AUGMENTED REALITY ON ARCHITECTURAL AND BUILDING ENGINEERING LEARNING PROCESSES. TWO STUDY CASES.

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ABSTRACT

In this paper we present the first conclusions of an educational research project which seeks to evaluate graphic and spatial capabilities improvement of undergraduate and master’s degree in architecture, construction, urbanism and design students, throughout their academic training period, and by the use of Augmented Reality (AR) technology. The whole project consists of twelve case studies to be carried out in several university centers. At this moment, after the two finished case studies, it has been demonstrated that by combining the use of an attractive technology, to create dynamic photomontage for visual evaluation of virtual models in a real environment, and by the user-machine interaction that involves the AR, students feel more motivated, development and evolution of graphic competences and space skills are increased in shorter learning periods, and their academic performance is highly improved. We have used for this experience mobile phones, laptops, as well as low cost AR applications.

Keywords: Augmented reality, Educational research, Architectural graphic representation
1 INTRODUCTION

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 AR in learning processes of architecture, urbanism, building construction and design of undergraduate and master students. We use for it mobile phones, laptops, as well as low cost AR applications.

In our case, in the field of the teaching research in the aforementioned areas, that are usually grouped in university centers and in architecture representation and visual communication departments, where equivalent studies hardly exist, the main contribution to the scientific knowledge, is the realization of different cases in which satisfaction, usability of AR technology, and improvement of students academic performance is being evaluated. We have demonstrate that through the easy use of the NPR (Non Photorealistic Render) 3D modeling and low cost AR applications on portable devices, in indoors and outdoors environments, in a very short period, students acquire a high level of graphic training, that allows them to create virtual and interactive photomontages, very useful for the evaluation of the visual impact of their proposals. There’s no wasted time on learning to use complex computer applications. Instantly, they can check their first sketches in a real site, or add some virtual information in order to explain their architectural proposals, a hypothesis, or just to explain some hidden information that could be useful on maintenance tasks or building processes. We call that 3D real time photomontage, retaking the tradition of the architectural photomontage, whose usefulness has been proved in the professional and academic environment as a way to evaluate future projects.

We assume that students, digital natives, are common users of TIC, they feel attracted for them, and can improve their use in a self-taught way, although they are not adequately trained about it. We try to exploit their attraction in order to study how this technologies and its implementation, by the use of new teaching methodologies, affects them in their three-dimensional visualisation and free manipulation of architecture forms. At the same time, we want to find out if this fact can help, from the beginning of the student’s academic learning, to improve their performance in the spatial comprehension process and graphical representation skills. In this way we use the AR technology, because the user-machine interaction enhances spatial coordination, and encourage observation and manipulation of the student virtual objects. It’s easy to use and needs a very basic virtual modelling training to be visualised, forcing the student to develop the ability of reading and represent geometric shapes on the computer, which could be useful for future professionals. We avoid, in short, complex systems, and we keep in touch with the creative process.

To reach this goal it is necessary to advance in architecture understanding and in specific didactic methods; this is the reason why this study is carried out in different universities, academic skill level and subjects, involving new teaching strategies, methodologies, materials and didactic tools design in the TIC scope. They all are being properly validated and tested, both for the academic performance improvement achieved, as for the satisfaction or usability of the applications and computing devices that have been used.

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 is integrated in different subjects, depending on its specific contents. We use laptops or school netbooks, and with them 3D models have been generated and visualized on the studied places, always using educational licensed software like SketchUP, Autocad, 3Ds Max, and exporting them using plug-in or AR free applications, such as Build-Ar or Mr Planet, Ar-media plug-in or Junaiio in order to be viewed through a web camera connected to a computer, or using 3G mobile devices, Android or IOs based.

2 BACKGROUND AND CURRENT STATE OF THE PROBLEM.

2.1 Background.

The background of this research should be found in first place in the work of the authors whose main purpose is the graphical academic training of future architects, as well as new strategies development to enhance academic performance. In particular, we have now shown [1] that freehand drawing, realised in digital boards, tablets, or lpaids, is more than an acceptable substitute for traditional drawing, and its utilisation in combination with TIC, improves the student graphical instruction and their academic performance.

