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Visualization methods in architecture education using 3D virtual models and augmented reality in mobile and social networks

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Abstract

Migration to new visualization techniques is a trend that allows for a better spatial understanding. In order to evaluate the resilience ability of first-year students of Spanish architecture degree, we have compared two learning methodologies: the traditional generation of printed plans, and the generation of interactive 3D models using new systems of publication and interaction. The main objective of the study is to evaluate the new methodology that assumes that the use of friendly technology in the classroom makes it much easier and satisfying for students to follow the subjects, allowing better acquisition of the skills they are learning.

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1. Introduction

Currently, the use of new technologies in education is an influential and rapidly evolving factor that can be found from the first cycle of primary schooling all the way through to the later stages of university education. Most of the systems that have been developed have proceeded from the initial assumptions that they allow a greater ease of learning and monitoring of content by students and a better school performance based on the academic results (typical assumption and classical error of usability studies). On the other hand, we think it is true to say that neither of these assumptions is based on usability and satisfaction studies previously performed in order to adjust, and change the technology and content according to the profile of the student or the specific needs of each subject.

For these reasons, this article, which describes the results obtained from the implementation of a new teaching approach, focuses on the use of mobile technologies for visualization and presentation of architectural models in 3D. The aim of this study is to assess whether this approach is better suited to the technological profile of the student over traditional techniques in order to improve both cognitive skills and all those related to the use of computer graphics techniques for managing projects and architectural models described in the academic plans of Architecture

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and Building Engineering degrees, according to the main rules proposed in the European Higher Education Area (EHEA).

2. Docency and technology

The use of technology in education is no means a new occurrence. The popularization of low cost home computers in the early 90s and mass access to the Internet in the same decade greatly enhanced the possibilities of distance learning (e-learning concept), allowing access to all types of digital content: basic texts, images and videos as advanced three-dimensional models, and computer graphics.

At the end of the last century a number of relevant studies focusing on how to incorporate new technologies in university teaching were conducted (Rogers, 2000). Based on the results of previous studies (Green, 1998), it is important to establish the need to include technology as a tool to complement the work and teaching agenda, to control its correct use, and to allow for preparation by teachers and students, taking the first step to a paradigm shift in technological education: the passage from the concept "teaching" to "learning". On the basis of this, in the following sections we will review, define and discuss the theoretical basis on which our study has been based.

2.1. From e-learning to new technologies in the classroom

Most previous work resources, the main objective of which is the inclusion of technology in teaching systems (Area, San Nicolás, & Fariña, 2010), are focused on the optimization and generation of "good practices" for creating virtual classrooms, distance learning (e-learning), and semi-face teaching (Kuh & Vesper, 1997). For this reason, these studies have focused on optimizing content for Web services, sharing Intranet methods, using center's self-evaluation systems and other training aspects widely developed in previous literature (Tremblay, 2006; Mena, 2007; Cheung, Lam, Im, & Szeto, 2009). The evolution of mobile technologies and the increasing power and sophistication of mobile phones, leading to the advent of Smartphones, and tablets in the last five years, have created a new body of research that is being carried out a thorough study into the use and optimization of these devices in ubiquitous training, allowing collaborative work with faculty members and other students of the classroom, both onsite and virtual (Lu, 2012; Parsons, 2012).

The constant development of these digital technologies allows new models of information and requires user's skills improvement to manage all type of data in digital environments. These types of skills are often referred to as "digital literacy" (Pool, 1997), and define a new type of user called "digital natives", people who have been exposed to such technology almost from birth (Prensky, 2001). As described Eshet-Alkalai (2004), we can define a detailed description of the main skills ranging from cognitive to motor, sociological, and emotional, that the use of technology offers to all types of users. Gantt (2001) defines a capacity of short-term retention of 20% of all information that we hear, 40% of the information that we see and hear, and 75% of the information that we see and participate in, a clear example that interaction and collaborative forms are more completely that classical models of education.

