
How many hours a day do you use the computer?					
	<1	1-2	2-4	4-8	>8
You use the computer to:					
	Estudy	Work	Leisure	Other	
INTERNET, SOCIAL NETWORK AND OTHER TOOLS					
Which device you use to connect to Internet?					
	Mobile	Ladtop	PC	Smartph.	Tablet
How many hours a day you connect to Internet? (regardless of the device)					
	<1	1-2	2-4	4-8	>8
Where you usually connect to Internet?					
	Home	Univ.	Work	Cíber	
	WIFI públic	Mobile	Other		
What type of connection you usually use? (regardless of the device)					
	WI-FI	ADSL	3G	TV	Other
Which services from Internet you usually usually use?					
	E-mail	Chats	Browser	Games	
	Architecture	Blogs	Sports	News	Others
Do you use social networks?					
To what do you use the social network?					
	Professional	Estudies	Friendship	Others	
APPLICATION					
Which Social Network applications you use?					
	Facebook	Twitter	Tuenti	Linkedin	
	MySpace	Hi5	Orkut	Other	
Which applications you use to share files? (photos, videos, texts, CAD, etc.)					
	Dropbox	yousendit	Rapidshare		
	Picasa	Flickr	Other		
What image editing applications and CAD have you used?					
Indicates the following values: 0-none. 1-low, 2-medium, 3-high					
	AutoCAD	REVIT	MicroSt	Rhino	
	MAX	M Design	SketchUP	Adobe	
	Ilustrator	Other			
Do you play games?					
What platforms do you use?					
What kind of videogame you use?					
COMPUTER AND LADTOP					
Do you have computer or ladtop?					
Brand:					
Model:					
Which software you use to work and exhibit projects at school?					
	AutoCAD	REVIT	MicrStation		
	MAX	M Design	SketchUP		
	Ilustrator	Rhino	PhotoShop		
MOBILES					
Do you have mobile phone? Yes/No Brand: Model:					
3G:	Yes/No	Big screen?	Yes/No		
Which options you use in your mobile phone?					
	Internet	SMS	MMS	APPS	
	Music	Videos	Cam	Other	
What kind of contract you have?					
	Prepayment	Contract			
Which phone operator you use?					
	Movistar	Vodafone	Orange	Yoigo	Other
AUGMENTED REALITY					
Do you know what is Augmented Reality?					
How did you know?					
	Teacher	Adv			
	Internet	Friend	Other		
Do you think it may be useful in your studies?					
Do you think that applying the RA can enhance your presentations?					
Do you think the AR will be complicated in its implementation?					
Do you think that the RA technologies may be a limitation for the final user?					
Do you think that AR can help you in defining a project?					

TABLE 2 USER EVALUATION OF TECHNOLOGY

1	2	3	4	5	6
Totally agree	disagree	Neither agree nor disagree	agree	Totally agree	Do not know/ no answer

1	*2*	*3*	*4*	*5*	*6*	***MATERIAL***
□	□	□	□	□	□	The course material has a good presentation. (Notes, camera, software)
□	□	□	□	□	□	The structure of the course sessions and type of exercise is appropiate.
□	□	□	□	□	□	It is easy to manipulate the marks of the exercises.
□	□	□	□	□	□	The working scale models suitable for the exercises and manipulatevirtual elements
□	□	□	□	□	□	The application of Augmented Reality has been stable (no crashes)
1	***2***	***3***	***4***	***5***	***6***	***CONTENT***
□	□	□	□	□	□	The number of exercises proposed are sufficient to work the hours proposed..
□	□	□	□	□	□	I have been able to solve the exercises presented.
□	□	□	□	□	□	I have had time to do the exercises marked by the teacher in each case of study.
□	□	□	□	□	□	Theoretical explanations are sufficient to know the contents. You do not need any other explanation for the exercises.
□	□	□	□	□	□	At the level of assessment are 4 exercises, how many do you have corect?
1	***2***	***3***	***4***	***5***	***6***	***APPLICATION OF AUGMENTED REALITY TECHNOLOGY***
□	□	□	□	□	□	Familiarity with the gestures and manipulate virtual objects has been easy.
□	□	□	□	□	□	By manipulating the virtual figures there is no delay in the display, the virtual image does not produce "skipping frames"
□	□	□	□	□	□	Virtual three-dimensional figures are perfectly and do not present difficulties of definition.
□	□	□	□	□	□	How to use the material (books) and Augmented Reality Technology was easy and intuitive.
						OPINION OF THE RESULTS
□ Y	□ N					Do you think that the sessions meet the purpose for which they were designed? (known AR applications in Architecture)
□ Y	□ N					Augmented Reality System used in the sessionss is nice to use?
□ Y	□ N					The sessions with Augmented Reality, do you find useful to improve the presentation or projects?
□ Y	□ N					To make this content, could have worked independently? That is, without assistance from the teacher.
□ Y	□ N					Do you think additional theoretical material needed to perform the exercises of the sessions?
□ At class □ At home □ Other						Where would youperform the exercises outlined in AR?

