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Relationship between student profile, tool use, participation, and academic performance with the use of Augmented Reality technology for visualized architecture models

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ABSTRACT

In this study, we describe the implementation and evaluation of an experiment with Augmented Reality (AR) technology in the visualization of 3D models and the presentation of architectural projects by students of architecture and building engineering. The proposal is based on the premise that the technology used in AR, such as mobile devices, is familiar to the student. When used in a collaborative manner, the technology is able to achieve a greater level of direct engagement with the proposed content, thereby improving academic outcomes. The objective was to assess the feasibility of using AR on mobile devices in educational environments and to investigate the relationship between the usability of the tool, student participation, and the improvement in academic performance after using AR. The validation was performed through a case study in which students were able to experience a virtual construction process overlapped onto real environments. Results were obtained by students' pre-tests and post-tests. In line with our assumptions, the use of mobile devices in the classroom is highly correlated with motivation, and there is a significant correlation with academic achievement. However, the difficulty of using and generating content is a complex factor that suggests difficulty when implementing more complicated models.

1. Introduction

Information Technology (IT) represents a set of tools and applications that allow the incorporation and strengthening of new educational strategies, many of which have been defined in new teaching frameworks in the last two decades (Dede, 2000). In an international educational framework, such as the European Higher Education Area (EHEA), which runs the university studies of member countries, such as Spain, where this project was undertaken, the application of IT in the educational process is particularly relevant. The interest of educators in using these technologies in the teaching process presupposes greater engagement and an increase in student motivation in understanding the content (Kreijns, Acker, Vermeulen, & Buuren, 2013; Roca & Gagné, 2008; Shen, Liu, & Wang, 2013), leading to improved academic results. A number of studies have investigated the questions, problems, and solutions that allow for educational innovation using IT (Guiliarte Martín-Calero, 2008) and many types of comparative educational practices and test the effects of incorporating these practices into the learning/educational process (e.g., Law, Pelgrum, & Plomp, 2008).

With regard to university teaching, specifically the fields of architecture and building engineering, space visualization and conceptualization are essential aspects that the student must master before initiating his/her professional career (Leopold, Górska, & Sorby, 2001). Tools that use computer-assisted design (CAD) technologies and, more recently, building information modeling (BIM), help to create virtual models that are nearly identical to actual structures and have great capacities for architecture management and teaching discussion. Because of the improvements and evolution of this tool, which can be grouped into wider concepts, such as architecture engineering construction (AEC) or computer-aided architectural design (CAAD), the usefulness of such technologies as computers and design programs in teaching is clear (Al-Qawasmi, 2005; Doabelis & Brinkis, 2006; Pozzi, 2012). Combined with the continuous development of and cost reductions in mobile technologies, both professionals and students can increase their working capacity and use programs and technologies that allow them to manage, visualize, discuss, and evolve every type of model and project more efficiently in both 2D and 3D (Bouchlaghem, Shang, Whyte, & Ganah, 2005).

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One visualization technology that is gaining attention and is being incorporated into every field is Augmented Reality (AR). Its creators (Milgram & Takemura, 1994) define AR as a virtual reality variation in which the user can see the real world with virtual objects mixed or superimposed upon it. In contrast to virtual reality, AR does not replace the real environment; rather, AR uses the real environment as a background. The final result is a file with data, static images, or a dynamic 3D virtual model superimposed onto a real-time video of the environment (Billinghurst, Kato, & Poupyrev, 2011; Kaufmann, 2002). This scene is shown to the user via a computer screen or other device, such as a projector, digital board, special glasses, smartphone, or tablet. This concrete superposition capability between virtual models and reality makes this technology an interesting resource in any type of teaching in which improving students' spatial comprehension may be required. The present study is performed within the context of the use of AR in architecture and building engineering instruction to improve students' spatial comprehension, a topic that few studies have investigated (Broll et al., 2004; Malawi & Srinivasan, 2004; Piekarski & Thomas, 2001; Tonn, 2008). However, the main problem in architecture and building construction is how to integrate virtual objects with actual images. The integration must be accurate and at the right scale to achieve the hypothetical situation and size matching in an actual scene. If a student can control these parameters and avoid possible mistakes, he/she will achieve an improvement in spatial capacity for analyzing any type of architectural figure using a familiar technology, such as his/her own mobile device (e.g., laptop or telephone) and can work collaboratively in knowledge creation and generation with his/her classmates and the faculty.

The present study has two main objectives. First, we analyze the implementation process, the difficulties of use, and the degree of student satisfaction when using an advanced visualization technology with personal mobile devices. Second, we investigate the relationship between motivation, participation, and final academic grades of university students. Analyzing the results of these objectives will lead to a better understanding of how to implement new teaching methods with mobile technologies. Thus, greater acceptance and motivation from the student body will be achieved. In an intrinsic manner, online content adaptation and new synchronous and asynchronous e-learning methods should have characteristics that would theoretically be demonstrated in improvements in spatial abilities and academic grades for architecture students.

2. Literature review

2.1. Good practices for technology acceptance

The interest, need, and urgency of implementing new technologies in education and universities in particular is a relatively new situation (Rogers, 2000). However, technological innovation, which is intended to improve the student learning process, must be capable of providing support to address difficulties that could arise with the student in the use of and interaction with technological elements. These elements must not obstruct the auto-learning process, which is altered by this technology, and the students must be motivated with the new educational methodology.

It is not unusual for the faculty to be the first line of resistance against technological innovations in teaching. There is a natural reticence in the academic field about the use of technologies that are associated with leisure or personal relationships, such as mobile devices (e.g., telephones, tablets, iPods), the Internet, texts, and audio content, such as podcasts. It is beneficial to consider that appropriate content for these devices does not displace teaching but rather provides increased value and positive student perceptions of the subject being taught. Callaway (2009) tied the use of technologies that are familiar to students to better academic performance, one of the recent principal "fears" of professors with their implementation.

Another major deterrent to implementing IT in teaching is the administrative environment: professors must be trained (Georgina & Olson, 2007) and must be capable of giving full-time support to students, the success of which is dependent on the professors' willingness and ability to devote the time required for the training, modification, and actualization of the related content, including a post-evaluation of all processes (Champeny et al., 2004). These premises assume an economic investment that not all institutions will accept (Hu, 2006) and that many teachers will not make unselfishly (Milliken & Philip-Barnes, 2002). Without a motivated teacher and environment, the success of implementation will be decreased and the student will have a negative perception of IT usage in education, which could evolve into a lack of interest in the subject.

To incorporate a new IT-based methodology into a specific teaching environment, some recommendations for avoiding student rejection must be considered. The literature defines so-called "good educational practices" that are primarily focused on virtual rooms, distance education (or e-learning), and semi-present teaching (Área, San Nicolás, & Fariña, 2010). These studies have focused on maximizing profit from web service content, alternative methods using the intranets of each university, and auto-evaluation systems of information (Chickering & Gamson, 1987; Epper & Bates, 2004; González & Rodríguez, 2010). From the specific characteristics that shape these practices, four points can be extrapolated, as indicated by the following principal objectives:

- Promotion of professor-student relationships, allowing for a more effective feedback process.
- Dynamic development among students, which is made possible by collaborative techniques.
- Contribution to better task realization by heterogeneous learning methods, meeting high expectations.
- Applying teaching/learning methods based on teaching innovation and new IT technologies.