We find a great number of solutions implemented to obtain a better education performance, especially in areas where the use of visual information is very important such as in the frameworks of multimedia, design, communication, or architecture, and in any other area of higher education. Centered in examples related to architectural/construction and their education (Whyte, Bouchlaghmen, Thorpe, & McCaffer, 2000; Rafael, Pérez, & Dueñas, 2006; Wang & Schanabel, 2006), we found studies using whiteboards, interactive books, social media and other resources related to the visualization of 3D models, buildings and spaces in the architecture education, as interactive models, spatial analysis or new 3D mobile interactions using augmented reality, one technology that has undergone remarkable development in the last few years (Redondo, Fonseca, Sánchez, & Navarro, 2012).

The introduction of more user-friendly technology (such as mobile phones, tablet, social networks, etc.), in the learning process is an educational strategy that allows for the replacing of traditional, often boring, lectures. With these new methodologies the teacher is able to achieve greater motivation in the monitoring of contents and has access to a new interface to share educational material that allows work to be timeless and adaptable to the professional technologies by the students.

2.2. User Experience (UX) applied in education

The main errors that we can found in any UX study could be summarized in four points (Navarro, Fonseca, Redondo, Sánchez, Martí, & Simón, 2012): a tendency toward a generic approach (ignoring the specific purpose of the study); overvaluation of expert opinion (making a substitution of the final user opinion); excessive valuation of percentages and probabilities (without understanding that each case is unique); and a tendency to dismiss the qualitative studies in favor of quantitative. For this reason, we based our study on a methodology that allows us precisely to identify the profile of the users (students) and their level of knowledge and adaptation to technological resources and social networks. From this first study, focusing on the evaluation of the pedagogical potential of a particular technology in a particular environment, we have proposed a series of practices and implementations specifically designed for their evaluation. The design of the user profile and final evaluation test were generated from models previously used in research focused on the teaching field in relatively similar frameworks (Martín-Gutierrez, 2010), so that this methodology is now scientific accepted.

Currently, examples of these errors are easy to find in all types of schools and educational centers, where the implementation of technologies is justified as a qualitative improvement in teaching and learning ability of the student. These statements are made without any UX study, generating relative truths that are assumed to apply to other frameworks. Our study, attempting to avoid this error, proceeds without making such previous assumptions and consider whether the implementation has been carried out adequately or needs adjusting.

2.3. 3D models and advanced visualization

One of the main problems encountered in the design phase of the experiment was to display 3D models in mobile devices and blogging systems easily and in free mode. Our belief is that the success of a technology-based education depends to a large extend on the technology being accessible, and easy to use by teachers and students.

The students of our faculty (the experiment was carried out with first level students of Architecture and Building Engineering degrees of La Salle – Universitat Ramon Llull, Barcelona, Spain), have access to free educational licenses of all Autodesk products, the leading company worldwide in the marketing of software related to CAD (Computer Aided Design) and BIM (Building Information Modeling), two technologies closely linked to teaching and professional frameworks of architecture and construction. In this first level the main objective is to provide students with spatial skills and the ability to represent 2D and basic 3D models using AutoCAD®. In the second and third levels the students improve their representation skills by using more advanced tools like 3DStudio® or Revit®.

One system that enables publishing, visualization and interaction with 3D models online is the PDF3D format (http://www.pdf3d.com/). This format allows for great interactivity and is possible to attach inside a blog, but presents two major problems: it has no direct connection with AutoCAD® outputs and requires Acrobat® version 8.0 or later, a non-free solution. There are systems that do not entail any cost, such as for example working with Sketchup® (with a free version downloaded from http://sketchup.google.com/ and direct connection with AutoCAD®), but these entail the additional need to install additional plug-ins.

inally, the selected system improves all problems of the previous models explained: we have generated the 3D models directly from AutoCAD® using export tool "DWF3D", generating a DWFx file. In the installation of AutoCAD® package the system installs the Autodesk Design Review®, a free program that reads DWF and DWFx native Autodesk formats. DWFx has similar properties in the visualization, interaction and publication that PDF3D, and does not need any plugging or payment software, being possible to publish inside a blog. The main advantage of DWFx format is the interaction with the 3D models, allowing the students better spatial comprehension using the configuration of different parallel and perspective views, active and inactive layers, objects, blocs, and other interesting tools in construction as dynamic sections (see Fig. 1).