☐ Very good ☐ Good ☐ Acceptable ☐ Bad ☐ Very bad	How to value the Augmented Reality Technology to work with three-dimensional models?
☐ Very interesting ☐ Interesting ☐ uninteresting	Augmented Reality seems ….
☐ Very Original ☐ Original ☐ Unoriginal	Augmented Reality seems ….
☐ Muy useful ☐ Useful ☐ Unuseful	Augmented Reality seems ….
☐ Stimulating ☐ Middle term ☐ Frustrating	Augmented Reality seems ….
☐ Flexible ☐ Middle term ☐ Rigid	Augmented Reality seems ….
☐ Excellent ☐ Good ☐ Regular ☐ Bad ☐ Very bad	**Global Opinion of the sessions of Augmented Reality**
	OPINION TO THE FUTURE
☐ Y ☐ N	Do you think the use of three-dimensional tools can improve your focus and motivation for the development of the contents of the subjects of the projects?
☐ Y ☐ N	Do you teach intensive courses suitable for students to improve the techniques or representation?
☐ Y ☐ N	Would you have preffered this course based solely on models?
☐ Draw by hand ☐ Software ☐ Mobile phone ☐ Internet at home ☐ None of the above	What other support would you have liked this course?
☐ yes ☐ no	If you could touch and manipulate the pieces physically to rotate, to move or to scale, do you think it would have helped better visualize the piece?
☐ yes ☐ no	Do you teach intensive sourses suitable for students to improve knowlege of the Augmented Reality technology applied to projects?

IV. CASE STUDY 1: USING AR IN THE CLASSROOM

We assume that students, digital natives, are common users of ICT, feel attracted to them, they can quickly learn how to use them in an intuitive way, and improve their use in a self-taught way. But most of the times they are not adequately trained about it. We try to exploit their attraction in order to study how these technologies and its implementation, with the use of new teaching methodologies, have an impact on their three-dimensional visualization and free manipulation of architecture forms. At the same time, we want to find out if this issue can help to improve their performance in spatial comprehension processes and their graphical representation skills, from as early as the start of their academic years.

In this sense, and as a teaching research project which involved large groups of students in regular courses, the solution adopted was to study how AR was integrated in different subjects depending on its specific contents. We use laptops or school notebooks, and with them 3D models have been generated and visualized on site, always using educational software like Gimp, SketchUP, Autocad, 3Ds Max, and exporting them using plug-in or AR free applications, such as Build-Ar or Mr Planet, Ar-media Inglobe Technologies or Junaio in order to be viewed through a web camera connected to a computer, or using 3G standard mobile devices Android or iOs based.

A. Methodology

For the development of every course it is necessary to create some didactic contents adapted to the subject and to the specificity of the proposed tests. We worked in coordination with the responsible for the subject who was in charge of the virtual construction exercises. In many cases it was necessary to carry out a brief training and to make some specific user manuals for 3D software or 3D modeling.

The experiment was conducted using the personal laptops of the students using the integrated webcam and additional ones (Logitech C200). This configuration allows seeing indoor RA models RA using 20x20 cm. Markers. The virtual models were generated by Google SketchUp (each student had a free license for this programme) and then, were exported to AR using the free plug-in Ar-media Inglobe technologies whose duration of 30 seconds allows basic adjustments. Alternatively, the teacher exports an AR model using the professional application ArExporter 2.0, so that students can see it for an unlimited time using the free viewer ArPlayer 2.0, once received by wifi or USB pen drive. (e.g. Fig. 1).

Fig. 1 Images of teaching experience in the classroom (left) and interior spaces of the school

The group size was 21 students to ensure it was a significant population sample. Similar number of students participated in other study cases. Using a specific questionnaire (see previous chapter), every student is asked about his performance assessment, about the amount of hours he or she has dedicated to the RA daily, and to consider if the educational resources have been appropriate to the complexity of the exercise.

As we have referenced, we use SEEQ based questionnaires as an instrument of evaluation and auto evaluation by students (Students' Evaluation of Educational Quality [46]. In a similar way Applications usability and used hardware will be evaluated. We take user concepts parameterization from ISO norm 9241-11 using a specific survey form, that will depend on the resources and computer technology used in every course.

