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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.

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