Considering previous recommendations and logical premises based on such cognitive studies as those of Gantt (1998), who asserted that human beings have a short-range retention capacity of 20% of what is heard and 75% of what is seen and done, it is necessary to migrate the traditional master class (where the student is limited to taking notes of what he/she hears and sees) to a learning system in which the student is an active content generator. This new paradigm is desirable as an optimal learning model, allowing student involvement in the subject and content and the ability to study collaboratively. Similar to what occurred with Internet content (i.e., the evolution to Web 2.0 or 3.0), the student is given an active profile (referred to as a "3.0 student"), and the student who is aided by more familiar technologies is able to place himself/herself in a more comfortable and satisfactory study environment.

In accordance with Massy and Zemsky (1995), any methodology that promotes the inclusion of IT in teaching must have the following objectives:

- Personal production help: applications that allow both the professors and students to carry out tasks faster and more efficiently (e.g., calculation sheets or text processers, draw programs).
- Content improvement: the use of tools that allow for the notification and modification of content rapidly and efficiently (e.g., e-mail, digital content, video, multimedia resources) without changing the basic teaching method.
- Paradigm change: at this level, the teacher reconfigures the teaching activity and learning activities to utilize the new incorporated technologies.

Examples of educational methodologies that have implemented the two first objectives are common, but examples that incorporate the third objective are much less common. In those cases in which the third objective is implemented, most of the solutions involve basic tools and derived applications of an Internet connection (Ruiz & Abella, 2011) while taking for granted the presence of mobile devices or an Internet connection, not for advanced options, such as analysis, interaction, or professional visualization, as proposed by the present study. The following is an analysis about how the incorporation of mobile technology leads to content and teaching dislocation and how the use of technology that is familiar to the user (in our case, the student) generates an intrinsic increase in motivation to use this type of content.

2.2. New learning strategies, from e-learning to mobile learning using AR

The study of the relationship between student motivation, degree of satisfaction, and the user experience or student perception in the interaction with and teaching of applied collaborative works is extensive, with recent contributions that have helped to design new e-learning experiences or dislocated teaching using IT (Giesbers, Rienties, Tempelaar, & Gijselaers, 2013; Sun & Hsu, 2013).

The same is not true when the focus is the use of mobile technology and AR applications, which are more extensively studied from a technological perspective (the Institute of Electrical and Electronics Engineers (IEEEs) International Symposium on Mixed and Augmented Reality (ISMAR) is the global reference in these advances) or from the perspective of sociological and communication impacts (as addressed by the annual conference of the International Communication Association) instead of its educational capacity or ability to transform teaching, which is the focus of the present study.

The evolution of mobile technologies and the increased power and sophistication of mobile phones, which has led to the advent of smartphones and tablets in the last five years, have created a new body of research on the use and optimization of these devices in ubiquitous training, allowing for both onsite and virtual collaborative work with faculty members and students (Lu, 2012; Parsons, 2012). The increasingly advanced and comprehensive but easy-to-navigate applications directly generate a greater utility perception from the user and a better attitude about using this technology (Kuo & Yen, 2009); these premises represent one starting point for a more consistent inclusion of these technologies in teaching.

These new practices or teaching strategies, which are based on mobile collaborative environments and the use of social media, are defined and grouped in recent works, such as the book entitled Social Media and the New Academic Environment: Pedagogical Challenges (Patrut, Patrut, & Cmeciu, 2013). Expanding on the definition of the "Learning 3.0" concept, it is possible to define a personalization of the generic "M-Learning" concept, which has the following principal characteristics: the interaction between the user and content, the contribution of media to immersive environments, the incorporation of communication technologies, the use of new contexts for education, and the awareness that sharing and recording the process of learning is possible. The definition of Learning 3.0 includes technology because it involves the provision of collaborative tools, such as blogs and wikis (Moran, Seaman, & Tinti-Kane, 2011), mobile-device interactions (e.g., iPhones, Android mobile phones, Wiis, iPods), new virtual simulation training environments (e.g., Second Life, AR), and connectivity tools for searching locations (e.g., 2D codes, Google Maps). The collaborative training tools between teachers and students can be strengthened when they use familiar technological resources where students can demonstrate their receptiveness. The integration of mobile devices with multimedia applications provides students with immediate access to information (unlike traditional methods) and expands their experience beyond the academic environment.

There are few documented relevant teaching experiences. Within the framework of medical education, we studied the availability of medical information anywhere interactively through mobile interactive learning objects (MILOs) (Holzinger & Maurer, 2005). In addition, applications have been reported for language learning (Chinnery, 2006) and university organization management through personal digital assistants (PDAs) (Corlett, Sharples, Chan, & Bull, 2005), allowing for schedule consultation, calendars, messaging, and teaching materials. It is also important to cite studies in archeological and historical frameworks (Ardito, Lanzilotti, Pederson, & Piccinno, 2008) that are relevant to the present study because they focused on outdoor teaching strategies, in addition to studies focused on geology and the natural sciences (Yuh-Shyan, Tai-Chien, & Jang-Ping, 2005).

Although a qualitative assessment of results and teacher recommendations is still pending in the above mentioned studies. On the other hand, highlight the specific case of education in architecture and urban planning where those type of studies are practically nonexistent, but they are necessary because the location of a building or city and its context (e.g., the resident's living experiences, transverse and setting knowledge) are essential for understanding and designing all types of geographical information (Lynch, 1998; Norberg-Schulz, 1971). The first studies that evaluated the use of IT in teaching activities related to architecture/construction were focused on the use of whiteboards, interactive books, social media, and other resources related to the visualization of 3D models, buildings, and spaces in architecture education (Rafael, Pérez, & Dueñas, 2006; Wang & Schnabel, 2006; Whyte, Bouchlaghem, Thorpe, & McCaffer, 2000).

More recently, immersive technologies have been used in virtual and AR worlds, and their usefulness has been assessed by a number of international projects (Alvarez, Alarcon, & Nussbaum, 2011; Brederode, Markopoulos, Gielen, Vermeeren, & de Ridder, 2005; Di Serio, Ibáñez, & Kloos, 2012; Galantay, Torpus, & Engeli, 2004; Pan, Cheok, Yang, Zhu, & Shi, 2006). These experiences, which used AR in the areas of entertainment and education, demonstrated the vast potential of this technology. In education, however, AR might be considered a new tool, and further studies are necessary, with particular attention paid to the user experience and learning process. Concretely, the entertainment capability of these technologies can increase interest in less interesting classes, including classes in which the content is presented with no interaction with the student, which could lead to demotivation and loss of interest (Chen & Wang, 2008; Di Serio et al., 2012).