Students were required to “complete”, somehow, the real space where they work every day with virtual information, having in mind their knowledge as building engineers (see Fig. 2).

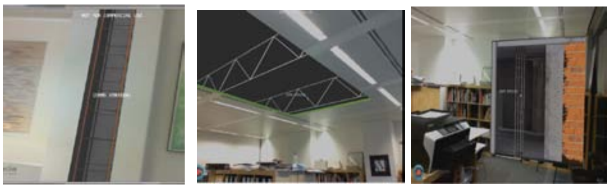

Fig. 2 Sample images of the proposals made by the students during the course

B. Results and Discussion

Over 85% of students were able to complete the exercise. All of them designed their virtual proposals, and were able to view them on the desktop using flat patterns. That activity helped the students to improve their competitions and skills on graphical computer science, beyond current knowledge of traditional technologies. AR technology allows them to view their proposals blended with real space, which would not otherwise have been possible. They get familiarized with the use of markers as elements to interact with three-dimensional digital content and the technology helped them to increase understanding of their proposals, and to share some ideas.

In relation to students personal training and the prior knowledge level of the technology, it should be noted that the most often used applications were “Email” and “internet browsers” followed by office applications, CAD and photo editors. Less knowledge resulted in LINUX and AR systems. (Scale: 0 = none, 3 advanced). Therefore, despite the prior ignorance of AR technology, it was rated very positively at the end of the course. (e.g. Fig. 3).

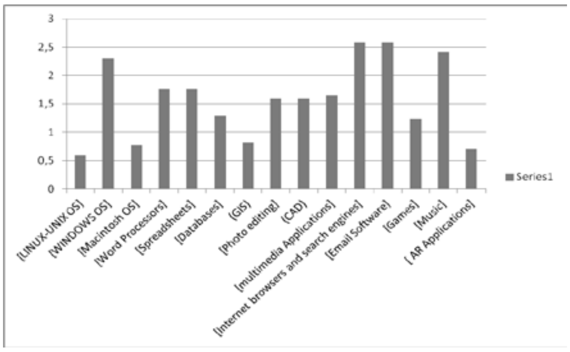

Fig. 3 Results average table about the prior knowledge of the technology

Related to the opinion, teaching content, and material of the course, it should be noted that it was very high rated. Material representativeness, number of exercises in accordance with the objectives was optimal. The final average rating was more than 4.00 out of 5 points (e.g. Fig. 4). The worst rated question was referred to the possibility of learning such content independently.

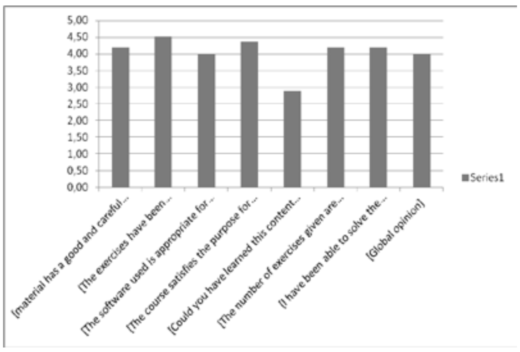

Fig. 4 Rating table about global opinion, content, and material of the course

And related to augmented reality technology and software used, 100% of the students found them useful in the field of architecture and building construction, despite having no prior knowledge of it. (e.g. Fig. 5).

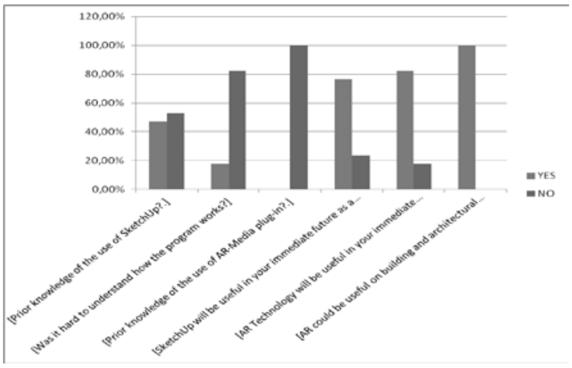

Fig. 5 Percentage responses related to augmented reality technology and software used

The overall assessment of the course was 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 (0.69) was detected with: the representativeness of the exercises and the quality of the presentation. So these variables are crucial to the success of this teaching experience. Not being so correlated with the fact of being able to solve the exercises independently or with the number of exercises proposed. The strongest correlation (0.86), however, was in the use of appropriate software, and this is, therefore, the most important variable to be considered in future work.