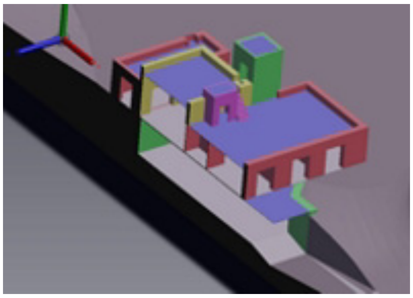

Figure 1. Example of dynamic section using a 3D DWFx model.

3. Case study. Definition and methodology

The study was carried out with the students of "Informatics Tools I", a module in the first-year course of Architecture and Building Engineering. We divided the experience into two phases in order to compare them in a final discussion and analysis phase:

- In the first, the students developed site plans, floor plans, elevations and sections of different architectural projects (selected by the working groups and based on the proposed agenda for the current academic year and course) using AutoCAD2012® (all the students have free access to a full educational license program). The students must print plans generated by the DWF format (native Autodesk) or PDF format. The correction of the plans is conducted face to face, thus providing indispensable assistance of students, and all prints needed to get a correct sheet.
- In the second phase, students generated a 3D model of the project and both the model and the plans associated with it, and these were posted on a personal blog. This blog was shared with the public through a link on a corporate blog of the subject (http://blogs.salleurl.edu/, public access to all blogs inside "Eines de Representación I"), and to complete the experience the students generated printed QR codes (Quick Response), which have been distributed by the faculty for their public free scan and navigation to the student blog (see Fig. 2). With this system, students and faculty are able to view and discuss all projects with the generation of new streams of interaction and feedback with the new changes and continuous correction deliveries.

Figure 2. Example of QR Codes public exhibition linking to a personal student blog with 3D models.

Because of publishing features that support blogging systems do, not allow access in certain formats (only image and video formats can be include directly in a blog), students uploaded their files in storage media such as Dropbox® or Autodesk Cloud®, which allow for the public link to be exported to the files to include them in both html pages and personal blogs (following the same procedure using payment formats such as PDF or PDF3D).

We used a structured test, based on previous methodologies to evaluate the student interaction and satisfaction (Martín-Gutierrez, 2010), with a sample population comprised of 73 students: 37 men of an average age of 19.95 (Standard Deviation: 4.71), and 36 women (Av: 18.95, SD: 1.29). From this sample we derived a subgroup of 6 men and 10 women who are repeaters of the subject. Taking into account that in the previous year the second phase of the experiment was carried out using traditional methodology as phase 1, it seemed likely that assessment of this subgroup would prove an interesting means to analyze if the new proposed method represents better value.

To assess the degree of adaptation and student satisfaction, and specifically to compare the second phase (virtual interactive method) with the first (classic print system), we conducted a structured virtual survey (using intranet mooddle system) of 22 questions, using a Likert scale in which every answer was assigned a numerical value. The survey was designed with two main objectives: to obtain the technological profile of the student in terms of the use and habits with mobile and Internet technologies, and to obtain their overall assessment of the work performed by comparing the two methodologies. On the other side and to assess the academic level achieved with the implementation of the second methodology of work, we will compare the results of this course to other academic years where the traditional methodology was used in both the 2D design phase and in 3D, as well as a control group of this academic year that has made the full process using traditional system.

Analyzing the technological profile of users, 81% have a Smartphone (in contrast to 17% who have a simple mobile phone), they are more accustomed to working on portable laptops (97.3%) than on classic personal computers (64.8%), and only 25% of students have a Tablet device. We did detect differences in the behavior of men and women regarding the use of smart phones: this device is most commonly used by women (91.2% vs. 70.2% of men), and its use is centered in leisure time and social applications (92.3% vs. 67.4% of men). The relative frequency of personal computer and laptop use is more equal between men and women, and these devices are most commonly used for training (90.5%), leisure time (92.1%), social networking (89.7%) and other digital applications (86.3%).