AR and virtual reality (VR) share common features, including immersion, navigation, and interaction (Dunleavy, Dede, & Mitchell, 2008). However, AR has two main advantages over VR. First, AR allows for collaborative experiences in a real scene. Users can work with computer-generated objects as if they were real objects in a real environment, in real time. Second, AR allows for tangible interactions. By superimposing virtual objects onto a real environment through markers, the user can modify and manipulate the scale, position, and location of virtual objects. AR technology, by providing new interaction possibilities, promotes active student participation in its own knowledge construction.

2.3. 3D digital and mobile visualization of content in architecture framework

In architecture education, the visual component is one of the more relevant aspects with which the student works and studies and which the student must correctly interpret (Boeykens, Santana-Quintero, & Neuckermans, 2008). Spatial information is represented in a number of ways, ranging from traditional methods, such as printed plans and physical models (working from 2D to 3D), to modern methods, such as digital printed plans and tridimensional models, which allow a greater level of detail and the ability to navigate and actualize potential changes instantaneously (Fonseca, Redondo, Sánchez, Villagrasa & Martí, 2012). The different methods of visualization allow both students and professionals to work collaboratively and communicate their ideas and the space and project more efficiently (Bouchlaghem et al., 2005).

Focusing on the specific case of AR, previous studies have suggested that the introduction of this technology is feasible in different areas of the architectural education framework, including design, excavation, staking, inspection, coordination, and supervision of tasks (Shin & Dunston, 2008). Specifically, in the field of architecture and urbanism, AR can be used to predict the impact of construction on the landscape (Sánchez & Borro, 2007). In the rehabilitation of buildings, AR has been tested as a tool for viewing the final appearance of the work and changing materials, colors, and textures on mobile devices at a one-to-one scale (Tonn, Petzold, Bimber, Grundhöfer, & Donath, 2008). This capacity of AR technology, which shows a "completed" reality superimposed on reality, allows for the creation of an impossible image of what does not exist as a result of the analysis of existing building systems (e.g., structural, facilities, and envelope) and geo-location and photo composition. AR could facilitate rehabilitation and maintenance tasks, systems verification, and interactive updates in the same place and in real time, promoting more efficient management and control processes of building construction elements (Sánchez, Redondo, Fonseca, & Navarro, 2013). All of these improvements in space visualization and interpretation have clear relevance to the professional world and lead to a teaching process that allows for the rapid assimilation of concepts by the student (Vechhia, Da Silva, & Pereira, 2009).

One of the main problems encountered in the design phase of this type of educational experiment is how to display 3D models in mobile devices to allow different interactions to occur easily and inexpensively using free options. Our belief is that the success of a technology-based education depends largely on the accessibility of technology and the ease of use by teachers and students, in accordance with other studies that affirm that ease of use generates a better perception of the usability of specific systems (Kuo & Yen, 2009).

With the previous hypothesis as the starting point, it is necessary to use methods that will not add costs to the student. Moreover, with a focus on architectural visualization, it is necessary to highlight the need to work with free software and with the most compatible formats and programs. Reaching this point, it should be noted that with the increasing number of applications, viewers, and systems that facilitate digital design, it is difficult to find one general solution among different professional sectors (Khiati, 2011). This working ambiguity is easily observed depending on the geographic area, with different preferred programs depending on the country and region and even according to the university or labor task within the same geographic area.

In the Catalan architectural educational framework, the products developed by Autodesk (San Rafael, CA, USA), a software leader related to CAD and BIM technologies that has free licenses for three years of the best known and most commonly used software in drawing and modeling in 2D and 3D, including AutoCad©, 3DMax©, Maya© and Revit©, are the foundations of architectural work today. This type of multi-format work platform allows for the connection between diverse architectural and building design steps, specifically in the educational framework, allowing for a major work delocalization, as is happening with new devices and operative systems that work and upload content directly to the cloud. The proposed solution by Autodesk® is AutoCAD®WS, a software program that works directly in the cloud to store files, directly allowing for the visualization and editing of any type of fixed or mobile support through environmental interfaces.

With regard to the visualization framework, the working systems and available programs for any format or device are innumerable. However, attention should be focused on the most common formats because of their frequent use and standardization (at least in the project study framework, where the authors have 40 years of architecture teaching experience in the Catalan framework) and evaluate how they can be adapted to educational projects and free usable solutions. For example, we can affirm in the Catalan sector that the most common format for 2D content publication is the portable document format (PDF) due to free programs, such as Adobe PDF (Adobe Systems Incorporated, San Jose, CA, USA), doPDF (Softland, Cluj-Napoca, Romania), and Cute PDF (Acro Software, Inc., Haymarket, VA, USA), examples that allow printing and professional work with regard to reproduction. In recent years, this format has incorporated the capability to visualize and interact with 3D models (PDF3F format). In this case, however, it is necessary to work with free versions of software programs; however, use of such programs is not possible when generating models because it is necessary to pay for programs, licenses, or converters.

With Autodesk products, 3D model generation is possible directly from programs in DWFx or OBJ formats, but this option is not available in all of their products. Such a format as DWFx, which is owned by Autodesk, allows for visualization and interaction on computer and mobile devices by installing Autodesk Design Review© or AutoCAD WS, which evolved to Autodesk360©. This format allows one to work on all types of models both locally and on the Internet, which is now known as "the cloud." The DWFx format is the functional equivalent to PDF3D (Gatt, 2012) and provides a free solution, but it is not common to find presentations in the Catalan teaching architecture framework that use this format.

The opposite case is found in Google Sketchup© (Google, Inc., Mountain View, CA, USA), a visualization and presentation tool for all types of 3D models. This solution provides free and student options and professional licenses, allowing common CAD/BIM formats, such as DWG, DXF, OBJ and 3DS, and raster image formats, such as JPG, GIF and BMP, to be imported. This capability of combining raster and vector elements in a simple and usable work environment has led to an increasing flow of use in architectural project presentations, while it is common to run more complex applications, such as 3DMax©, Revit©, or ArchiCAD© (Autodesk), when applying texture exercises for pictorial and realistic redirection. Another advantage of this platform is its capability of exporting compatible formats for reference architecture (RA) system visualization, which is a basic aspect of the present study.

3. Method

3.1. Participants and design

The project was modeled by the CAD/BIM Group of the Architecture Department of La Salle, Ramon Llull University. The study was performed during the 2011–2012 academic year with students in their third year of an Architecture and Building Engineering degree. The experimental framework was completed in the course "Representation Systems II," a nine-ECTS-credit course that is taught annually. A total of 57 students participated in the study (29 females and 28 males, mean age = 19.45 years, *SD* = 3.05). All students previously took drawing, design, and 2D and 3D modeling courses (a total of 18 ECTS credits over the course of three semesters).

We worked with two groups of students. The first group (G1) had nine students from the Tarragon Campus, still this group in which initially was designed the experience and the methodology to be followed (Fonseca, Martí, Navarro, Redondo, & Sánchez, 2012). The second group had 36 students from the Barcelona Campus following the same methodology (Currently the Architecture degree of La Salle is performed in the cities of Barcelona and Tarragona). This second group was divided into two subgroups: those who took the course for the first time (G2 = 36), and those who were repeating the course (G3 = 12). For this latter group, when they took the course the first time, the course used a traditional teaching system through printed layouts for both 2D and 3D information, so this group will provide a subjective and concrete comparison of the two methods subjectively. While the G1 and G3 groups had a single teacher, the G2 group was taught by three instructors, so the average number of students per teacher was similar in all cases (initial guidelines are carried out jointly in the group G2, while for the practical realization are divided into small groups tutored by a teacher).