V. CASE STUDY 2: SCENE ILLUMINATION

A. Methodology

In this case, exercise was divided into two phases. In the first one, the fundamentals of technology, such as rendering, occlusion, tracking and register systems, were taught. We showed examples of most widely used applications implemented in different areas, so that, the student was aware of the possibilities that the use of the technology offered.

Since we were working on indoor representation, we paid special attention to one of the weaknesses in the scenes of augmented reality, lighting immersion. Because most of the times, the virtual model lacks realism and is not integrated sufficiently into the scene to be credible. The problem lies in lighting conditions differences from real environment and virtual objects superimposed. This problem takes on special significance indoors, to visualize interior design proposals, because a non-integrated scene may seem unlikely and unattractive (see Fig. 6).

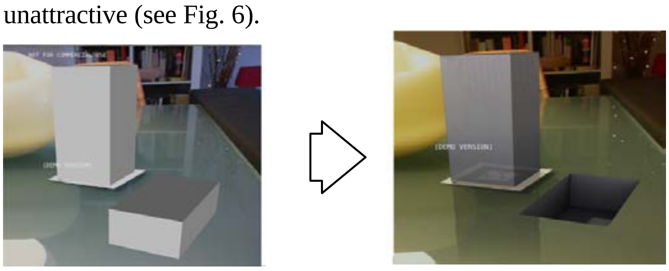

Fig. 6 Images from the same model using occluders and lighting integration modelling techniques

To solve this problem, students were trained to create textures and incorporate light conditions from surroundings, and also to cast shadows from virtual objects on real environment. They should create a virtual object identical to the real one. This object had, as a texture map, the image of virtual object casted shadow, simulating the environment light conditions, and should be transparent where it is was not projected (e.g. Fig. 7).

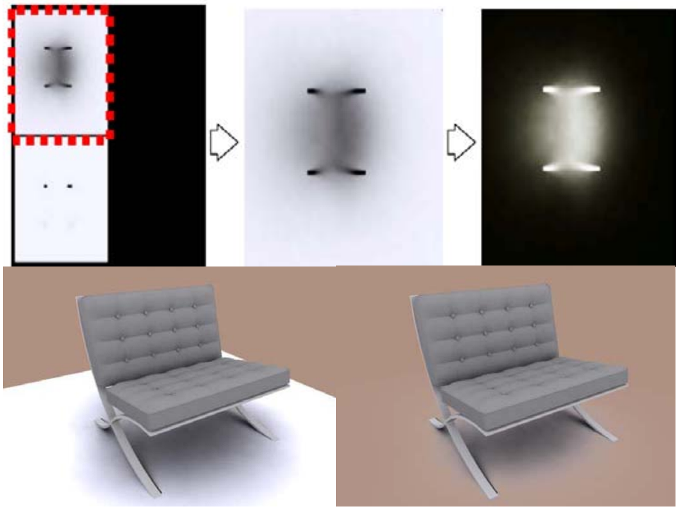

Fig. 7 Texture maps to cast shadows in real space. On model basis, a lightmap is assigned as the main texture, and its inverse image is assigned as an opacity map to acquire transparency. So black pixels remained transparent, leaving visible only the cast shadow area

We assumed that the knowledge of virtual objects modeling was acquired during their training as engineers or architects in previous courses related to computer graphics tools to represent and manipulate images and virtual models.

In the second phase, students were required to create an AR scene in which we should take into account the ambient light conditions. Each student chose a random school space, and modeled their proposals, previously tested in the classroom, with different levels or layers to show in. Once we solved and discussed each specific case, modeling problems inherent in this technology as registration, texturing, lighting and occlusion, we proceeded to register (positioning) the model in its real location (classroom, school interior space.)

That exercise allowed students to familiarize with the software provided and with flat patterns as suitable elements to interact with three-dimensional digital contents. Also it helped to verify feasibility of AR technology since proposals became more understandable, once virtual information was overlapped on real space. We tested occluders, environmental elements that were not visible in the scene but allowed to hide parts of the virtual model, to make the scene more believable.

B. Results and Discussion

Indoor AR technology implementation to visualize architectural proposals, as explained above, gave very different results because of the creative freedom of students and their different backgrounds. 90% of students were able to finish the exercise. They designed and modelled their proposals, and visualized their scenes on the desktop using flat patterns. Most of the students opted to design furniture pieces that incorporated in place (see Fig. 8).