With these data and assuming a high degree of interest in digital applications (ranging from 1: no interest, to 5: high level of interest, we have a mean of 3.85; SD:0.73), and high amounts of time spent using digital applications daily (with a mean of daily use of personal computer applications between 2 and 4 hours), we can assume a good adaptation of students to the new interactive model proposed. However, we need to verify the main results (see Table 1 and 2):

Table 1. 2D vs. 3D methodology of theory and practice classes

Phase 1 - Questions	**Men Average**	**SD**	**Women Av.**	**SD**
Evaluate theory 2D classes	3.22	0.42	3.32	0.53
Evaluate 2D practice methodology	3.22	0.48	3.24	0.43
Phase 2 – Questions				
Evaluate theory 3D classes	3.32	0.53	3.19	0.62
Evaluate 3D practice methodology	3.16	0.55	2.97	0.60

In Table 1, we can observe similar results between the different methodologies applied in phase 1 (2D) and phase 2 (3D). One difference is a small reduction in the evaluation of 3D practice system by the female students.

Table 2. Specific satisfaction questions about the methodology and contents

1.- Compare 2D vs. 3D methodology	**Men**	**Women**	**2.- Degree of satisfaction using advanced 3D methods**	**Men**	**Women**
Far better 2D system	3	2	Very satisfied	9	5
Better 2D system	5	15	Satisfied	18	18
Equal	16	8	Normal	10	13
Better 3D system	9	11	Dissatisfied	0	1
Far better 3D system	4	0	All dissatisfied	0	0
3.- Do you agree with the contents Of the course. Do They will be useful?			**4.- Degree of difficulty of the methodology used in 3D**		
Strongly disagree	0	0	High difficulty	8	4
Disagree	0	0	Some difficulty	14	6
Neutral	1	2	Little difficulty	14	22
Agree	13	17	Without difficulty/easy	1	5
Strongly agree	23	18	Very easy	0	0

In Table 2, we can observe the results of 4 structure questions about the opinion of students related to the methodological system proposed. In question one, the main data is that female students prefer the traditional methodology using printed plans to the online 3D method. This information, in line with conclusions of Table 1, is corroborated with the results of question 2, with a higher level of satisfaction using the online 3D model by the male students. With this information, we could affirm that the lower appreciation of female students could be due to the greater difficulty of use for this collective (in line with other multimedia studies that affirm a gender difference interaction with 3D objects and models, see Pausch, Snoddy, Taylor, Watson and Haseltine, (1996)), but this affirmation is canceled by the answer to question 4, which might indicate the necessity of re-defining the design of the experiment or analyze more data.

4. Conclusions and future lines

A final scale to be considered in the study to provide us clear information about the usefulness of the proposed methodology is curriculum evaluation obtained by the students. In the following Table 3, we can observe a summary of the practice notes obtained this academic year (with 3D new method), and the previous academic year (2010-2011) using traditional methodologies in both 2D and 3D phases:

Table 3. Academic curriculum. 2D vs. 3D

2010-2011 n (total number of students evaluated) = 117		**2011-2012** n (total number of students evaluated) = 94	
2D	**3D**	**2D**	**3D**
5.52 (SD:1.47)	5.48 (SD:1.87)	5.00 (SD:1.37)	6.98 (SD:1.70)

On the basis of these results we can conclude that the new methodology proposed and described in this paper helps students to acquire a better spatial understanding of their work, directly contributing to an improvement in their curriculum evaluation. However, according to the opinions obtained by the user survey outlined in previous sections, it is necessary to redesign the experiment, simplifying some tasks and starting others earlier in the process, most probably from the training phase in 2D (such as the creation of the blog and the uploading of practice exercise for viewing shared files).

The next phase (now in design process, to execute in the second course level), will be to export 3D models from AutoCAD® to Layar®. With this conversion, the student will be introduced to basic concepts of Augmented Reality (AR), but it is necessary that some basic training in conversion tools not explained in the first course be carried out. For example, it will be necessary to import the AutoCAD® models into 3DStudio® to apply illumination and materials, export models in OBJ format, and using a 3D Model Converter of Layar® generate the AR model in L3D format).

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