To evaluate the principal objectives of the study, the usability and degree of difficulty in the use of AR technology on mobile devices for education proposes and an assessment of the student's academic performance improvement, the experiment was performed in three stages. Student education consisted of specifically documenting the technology and project, practical performance of the diverse elements that compose the practice, and a methodology usability evaluation and degree of satisfaction. In the first stage, as shown in the methodological framework in Fig. 1, an initial test was completed to evaluate the student technological profile as well as his/her degree of knowledge and expectations of the proposed technology. From this information and the final test, we were able to measure whether the initial expectation was correct and the main problems of the method, the degree of satisfaction once the student is trained on a new technology and the weaknesses of the experiment to improve the method in future interactions.

In the test design process, to model the responses of implementing new technologies in university teaching resources, there are different models based on the user profile, which focuses on the efficiency and effectiveness of the course and on the level of satisfaction/usability and student preference (Martín-Gutiérrez, 2010; Navarro et al., 2012; Stanney, Mollaghasemi, Reeves, Breaux, & Graeber, 2003). Our case was based on ISO 9241-11, which provides several usability guidelines. Effectiveness (E1) was defined as the user's ability to complete tasks during the course in relation to "accuracy and integrity." Efficiency (E2) was defined as the assigned resources; the students were asked questions related to the expenditure of time and effort for solving the proposed exercise. Satisfaction (S1) was defined as the subjective reactions of users about the course.

Our tests were designed with two main objectives: to obtain the technological profile of the student in terms of his/her use and habits surrounding mobile and Internet technologies and to obtain an overall assessment of the work. To assess the academic level achieved after implementing the proposed project, we compared the results of this course to those from the previous academic year, in which a traditional methodology was used in the 2D and 3D design phases.

To design the pre-test, or technological profile test, and the post-test, or usage/satisfaction test, a structured test was used with the Intranet Moodle system of the university. All of the questions were scored on a five-point Likert scale (1 = never or strongly disagree, 5 = always or strongly agree). The model used was based on prior recommendations from Martín-Gutiérrez (2010) and was previously used in other teaching experiments (Redondo, Fonseca, Sánchez & Navarro, 2012).

3.2. Materials and procedure

The projects chosen for the experiment were preselected by the academic coordinators and the university studies board of directors. The projects are generally local projects that allow for a better approach and knowledge of each case by the student. The Tarragona group worked in a common theme that required the students to investigate Mies van der Rohe projects to obtain the required information prior to the work. In the Barcelona group, the projects were public buildings or projects designed by architects that are part of the university professorship.

In the 2011–2012 academic course, the projects were as follows: the Tarragona campus group had "Las casas no construidas de Mies van der Rohe" (unbuilt Mies van der Rohe houses), and the Barcelona groups had "Casa B-10" (1996–2001) by the architect Jaume Bach and "Casa A-M" (1999–2001) by the architect Elena Mateu. The chosen projects present diverse information that is available in books or present in monographs in the university library, with additional information from online sources, which allows the realization of all type of exercises proposed.

This exercise consisted of making an exposition to represent a group of the developed project layouts and had to include the graphic content. The documents and information had to be made available to the exposition visitor through 2D codes and AR techniques on mobile devices. Another objective of this exercise was

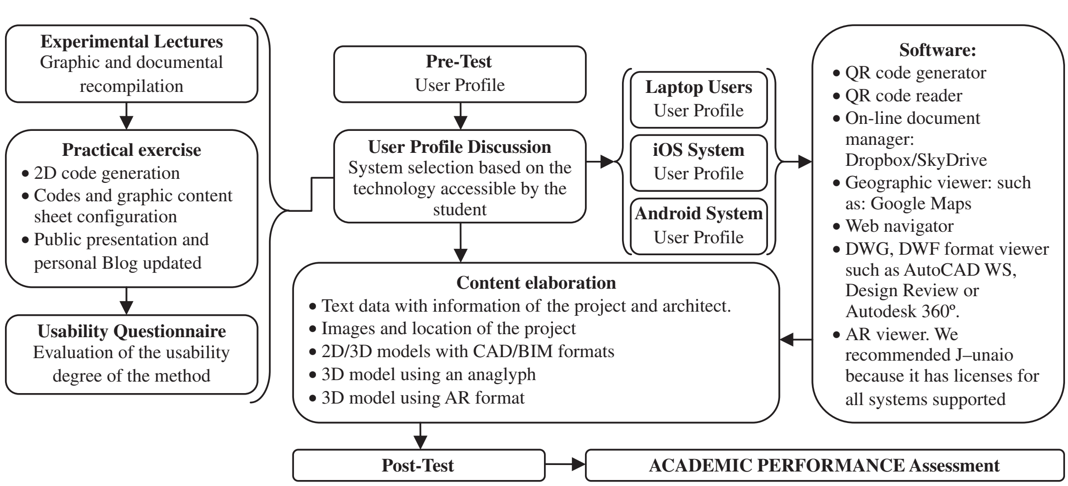

Fig. 1. General scheme of the methodological process.

to provide students with innovative presentation strategies for projects conducted in other subjects in the architecture grade.

The new visualization techniques with mobile devices require an adequate verification of all processes and documentation so that the work methodology can adapt in real time during each class session. The students received theoretical information in 2-h sessions to prepare the subsequent practical exercises. The exercise included a final practical exercise. The course was completed in six sessions, during which all theoretical and practical information was given. The students could consult and provide results comparing their progress with the other students of the class during the elaboration of the exercises. The same results were demonstrated in blogs that students produced at the end of each session, which made it possible to share experiences with all students and with the teacher.

Format and layout orders were established to include text, images, and graphs to represent the course exercises. The final work consisted of a set of six images with dimensions of 20×20 cm at a 150-ppp resolution and in a JPG file format. The students composed images in an editor application, such as Adobe Photoshop. One mandatory element that had to be included in every layout is the quick response (QR) code, which allows for virtual access to the rest of the content. These images were printed in color over a rigid support, with an example of a cube that contained six images on its faces for observation.

The projects were classified into different types: text documentation of the project and the architect, emplacement images, other architectural buildings, and project images of the same architect, 2D and 3D graphics of the project in CAD and BIM formats, stereoscopic images of the project, and 3D models in the RA format. To provide information using QR codes, applications capable of generating and reading those codes were used (these applications were freely chosen by the students among the large number of freely available applications on the Internet). Students also had to use other content management applications to share and publish each information delivery and format; the applications were chosen freely, with Dropbox and SkyDrive as the preferred applications. Finally, the documents were visualized using appropriate applications for each content type: Google Maps for geographic references, Internet Navigator for web references, YouTube for videos, AutoCAD WS for DWG contents, and Junaio for AR content, always beginning with free versions or student versions with no economic impact on the student.