We have also published studies of academic urban retrieval, including AR Technology, [2],[3] in low cost mobile devices, as well as works about teaching improvement using digital image [4]. At the same time similar studies related to spatial abilities development for engineering students that use AR, have been recently published[5]. They are focused in educational content edition to incorporate AR markers and, somehow, ensure and confirm the initial hypothesis of this research.
In second place, it is worthy to state in few words the concept of the architectural photomontage as a graphical register, the main idea of our proposal. It’s based on merging photographic picture, which represents a real environment, and a virtual model, and matching both vanishing points [6]. Projects adjustments related to their location and scale, the design of furniture elements for indoor and outdoor spaces, as well as technical documentation queries on real site, are competences and skills that future architects, town planners or designers, have to acquire on their academic training.

For all of it, new tools like AR, which allows in site design adjustments during the model creation process, are needed. In this sense, digital image has hardly overcome intentionality, perspective fitting problems, and tonal adjustments of traditional architectural photomontage, which has a long tradition from the beginning of the XX century. There are many examples like the Mies studies of 1921 for the skyscraper Friedrichstrasse of Berlin [7], or the studies of El Lissizitky, in 1925 for the building Der Wolkënbugel [8], who superimposed his drawings over images using conventional graphics techniques. Later on, utopian proposals and the new technological advances, attached to the pop aesthetic of the 60’s in Europe and Japan led iconic images of these photo montages in which the color brought expressiveness.. Special mention in this line are the works of the Team X collectives[9], Archigram[10] or Superstudio[11]. Recently, the new proposals of digital photo montages, break with the traditional perspective rules, for, in pseudo realistic collages, transmit more the poetic idea of their projects than their own future concretion. Contemporary references are the works from J.Nouvel[12] S.Hall[13], MVRDV Herzon & de Meuron[14] etc.

As we have already said, despite the use of recent digital representation techniques, these proposals, add nothing. They do not provide interactive and real time checking strategies, and do not take advantage of new interconnection and information sharing possibilities between users and participants on the project.

2.2. Current state of the augmented reality technology.

The technology which helps to overcome all these limitations and we are going to evaluate and incorporate to the teaching system is the AR. Their creators [15] 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, 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 at 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[16]. In the field of the education specific applications for maths and geometry have been studied [17][18]. In architecture the use of AR is anecdotic; the precedents in this field are the indoor studies [19] [20]. 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[21], the Luminous Table[22] or the Sketchand+Benchworks[23], where different data entry devices are combined in a virtual theatre. More recently,[24][25] different tests on building renovation have been realized. In the urban planning, we may mention [26] and in the infrastructure of the construction enginery [27]. In the architecture teaching stand out [28][29][30][31] 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 [32] which had shown a big interest for it.

In our opinion, the quantum leap and dissemination of this technology is due to it is accessible from mobile phones thanks to the libraries ARToolkitPlus [33]. 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 GoogleSketchUp are generalising the use of this technology, but mostly indoors.

2.3. The problem to solve.

The challenge we have to face year after year, is to incorporate in educational training processes, digital technologies. We are convinced that students feel strongly attracted to them and teachers do not always know how they should be embedded. From educational centers, there is a continuing insistence
on maintaining traditional strategies perhaps for fear to distort the contents of the fields due to the complexity that some traditional computer applications have. We are usually focused on drawings production or to the final presentation assessment, instead of promote ideation generation or increase spatial and graphical skills. We should use this spirit from students and the easy use of the AR and NPR, to study how it affects on the future professionals performance, giving priority to the contents and to the architectonic concepts, not to the learning of computer tools. This is the reason why it is planned to create a multidisciplinary team of investigators with knowledge in all the different areas implied. With them, we are designing new teaching strategies where tools and materials are being developed in the ICT and AR environment. Following this topic we have already done several feasibility trials through the Laboratorio de Modelado Virtual de la Ciudad, LMVC from CPSV, Centro de Politica de Suelo y Valoración of the Barcelona Tech. University, which demonstrate that low cost equipment and free applications are useful to carried out planned research.

Figure 1. AR application sample used for the virtual reconstruction of architectural heritage study in the roman city of Gerunda, Girona, Spain, carried out by the authors in the LMVC.