As we mentioned before, we evaluated user's assessment based on three points:

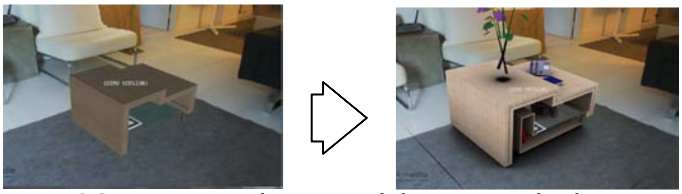

Fig. 8 Consecutive steps showing virtual objects integrated in the scene

- 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.

The average of the responses related to the effectiveness, efficiency and satisfaction of the course were very similar, ranging from 3.59 to 3.73, out of 5 (see Fig. 9).

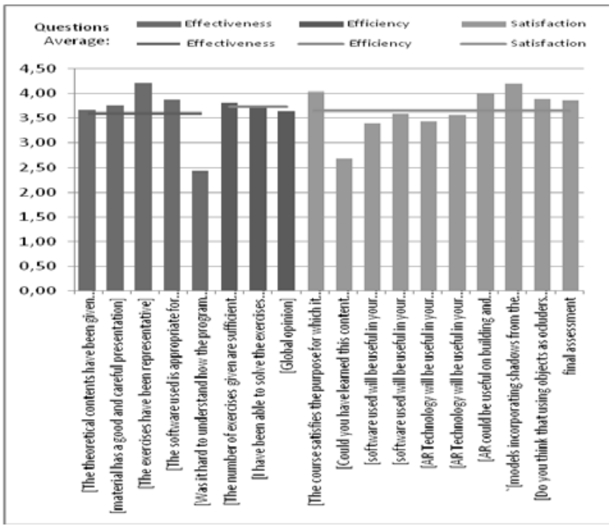

Fig. 9 Final average rating

In relation to student's personal training and the prior knowledge level of the technology, results were similar to Case 1.

Related to the opinion, teaching content, and material of the course, it was very high rated again. Material representativeness and the number of exercises in accordance with the objectives were optimal. The final average rating was more than 3.62 out of 5 points, which was lower than similar courses (case 1) probably due to the short time to carry out the exercise, and its difficulty. The question about the degree of satisfaction of the course in relation to the purpose for which it was designed (lighting integration tools in AR, to improve graphical representation) was of 3.86 points. And the possibility of learning such content independently was the lowest rated again. (2,57).

And related to augmented reality technology and software used, 90% of the students found them useful in the field of architecture and building construction, despite having no prior knowledge of it.

Finally it should be noted that lighting immersion, casting and receiving shadows from real environment, to make the scene more realistic, was the question with the highest score (4.29).

In this case, the overall assessment of the course was 3.67 points out of 5. As we said, this course was lower rated than the first one, but we should have in mind that in the first case students create freedom models, in random spaces, and they not should integrate lighting, so the exercise was easier than second one.

VI. CONCLUSIONS AND DISCUSSION

Regarding the project in its educational aspect, we have shown that using ICT, students with no prior specific training to AR, but motivated by these technologies, get substantial improvements in academic their performance and spatial awareness capabilities in a short time with a high degree of acceptance by them. We used for that a comprehensive educational strategy which combines the visualization and modelling 3D, incorporating agile and with a high level of usability digital graphics tools. We tested these strategies in two cases of study, supplemented with two different educational groups. In both we've got very remarkable improvement in performance.

As we understand, in learning processes, the most important are the concepts to study and to represent in each case, so that the rendering technology helps, enhances and facilitates the idea discussion, and even allows a rapid assessment and review of projects. We don´t try to generate realistic images or final nice presentations, but working models, prototypes faster and easier to manipulate.

In the immediate future we´ll repeat the experiments on larger groups samples, preparing more control groups at different levels of future architects, planners and building engineers, in order to obtain more reliable data and to obtain global conclusions.

Related to questionnaires and students global opinion we should notice that it was highly correlated with exercises representativeness and with the quality of teacher's presentation. So these variables are crucial to the success of these learning experiences. The fact of being able to solve the exercises independently or the number of exercises proposed on the course is not as important as we though at the beginning of the cases. Even more, the use of appropriate software could be the most important variable to be considered in future work. Finally, 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.

Finally, in relation to the type of exercises, no teaching experiences have been found, and it focused mainly on lighting simulation in virtual models textures to make the scene more believable.

In the experiment described, however, the image is often unrecognized in less favorable light conditions. And the scene is often inconsistent. That suggests that these systems are very sensitive to light conditions changes, and may become useless. The fact that indoor light conditions used to be under control could help to set the scene correctly.

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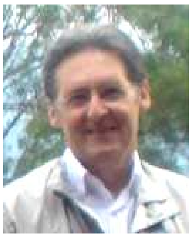

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