To develop the project, two main phases were established. The first was "Experimental Lectures," where graphic information and project documents were collected by the students. In the second phase, called "Practice Exercise," the students made 2D codes, and the last prints were configured with all content. The final results were presented through public exposition and personal blog posts. In the next figure we can see an example of the type of exercise requested.

3.2.1. Experimental lectures

This section was completed in the initial course sessions and consisted of classifying the necessary documents for each duty using the information obtained by students in the assigned projects. In addition, the students had to locate the Internet links that they used to create QR codes. This process was planned with the purpose of evaluating the individual competencies and ability to work in a group in association with investigation and work planning skills.

Once the information was found and classified, it had to be organized in a public Internet site. This information, which was created by the students, is one aspect that differentiates the current project methodology from prior methodologies in which all information was provided previously. Students, as mentioned previously, generally managed Dropbox and SkyDrive applications documentation because these applications provide access to all content in different formats to the public or with approved consent.

The obtained data were used collaboratively, which means that all participants could access the content. For the AR application, several types of documents have been published to describe the methodology to be followed depending on the chosen application. This process is dependent on the many existing RA applications on the market that use different methods, which are often not compatible with the device operative system used in the visualization phase. For example, in the case of Junaio, an application with solutions for both Android and iOS, the documentation had to detail the 3D model creation process of a user-only channel in the free application mode. The process went through the Metaio Creator installation, an application that allows the limited inclusion of a 3D model over a brand chosen by the user, generating a QR code that directly links to the model visualization when the chosen brand is scanned with a camera on a mobile device.

3.2.2. Practical exercise

The practical exercise was composed of several elements, including a title page with the project name, architect's name, and student's name. The title page must also contain the QR code of the course blog.

Other mandatory elements included the geographic placement of the project with the QR code that links to its location in Google Maps, an architect presentation with a brief text and a representative image of the project (including the QR code with the link to a web page with complementary information about the architect), presentation of the project with an outside image (including the QR code with a link to a web page or related YouTube videos), graphic documentation of the project in the CAD-BIM format (including the QR code with a link to the documentation in its original format on the Internet, stored in a public Dropbox or SkyDrive folder), presentation with pictures of the projects with an anaglyph of the building (including the QR code with a link to the original images in JPG format, stored in the same folder), presentation of a 3D model for AR visualization (in this layout, a QR code must appear that contains a direct link to the AR application and must also show an image that the application will recognize to display the object on a mobile device).

As mentioned previously, the students designed their expositions both physically (in a space at the university) and virtually (through publication on personal blogs). For the physical exposition, the minimum dimensions were 20×20 cm prints on photographic paper for the different required prints and proof that all codes and marks were accessible and worked with no problems, with the option of actualizing or downloading any type of required application in each case. In this manner, any visitor to the exposition had to have a mobile device with the required applications if he/she wanted to access the virtual content; otherwise, he/she would have sufficient information or instruction to gain access to the content (see Fig. 2).

The final evaluation of the student began with an average grade. The grade was weighted, with a 50% of the grade composed of a theory exam, where the student must accomplish diverse tasks with the informatics applications used during the course. The other 50% of the practical grade was based on the experience described in the present study. The practical grade consisted of the student's capacity to work in a group, investigate and select useful information, design capability, and ability to use diverse informatics equipment, such as specific applications for working with digital project elements related to the architecture and building world in 2D and 3D.

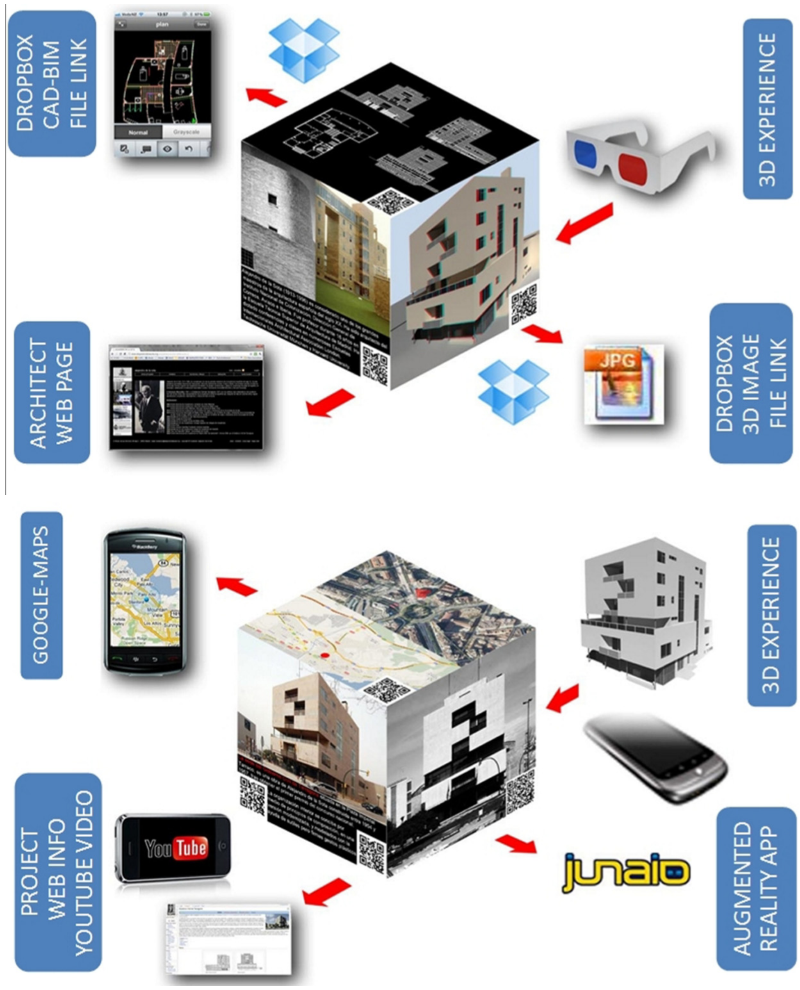

Fig. 2. Example of final practice with the content requested.

4. Results

4.1. User profile and motivation

At the beginning of the course (which was offered in the first half of the 2011–2012 academic year, September–February), the students were asked to estimate their degree of knowledge, usability, and interest in technologies generally and specifically in the use of informatics devices and mobile technology, the Internet, and social networks. In addition, questions were formulated to obtain the degree of knowledge and expectations of using AR prior to the experiment. The basis of this form is found in previous studies that suggest that higher interaction, usage, or interest levels produce better learning effects (Jung, Choi, Lim, & Leem, 2002; Kettanurak, Ramamurthy, & Haseman, 2001; Sun & Hsu, 2013; Swan, 2001). Additionally, demographic questions were asked, including age, gender, and grade.

The User Profile Test (Redondo, Fonseca, Sánchez, & Navarro, 2012) provided a first approach to the main interests and the student's working style. We descriptively highlighted the following items: all students (100%) connect online at home and at the university, mainly using laptops and mobile devices. The connection types used are Wi-Fi (90.8%) and asymmetric digital subscriber line (ADSL) (75.3%). Only 25.9% of the students work with 3G Internet connections with mobile devices. The most commonly used services are mainly e-mail (100%), browsers and download services (75.6%), and university queries related to architecture (100%). The use of chat rooms, blogs, news, or queries is less frequent (over 25%). A total of 81% of the students have a smartphone (17.5% have a simple mobile phone with no multimedia applications), and these students are more accustomed to working on portable laptops (97.3%) than on desktop computers (64.8%). Only 25% of students have a tablet device.