3. GENERAL METHODOLY. THE CASE OF STUDY.

3.1. Methodology.

The general used methodology is the study of case, which is used habitually in the educational evaluation. In our work, the case will be formed for postgraduate and master degree students groups. A new educational proposal will be tested, looking at both quantitative and qualitative review. Augmented reality will be incorporated on their learning training as a technology for visualization and compression of the architectural forms, as well as a graphical synthesis tool to show theoretical concepts that will be developed. We separate methodology into two different stages

3.1.1. Qualitative investigation.

Inside every study of case there will be established a few Contents. They will be structured from a general plan of studies and will depend on the specific content bonding with the rest in every school period. Hierarchy of knowledge to be acquired before and after every course, should be clear and close to Bloom's taxonomy [34]. It is a question of relying on a structure that should allow teachers to evaluate capacities improvement on every level. This purpose or objective for every course is based on the fact that the students are more or less familiar with the new technologies. Is to verify that when teachers use TIC tools, students pay more attention, academic performance is increased, and they fell more interested on realizing the exercises. Besides that, we want to check that once they use AR to visualize his proposals, performance and graphical skills increase even more. Students often do not show interest and are not motivated when they use traditional methodologies.

Materials and didactic contents. 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'll will work in coordination with the heads of the subject who will take charge of the virtual construction exercises. In many cases will be necessary to realize a brief training or make some specific user manuals for 3dsoftware or 3D modelling.

Equipments. Because of the importance of computer technology in this study we will describe the equipment used. In short, the basic equipment consisted of portable computers and even netbooks as Toshiba NB200 owned by students themselves. They were provided with a second simple webcam, like Logitech model C200. This allowed to see indoor RA models RA using 8x8cm to 20x20 cm. Markers. The virtual models were generated by Google SketchUp's free license of each student and they were exported to AR using the free plug-in from Ar-media Inglobetecnologies's whose duration of 30 seconds allows the basic adjustments. In the first study case the teacher exports an AR model using the professional application ArExporter 2.0, so that students can see it for unlimited time using the free viewer ArPlayer 2.0, once received by wifi or USB pen drive. In case of more advanced courses, we work with student’s own portable computers and educational licenses of different computer applications, Google SketchUpPro, AutoCAD, 3DStudio max, Photoshop, or even Build-Ar and MrPlanet, other free AR's applications that allow the use of two or more markers simultaneously. This could be useful for wide range viewing, because at least one marker could be recognized and visible. Outdoors, students will use more advanced webcam like Hercules Dualpix of 1 Mb, to allow viewing the
models up to 12 meters of distance with 50x50cm trackers, and avoiding always the direct lighting. Model size could reach then 16 Mb. For longer distances, it is recommended the use of a higher range webcam, with a minimum of 5 Mp, as Logitech C910 to allow viewing models of 25 Mb up to 25 meters away on 50x50 cm. Markers.

3.1.2. Quantitative research.

It refers to the part of the work dedicated to the information compilation. We have considered: Participants. There will be selected an experimental course and a control one if feasible. They will follow an ordinary course. The group size will be variable but it is necessary a minimum of 15 students to have a significant population sample. For that reason may be necessary to repeat the experiment. Measurement and evaluation of academic performance. As we described we'll try to work with two groups of students, once finished every process the teachers from both groups will evaluate the results together. Students satisfaction surveys. Using an specific questionnaire every student is asked about his performance assessment, about daily hours he has dedicated to the RA, and if the educational facilitated resources have been appropriate to the complexity of the exercise. We are based on SEEQ questionnaires as an instrument of evaluation and auto evaluation of the own students. Using a specific survey form, tall will depend on the resources and computer technology used in every course.

4. STUDY OF CASE Nº 1.


4.1.1. Main purpose and objectives of the course.

To try to solve the aforementioned deficiencies and to increase master's students skills, they all digital natives, most by force of events, and expert users of both computer and traditional graphical techniques, including collage, we propose an academic experience that tries to increase their competences in computer graphics generation in a new area, the AR, which allows to study, on site, virtual models, and their application on urban projects design. For this purpose, we present a case study of implementation of these new teaching methodologies targeted to Master of Graphic Expression Processes of CUAAD-UDG students. It has been achieved remarkable results by the use of AR.

4.1.2. Methodological proposal for educational innovation in the master course.

Taking into account the background described, we wanted to go one step further raising a dynamic and real time 3d photomontage updated version. We use for it standard devices like portable computer and free or low cost software. A perfectly available option if AR's applications are optical-registration based. Our contribution is the transfer of these AR technologies to education processes, specifically to an Urban design master course. Students have different profiles and they are supposed to work in multidisciplinary groups. Instead of fixed images and traditional photomontages, generation, we work on 3D and interactive photomontages registered on a real environment. Our aim is to demonstrate the usefulness and advantages of this technology for education, where flexibility and responsiveness allows addressing diverse problems. In this way we can work on 3d simple models from a urban scale to an object design for furniture, positioning and scaling them adequately.