We detected differences in the behaviors of male and female students regarding the use of smartphones: these devices are more commonly used by females (91.2% of females vs. 70.2% of males), and its use is centered in leisure time and social applications (92.3% of females vs. 67.4% of males). The relative frequency of personal computer and laptop use is similar between males and females, and these devices are most commonly used for education (90.5%), leisure time (92.1%), social networking (89.7%), and other digital applications (86.3%).

Table 1 contains the principal statistics obtained from the most directly related study questions. In general, the students are heavy technology consumers, both in usage, as shown in the previous data and in the daily time usage, and in interest. Practically, combining the use of computers (Mean (M) = 3.61 h, SD = 1.12) and mobile devices (M = 0.97 h, SD = 0.72), students use these devices nearly 5 h per day. More than half of the time is spent on Internet applications (M = 1.78 h, SD = 0.34) and social networks (M = 0.70 h, SD = 0.62); the overall model is a work-based model, but study or leisure is highly valued, with increased satisfaction values (M = 4.52 h, SD = 0.65).

However, studying the initial data about the degree of knowledge, interest, and usability that the student perceives in the incorporation of AR into architectural teaching, it is perceived primarily

Table 1
Descriptive statistics for main measures of student profile test.

User profile test	Mean	*SD*
New technologies		
General interest in computers and technology advances	3.93	0.71
Time spent using computer/laptop per day	3.61	1.12
Time online using Internet services per day	1.78	0.34
Time spent using mobile services per day	0.97	0.72
Time online using Social Networks per day	0.70	0.62
Level of satisfaction using online services	4.52	0.65
Augmented Reality		
Level of knowledge about the technology	3.22	1.55
Level perceived of useful related with Architecture degree	3.50	0.98
Predictable level of improvement using AR in presentations	3.83	1.11
Predictable level of difficulty using this technology	2.91	0.71

as a complex tool ($M = 3.22$, $SD = 1.55$), and the students lack clear forecasts of how can it affect, help, or improve the visualization and presentation of architectural projects. We obtained average levels that were lower than the mean of four, the threshold considered as a positive prediction ($M = 3.50$, $SD = 0.98$ and $M = 3.83$, $SD = 1.11$).

Pre-test mean scores are similar in all groups, and to estimate the probability that groups are significantly similar, we used the Students *t*-test (Gosset, 1908), using a null hypothesis (H_0) that there are no differences in scores between groups. Statistical significance (two-tailed) is 0.497, which exceeds the threshold of 0.05, which means that there is a very low probability that the groups are different in their skills and previous training (Table 2). The null hypothesis, which states that there are no significant differences between groups, is accepted.

To complete the assessment of the teaching experience before evaluating the previous results, we can conclude that the groups are homogeneous, where the greater difference is found in the use of concrete technologies: one-way between-group analysis of variance (ANOVA) using pre-test scores as the covariant was conducted to compare personal use, and it was found that females use mobile devices more often than males ($F = 5.073$, $p < 0.01$) and that females use social networks more often than males ($F = 4.272$, $p < 0.05$). With respect to the use of devices or technologies related to educational use or in the perspective of AR, there are no statistically significant differences between the different groups or by gender ($F = 0.279$, $p = 0.762$).

The prior lack of knowledge about the technology used in the experiment generated a medium/high degree of motivation ($M = 3.75$, $SD = 0.93$), defined as the mean between question 1 of the section "New Technologies," and questions 2 and 3 of the AR section (Table 1). This indicator and comparison with the results and opinions of the usability of the method are aspects that will be analyzed in the following section. Then, the degree of success was evaluated together with whether the implanted methodology leads to an increase in the student's educational motivation.

4.2. Tool use, content adaptation, and academic performance

After completion of the experiment, as outlined in the task scheme (Fig. 1), the post-test was completed. The main purpose of this test was to evaluate student assessments of the course content and the support technology (AR in this case).

Through the structured test, based on International Organization of Standardization (ISO) 9241-11, it will be possible to evaluate the feasibility of using AR technology on mobile devices in educational environments while focusing on the usability guidelines of effectiveness (E1), efficiency (E2), and satisfaction (S1). Finally, because the completed basic project scheme is the same in the experimental course as in prior courses and because in this case, the subject has a "subgroup" composed of repeater students (G3 = 12), student academic performance improvement could be compared using this method in addition to traditional methods.

4.2.1. Final test results

Table 3 shows the students' main perceptions, including their evaluation of the course material, the proposed methodology, per-

Table 2
Independent Samples Test.

PRE_TEST	*t*	*df*	Sig. (2-tailed)	Mean diff.	Std. error difference
Equal variances assumed	0.669	55	0.497	−0.05997	0.29913

Table 3
One-way ANOVA results.

Variables	G1 (*n* = 9)		G2 (*n* = 36)		G3 (*n* = 12)		ANOVA		
	Mean	*SD*	Mean	*SD*	Mean	*SD*	*F*(3.16)	Sig.	η^2
Material/contents									
(E1) The material of the lecture has a good presentation	4.01	0.25	4.19	0.50	4.00	1.09	0.427	0.654	0.250
(E1) The structure of the sessions/exercises are appropiate	4.33	0.51	4.08	0.53	4.16	0.87	0.383	0.683	0.230
(E1) It is easy to manipulate the exercises porposed	3.66	0.25	3.55	0.53	4.25	0.56	4.347	0.017*	0.502
(E1) Models scale are suitable to manipulate virtual elements	3.00	1.00	3.33	0.40	3.41	0.62	0.946	0.394	0.535
(E2) The number of exercises are related with time proposed	2.44	0.27	2.69	0.50	2.33	0.78	1.293	0.282	0.528
(E2) It have been possible to solve the exercises presented	4,01	0.51	3.44	0.53	3.58	0.44	2.164	0.124	0.514
(S1) Theoric classes are sufficient to know how to proceed	3.77	0.19	3.33	0.51	3.33	0.60	1.541	0.223	0.485
Application of AR technology									
(E2) The application of AR has been stable (no crashes)	3.22	0.69	2.97	0.42	3.16	0.69	0.620	0.541	0.522
(E2) Familiarity with the gestures and manipulate virtual objects has been easy	2.56	0.52	2.80	0.50	2.58	0.81	0.641	0.530	0.365
(E2) No delay in the visualization/manipulation of models	3.89	0.36	3.77	1.09	3.67	0.78	0.139	0.870	0.128
(S1) Level of definition of 3D virtual models	3.44	0.27	3.38	0.70	2.58	0.26	5.765	0.005*	0.549
(S1) Overall AR rating about useful to improve presentations of Architectural projects	3.22	0.19	3.02	0.31	2.41	0.44	6.616	0.002*	0.323
(S1) Rating about the experiment: viewing Architectural models with AR applications	3.56	0.27	3.25	0.70	2.75	1.11	2.516	0.090	0.726
(S1) Rating about how AR work with 3D complex models	2.34	1.25	2.46	0.65	2.08	0.62	1.417	0.251	0.737
(S1) Rating about usability of AR syst. and methodologies	3.56	0.28	3.36	0.52	3.00	0.54	1.819	0.171	0.491

* Mean difference is significant at the 0.05 level.

ceived usefulness, and level of satisfaction. We conducted a one-way ANOVA between the three student groups identified in Section 3.1: the Tarragona group (G1 = 9), the Barcelona non-repeater group (G2 = 36), and the Barcelona repeater group (G3 = 12).