4.1.3. Study of case, educational materials and evaluation.

In our work, the case focus on groups of some students of the Master on Processes and Graphical Expression in Architecture and Urban Projection; a multidisciplinary group of 24 licentiates in architecture, urbanism, graphical and industrial design who we have experimented with. The agenda was a combination of lectures and laboratory indoor and outdoor practices. Concretely in the Cultural University Center of the University of Guadalajara, Mexico, which is under construction. A previous urban model was proposed, and students were required to realize diverse contributions on facades and proposing in addition urban furniture around public central square. As we have described basic AR software was used. 4 theoretical classes of one hour and a half were given, and we spent 15 hours of practices in the classroom, distributed in four meetings. In one of the meetings there was a guided tour of the place, after that, the urban modelling began and some facades from the city were added to this basic
Working areas were defined for each group and they all developed a urban setting project. It included the design of the attached real facades, urban furniture and the corporate identity. The designed objects were viewed by AR in the exterior and in the foyer of the CUUAD for a first evaluation.

After that we worked in the area of the project to test models and for scale, vanishing points, and perspective, adjustment. The visualization was carried out by means of personal computers and webcams, using 30x30cm trackers, which were initially designed for indoor viewing. We achieved consistent visualizations up to 12mts of distance. Exceptionally in this case to obtain video images, the process was recorded with a video camera Sony Handicam CCD-TRV-138 using a graphics card Dazzle Hollywood DV connected to a laptop (Fig. 2 and 3).

The course evaluation was based both on assistance to it. (It was over 95%) as in the final delivery note. We have carried out one more objective evaluation based on a questionnaire, it had questions relative to the degree of satisfaction, usefulness and global valuation of the system. Besides that we asked about how this methodology helped the students to improve their competitions and skills on graphical computer science, beyond current knowledge. Anonymous surveys were distributed between the students and they were required to rate questions from 1 to 5. Students percentage of participation was 67 %. Questions got a score of 5 in 94% of the answers. In this context the experimental group has overcome fully the result of the group of control, pupils from previous year course. They worked in the same urban project but did not join the AR technology to it. So its final participation did not overcome 45 %.

As preliminary conclusions of our work, considering the acquired experience, we must stand out: In this Study of case, it have been demonstrated that the use of mobile devices like laptop equipped with webcams and combined with low cost applications of Augmented reality, are an acceptable substitute of the traditional photomontage technologies. It allows dynamic viewing of the students virtual models sited on their future emplacement, even in outdoor environments. Having in mind the obtained results, these strategies allow academic and professional performance improvement; shortening urban projects development time, and promote their creativity whether they are architects, town planners, designers, etc.

5. STUDY OF CASE Nº 2.


5.1 Main purpose and objectives of the course

Beyond the superimposition of a virtual model in a real environment, the characteristics of Augmented Reality technology (AR), merging virtual information on real environment, are usable in a wide range of applications on engineering and construction areas. They could offer potential advantages in all stages of the construction processes, from initial planning and conceptual design problem, to the management and maintenance of building systems throughout its lifetime. We believe that it could be useful in staking tasks, or facilities control too, as far as, this technology would facilitate the interpretation of drawings, technical documentation and other specifications, while these systems can generate a
real image superimposed on a specific stage of the construction process and by joining a database, showing different levels of information based on each user's queries.

In the present case, interior spaces of existing buildings, could be considered for example, the need to know about the building loads of an area, its thermal behaviour, or the location of certain facilities. All of them are possible virtual models that overlaid to real space, and should contribute to a better understanding of the building, and to a greater efficiency in construction processes, rehabilitation or building maintenance tasks.

In this paper, we describe a teaching experience conducted in the framework of the BEST BCN platform (Board of European students of technology, which brings together students from over 80 countries). It was carried out by 25 international students from various European nationalities, studying architecture and engineering. It was performed at the School of Building Construction of Barcelona in September 2011.

We aimed to assess the use of AR technology in the learning processes of the future building construction engineers, by applying a set of tools related to this technology. The experience was raised from two different exercises where the student should be able to communicate to other participants a greater knowledge and technical information of the building where they were working. They should, somehow, "complete" their real space with some constructive information.

The goal, therefore, was twofold: first, to evaluate the possibility of using this technology in indoor environments, linked to construction and maintenance processes, so that the user could acquire more technical knowledge of their environment, and secondly, with the application of these emerging techniques, we try to develop new alternative teaching methods to the traditional ones, that would return in greater efficiency and academic performance. Teaching experience so far unreported. (Fig. 4)

![Sample images illustrating the models generated by teachers for project and case study evaluation.](image)

Figure. 4. Sample images illustrating the models generated by teachers for project and case study evaluation.

On this case, the students were in an intermediate stage of their university studies and their habits in projects definition are just beginning. The working hypothesis is to see how much AR techniques can help the student in the initial process of projects elaboration. Their space-control skills may be important in the formal decisions and to implement their proposals.

5.2. Methodology and academic content of the course.

Contents definition was appropriate to an educational activity of a workshop course. It aimed to provide a better understanding of these new techniques. Cases also were tested in different size scales and different indoors spaces.

The workshop was divided into two parts: in the first one, student had some lectures about the fundamentals of the technology, such as recording systems, rendering, occlusion, tracking systems, and some examples of common applications implemented in different areas were showed. So, the student was aware of the possibilities offered by the use of this technology.

In a second stage we developed two exercises. Both were carried out with free software applications, educational licensed, or low cost as Ar-media, buildAR, Sketchup, and junaio, creating virtual models to be represented on mobile devices such laptops, Netbook, and if possible, on UMPC and last-generation phones. Those devices have become useful tools for the use of augmented reality. They are now equipped with more sensitive cameras, faster processors that can handle complex 3d image processing routines, and they incorporate accelerometers, compasses, gyroscopes, and positioning systems and location. All these features, which are often present in modern smart-phones, have made them prospective non immersive AR platforms.

To carry out the exercises, some common steps were followed. After introducing the activity to be performed, each participant selected a site (exercise 1) or an interior area (exercise 2) and recreated a virtual architectural proposal, choosing different levels or layers information to display. It was assumed that the Knowledge of the virtual object modeling was already acquired during their training as engineers or architects. Once resolved and discussed in each specific case modeling, registration, texturing, lighting and occlusion problems, which are inherent in this technology, we proceeded to register the model in its actual location using an optical marker recognition based systems. We avoid the use of an optical marker-less recognition system because these systems are more sensitive to changes in environmental light conditions, and in previous experiments, natural features were unrecognizable and the scene was unstable and useless.

5.2.1. Exercise 1

Consisted of creating a "collaborative" scene where each student should be able to develop a virtual proposal for the expansion of the engineering school. They should be able to view it
and explain it by using AR technology. The scene was generated within the working class, and somehow, intended to replace the creation of a real model that may have been the classical system used to explain those proposals. This first exercise intended to familiarize students with the use of flat markers and software. Each marker was associated with one student proposal, a virtual architectural model in three dimensions, to be displayed within a virtual model base. We used SketchUp 8, in its free version. This program also allows you to import nearby georeferenced buildings models that students used as a base model. As AR application we used SketchUp plug-in, from AR-Media, also in its free version. That plug-in allows the simultaneous use of several markers associated with each one of the students proposals. That feature was critical to make the collaborative scene possible. This free version contains all the possibilities of the paid version, but is restricted to 30 seconds for viewing the scene. (Fig. 5)

Figure 5. Examples of a collaborative scene created from exercise 1 using different models.

5.2.3. Exercise 2

In the second exercise the students should "augment" the real space where they were. They should design virtual proposals to evaluate some changes in that area, or provide it with additional technical information (facilities, structures, etc ...) that could be useful for future maintenance tasks. The scene was generated in an interior space, but outside the classroom, so that the display devices should be mobile. In this case, laptops, equipped with additional webcam. We used in the same way Sketchup 8 in its free version, and the Plug-in AR-Media, which in this case was helpful in allowing the work with "occluders", environmental elements that were not visible in the scene but allowed hide parts of the virtual model. This feature helped to make the scene more believable. Each student chose a random school indoor space, choosing different levels or layers of information to display. They modelled their proposals, previously tested in the classroom, and performed a scene that should be the result of merging the real environmental information and their virtual models superimposed. (Fig. 6)

Figure 6. Examples of an augmented scene created from exercise 2 using different models and indoors spaces.