With this analysis, the perceptions could be evaluated based on the three proposed usability guides.

The results indicated significant differences among the groups for the degree of difficulty for the proposed exercises ($F = 4.347$, $p < 0.05$), the perceived level of definition using 3D AR models ($F = 5.765$, $p < 0.05$), and the overall perceived usefulness of AR for improving architectural presentations ($F = 6.616$, $p < 0.05$). In all cases in which statistically differentiated behaviors were detected, the average that generated said answer was given by the repeater subgroup (G3), which opens an avenue to investigate the existing relationship in the repeater's educational condition with the effected values in said indexes.

In the first observed difference related to the ease of environmental manipulation, while the students taking the subject for the first time found a medium level of difficulty (G1: $M = 3.66$, $SD = 0.25$ and G2: $M = 3.55$, $SD = 0.53$), the repeater students utilized the proposed method in this exercise more easily ($M = 4.25$, $SD = 0.56$), making personal and subjective comparisons with their previous experiences with the traditional methods of the previous course.

Evaluating the other significantly differentiated values, clear prior conditioning was present: the previous realization from the repeater students of subjects related with architectural projects and construction techniques of the third degree course. In those subjects, which were not studied previously by G1 and G2 students; it is emphasized in the architectural project presentation methodologies, both at constructive and executive levels that special attention must be paid to the detailed visualization of materials and textures. Likewise, and from this third course, the projects of study change from detached houses to large public projects, which increase the relevance of visualization in the space and work conception with 3D complex models.

Based on the prior experience of the G3 group, the significantly lower values of the level of definition of 3D virtual models are justified (G3: $M = 2.58$, $SD = 0.26$), as they are compared with students who did not need to debug the visualization of complex projects (G1: $M = 3.44$, $SD = 0.27$ and G2: $M = 3.38$, $SD = 0.70$). Similarly, for the overall perception rating of AR regarding its usefulness for improving architectural project presentations, the G3 group, which has more experience, "fails" the AR technology (G3: $M = 2.41$, $SD = 0.44$), in contrast to the other groups (G1: $M = 3.22$, $SD = 0.19$ and G2: $M = 3.02$, $SD = 0.31$), partly because the first group knows the needs and requirements that are more commonly used in the project subjects.

This clear doubt about the adequacy of AR for complex project realization is compounded by the low reviews obtained for the obtained perception of the visualization of complex models, not only architectural projects. All students with some experience in project and construction subjects in the first two degree courses agreed to fail to the technology in this category (G1: $M = 2.34$, $SD = 1.25$, G2: $M = 2.46$, $SD = 0.65$, and G3: $M = 2.08$, $SD = 0.62$). This result is a possible initial point for future studies and improvements to increase the reviews and utility perception of AR.

4.2.2. Evaluation of usability guidelines

As mentioned previously, we evaluated the user assessments using questionnaires based on ISO 9241-11. The overall assessment of the experiment was approximately 3.5, which is similar to the results obtained in previous studies (Redondo, Navarro, Sánchez & Fonseca, 2012), confirming the feasibility of using this technology in educational environments.

The average responses related to effectiveness (E1) and efficiency (E2) are very similar for all groups and are not statistically significantly different, as shown in Table 4. The satisfaction levels ("S1" in Table 3) are close to the level of significance ($F = 3.68$, $p = 0.070$). The minimum correlation between variables is 0.854, indicating a strong relationship between effectiveness, efficiency, and satisfaction in using this technology.

4.2.3. Academic performance

A final scale that was considered in the study to provide clear information about the usefulness of the proposed methodology is the curriculum evaluation by the students. Table 5 lists a summary of the grades obtained during the academic year (with the AR methodology) for all groups and the academic results for all groups of the previous academic year (2010–2011), when traditional methodologies were used.

The academic results of the 2011–2012 year show the averages of the group in Tarragona (G1'), which are 100% different from the experimental group due to the fact that there were no repeaters in this group, the students from the Barcelona group who passed the last course (G2') and are therefore also different from the G2 experimental group, and the academic results of the G3 repeater group, who took the same course with both methods. The group G2' includes the results of a group of 10 repeater students who took the course for the second time; their results are not statistically different from the students who passed the course the first time.

Comparing the practice Section 4, which is the basis of our experiment and which used a different methodology compared to previous years, we can confirm a statistically significant increase in the practice degree of all groups of the 2011–2012 academic year compared to the previous year. We found an increase in the practical grade, which has a mean of $M = 5.62$ ($SD = 0.03$) in the previous year compared to the new mean of $M = 6.54$ ($SD = 0.18$). The differences are significant ($F(7.7) = 11.56$, $p = 0.027$), indicating that the proposed method helps to improve student performance. In addition to the improvement in the practice grade, we also found a significant increase in the spatial skills of the students, as evaluated in the theoretical exams. The students had a previous mean of $M = 4.94$ ($SD = 0.45$), which increased to $M = 6.04$ ($SD = 0.27$), a difference that is statistically significant ($F(7.70) = 7.42$, $p = 0.052$).

5. Discussion

The basic purposes of this study were to determine whether the use of familiar technology, such as mobile devices, social media, and new interactive and collaborative methods, to visualize architectural models improve the motivation and academic performance of students. The results indicate that AR is a good system to visualize simple models but that it is less able to manage projects with high levels of detail and volume. The experience was welcomed by the students, who appreciated using the new methodology as applied to architecture education and appreciated the technology even more if these types of exercises help to improve their academic performance.

Table 4
Usability responses.

Variables	G1 (*n* = 9)		G2 (*n* = 36)		G3 (*n* = 12)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Effectiveness (E1)	3.75	0.32	3.78	0.17	3.95	0.14
Efficiency (E2)	3.22	0.52	3.13	0.20	3.06	0.35
Satisfaction (S1)	3.31	0.26	3.13	0.12	2.69	0.19

Table 5
Academic curriculum.

VARIABLES	2011–2012						2010–2011					
	G1 ($n = 9$)		G2 ($n = 36$)		G3 ($n = 12$)		G1′ ($n = 12$)		G2′ ($n = 52$)		G3 ($n = 12$)	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Practical grade (PG)	6.12	1.21	6.52	1.47	6.98	1.70	5.55	0.56	5.83	0.69	5.48	1.87
Theory grade (TG)	5.89	1.01	5.94	0.98	5.79	1.12	5.03	0.89	5.25	0.53	2.52	0.36
Final grade (50%PG + 50%TG)	6.00	1.11	5.73	1.22	6.38	1.41	5.29	0.72	5.54	0.61	4.00	1.15

Table 6
AR main method variables.