5.3. Evaluation of the study

Students were required to work in a final presentation that should include a description of the different "augmented" spaces they had work in. It was useful for checking the effectiveness of this technology in the learning process. As we show below, it was demonstrated that the AR Technology implementation on learning processes improved their spatial skills and encouraged their creativity2.

In parallel questionnaire 3 were conducted specifically oriented to assess the degree of satisfaction of the activity and to get a global opinion of the technology applied. So, questionnaire was divided into three sections. First, we asked about personal issues, age, gender, level and type of training, the prior knowledge about various programs, etc.... In the second section we asked about the content and course material that students worked with, and finally, we surveyed on the usability and usefulness of the technology learned.

5.4. Results

The implementation of the use of AR technology in different environments, as explained above, gave very different results, because of students’ creative freedom, and their different backgrounds.

In the first case, 100% of students were able to complete the exercise. They all designed their virtual proposals, and the environment constructed from nearby geolocated models, and they 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 inside a virtual model, 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.

On the second case, 65% of students were able to finish the exercise. Most of them designed their virtual proposals and were able to visualize them in their real indoor space. Visualization “in site” helped to correct some proposals and made them more consistent according to real space requirements. In relation to the questionnaire, we

2 A Video of the students activity can be found on: http://www.youtube.com/watch?v=o696Jp58bUk
3 Questionnaire can be found on: https://docs.google.com/spreadsheet/viewform?formkey=y=dDhicnk0d1dSMkY0OS1sRnFBLXRhMGl6MA
obtained a total of 17 responses. In relation to students personal training and the prior knowledge level of the technology, should be noted that the most often used applications were "Email" and "internet browsers" followed by office applications, CAD and photo editors. The 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. (Fig 7)

**Figure 7.** Results average table about the prior knowledge of the technology.

Related to the opinion, teaching content, and material of the course, there 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. (Fig 8) The worst rated question was referred to the possibility of learning such content independently.

**Figure 8.** 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. (Fig 9)

**Figure 9.** 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 consider in future work.

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.

**5.4 Particular conclusions, discussion and future work.**

In relation to students academic performance improvement: We could say that the combination of practical "on site" testing, using current technologies of augmented reality, combined with the study and classification of information, and how it is generated and displayed, as well as the establishment of the theoretical basis of this technology to use with mobile devices in the field of building, allowed:

a. Spatial skills improvement for analysis and description of existing buildings. Encouraging creativity and helping to recreate and modify more consistent proposals in real time and in their real environment.

b. Dissemination and exploitation of the generated models, that could be useful both for other subjects such as facilities, construction, structures, in order to facilitate understanding of its contents, and above all, to rehearse with them the possibility of managing all the information in one model of the whole building, to visualize virtual scenes, coordinate and manage maintenance tasks,
etc ... all on the real space, and depending on the demands required by each user.

In relation to the use of devices based on optical recognition systems for registering virtual models in indoor spaces, we highlight some of its advantages: High accuracy achieved with the 3D registration (near to 1cm), objects generated by computer can easily be linked with markers; the possibility of implementing elements of interaction (based on distances and rotations between marks); and the economy of the systems (as they often are GPL licensed and registration only requires a webcam). However, we must also take into account its limitations, for example, the strong dependence of the light conditions, the working local scale (distance camera-brand) and the fact that the physical environment is altered by the marks. Especially critical in the case of existing buildings. So, marker-less based optical tracking system might be more appropriate.

6. GENERAL 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 a 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 is 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 consider 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.

From the point of view of the applicability of these strategies, the preliminary conclusion is that the use of pattern optical recognition based AR system requires large trackers. It could be valid for distances no more than 25 meters and in optimal lighting conditions, useful to work outdoors in optimum environmental conditions. Besides that, if the virtual model must be watched at a large distance, it requires reorientation to be projected onto a tilted tracker, eg 45 degrees that is more easily recognizable. Instead we have had no problems with file sizes, with Ar-media, models can run more than 5 MB. However, we have proven that if you have good coverage Wiimax or a modem is possible to download the file using a Dropbox application. This option is applicable in indoor wireless coverage. Slowness and network capacity can be a problem if it has to transmit a large file.

7. REFERENCES.

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