AR-variables	*PRE-test levels perceived*	*POST-test real levels*			
	Mean	Global mean	Mean (G1)	Mean (G2)	Mean (G3)
Useful	3.50	2.88	3.22	3.02	2.41
Improv. Arq. project	3.83	3.18	3.56	3.25	2.75
Usability	2.91	3.30	3.56	3.36	3.00

In the discussion of the proposed method, we evaluate the incorporation of AR in architecture education based on three main variables: usefulness, level of improvement of project presentations, and difficulty of use. For this purpose, we compare the means of those variables in the pre-test (where all data are related to student perception with no knowledge of the technology) and the post-test (where the student had worked with AR and evaluates its performance) (Table 6).

Our findings show positive aspects: students evaluate AR as a technology that is easier to use ($M = 3.30$) than was expected a priori ($M = 2.91$), which improved student participation and motivation as observed in the different academic sessions and led to an improvement in students' academic performance (Table 5). However, the level of perceived utility ($M = 2.88$) and the results related to whether AR is a good system for architectural visualization ($M = 3.18$) were unexpected ($M = 3.50$ and $M = 3.83$, respectively) or cannot be compared with the resulting quality of work in other 3D formats, both digital (e.g., DWFx interactive models) and physical (e.g., mockup). The preliminary experiments that were conducted by the students showed a good fit to simple models, but the results were not the same when the model was more complex, either in structure or volume.

However, the previous statements are based on averages, which do not have statistically significant differences ($p > 0.5$). We can only confirm that there are significant values when considering students who have repeated the course. In this case, the perception of the main variables of the study, the usefulness and improvements of AR for architectural project presentations, are decreased, with a high level of significance ($p = 0.044$). This value confirms the previously stated hypothesis that AR technology is not an optimal fit to display specific details or complex architectural models based on the previous experiences of course repeaters with this type of project.

Other results that were extracted from student–teacher interactions and final interviews about the experience show us some problems that will have to be improved in future experiments to increase the level of satisfaction and adaptation of architectural content to AR technology. We find problems related to the connection between technologies and formats. For example, AutoCAD does not export directly to the OBJ format (which is the necessary format for uploading the 3D model into the Junaio system), and some colors and materials that are used in AutoCAD, 3DMax, or Sketchup are not imported correctly into Juanio. Other problems are directly related to the size and system of visualization: 3D models shake excessively when displayed on mobile device screens, and the model size is limited by the method of scaling within Junaio and the screen size (those situations are the main problems for observing small objects and architectural details).

However, the results of the students' pre- and post-tests have demonstrated that by combining an attractive technology and user-machine interaction that involves AR, students feel more motivated, have increased graphic competencies and spatial skills in shorter learning periods, and have strongly improved academic performance.

6. Conclusion

The results of the present study were in line with our assumptions that the use of mobile devices in the classroom, motivation, and academic achievement are highly correlated. However, the difficulty of generating content and the visualization of optimal models and details are complex factors that suggest difficulty in implementing this technology in other subjects related to architectural education.

The level of interaction of the students in all phases of the proposed methodology produced a high level of interest in the subject with increased monitoring, new interest in visualization techniques, such as AR, and higher learner perceptions. Working with a collaborative interface, interactive discussions of all projects, and the capacity to generate physical and digital expositions are activities that have generated an active student, with significant improvements in spatial, research, and interaction skills. One of the highlights of the experience has been the change in perspective that was generated once the student was aware of how their work was perceived publicly. With the publication of their project advances in personal blogs and the mutual exchange of opinions with peers and faculty, the student no longer considers the project as a simple, isolated practice exercise but instead considers it a project with an immediate impact on the Internet and a continuous improvement in presentation quality. One of the actions of the experience that generated a better response was when the students needed to search for information related to their projects online. Preliminary results were links to their personal blogs and those of their colleagues. These blogs, as they have been updated and enriched with many types of digital content, have gained public status, resulting in an increased level of awareness and student motivation about the importance of maintaining information with an appropriate minimum level of quality.

The overall assessments of efficiency, effectiveness, and satisfaction were all approximately 3.5; thus, we can confirm that students felt satisfied and motivated when using this new methodology. In addition, the representative exercises and material presentation appear to be crucial to the success of this type of teaching experience. However, variables related to the ability to solve the exercises independently did not correlate significantly with the final course assessment.

With regard to the second research question, the results demonstrated how AR technology, through student motivation, could help to improve students' academic performance. All groups achieved gains in performance results, particularly those students who were repeating the subject. All of the students were more engaged and participated in the course activities, particularly in the task of interaction with 3D virtual content, thus maximizing the learning process.

This study has several limitations and provides a number or variables to improve in future studies, as well as some research suggestions. First, it is necessary to compare similar experiences between different courses to ensure that a student's previous experience in architectural project subjects is relevant to his/her understanding of how to use the AR technology. It will be necessary to design models and exercises with different levels of difficulty based on the needs defined by projects in different courses. Second, it is necessary to improve the evaluation of students' perceptions of motivation and satisfaction about using mobile devices, social networks, and advanced tools in visualizations. It will be necessary to design tests and structured interviews to collect more information about the experiences throughout the course, not only in the first or final class.

Finally, we can confirm that AR technology on mobile phones in architecture and building construction education offers an opportunity to visualize different stages of a constructive process "in situ", helping to improve the understanding of the process. This fact allows for the verification and comparison of different scenarios and virtual proposals prior to real construction. In addition, this technology could replace real interventions. To achieve this goal, it is important to study the ability to view different models with the same marker to show different layers, models, textures, and illuminations. Furthermore, it will be necessary to establish systems that allow for fluid exchanges between applications and the avoidance of problems involving formats, versions, or loss of information, as occurred with colors and materials in the present study. While the framework of CAD/BIM has standardized formats, such as DWG, DXF, or 3DS, these formats are not adequately adapted to existing AR applications. In this regard, the work being performed within the "AR Standards," a collaborative initiative that works to solve the current problems of this technology and adapt to all types of services and needs will be critical (more information is available at http://www.perey.com/ARStandards/). As standardized exchange formats are adopted, the display of complex 3D models will be more accurate, solving one of the current critical problems of this type of technology.

Finally, indicate that this educational research project falls under the Interest Group for Logistics and Teaching in Architecture (GILDA), an inter-university group centered in the architectural framework assigned to the ICE (Institute of Education Sciences at the Polytechnic University of Catalonia – UPC), specialized in the field of teaching technology disciplines. The authors represent teachers of Visual Communication Architectural Graphic Expression Representation (EGAI/II) together with the "Informatics Tools" subjects of architecture at the Universidad Ramon Llull (URL) and usability experts in educational research. This project was made possible by the Fundamental Research Project Not Oriented of the VI National Plan for Scientific Research, Development and Technological Innovation 2008–2011, Government of Spain, N° EDU-2012-37247/EDUC, titled: "*E-learning 3.0 in the teaching of architecture. Case studies of educational research for the foreseeable future*".

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