Evaluation of an interactive educational system in urban knowledge acquisition and representation based on students' profiles

Monica Sanchez-Sepulveda[1†], David Fonseca[1], Alicia Garcia-Holgado[2], Francisco Jose Garcia-Peñalvo[2], Jordi Franquesa[3], Ernesto Redondo[3], Fernando Moreira[4]

[1]*La Salle, Ramon Llull University 08022 Barcelona, Spain*
[2]*University of Salamanca, 37008 Salamanca, Spain*
[3]*Polytechnic University of Catalonia 08028 Barcelona, Spain*
[4]*Portucalense University, 4200-072 Porto, Portugal*
[†]*Correspondence: monica.sanchez@salle.url.edu*

Abstract

The aim of this article is to study how students currently understand the conception of space through different media and how that understanding helps them to intervene in the space. First, the process of teaching and learning as well as innovative supporting technologies are analyzed, revealing the characteristics of the contemporary student profile and better ways of teaching according to it. Second, we describe the evaluation of an experiment with a virtual reality (VR) system for urban project design with students of architecture from two universities. The premise is that the technology used in VR is familiar to the current profile of students. This paper aims to study the advantages and disadvantages of this trend and to find a balance. To do so, we use a quantitative method to evaluate students' profiles and their level of satisfaction with the system. The results were obtained by a questionnaire and a survey, which show the role and use of technologies in the students' environment and the degree of satisfaction when using it in the educational processes. In line with our assumptions, the value of satisfaction in the use of an advanced visualization technology in the classroom reveals a high level of motivation in general with differentiation between students in their first and last phases of studies.

Keywords

3D interactive learning environments, architecture education, urban design, virtual reality, visualization.

1 Introduction

Learning can occur without teaching, but unfortunately, the converse is not true. Students build their minds by constantly making and changing connections between what is new and what is already known in a dynamic process. In this Digital Era, a period that is related to computers, learning methodologies differ immensely. In addition, people prefer to learn in different ways: hands-on activities, reading and writing, watching demonstrations and videos, or listening to a lecture (Rachmatillah, Munir, & Anam, 2019). These preferences are key to the different ways people learn most easily, commonly known as learning or processing styles. Should instructors then teach their material in different ways to accommodate these different styles? They should probably prepare students for life in the real world by not giving them special treatment. However, knowing and being able to take advantage of students' learning-style strengths also helps instructors prepare them for the real world.

Currently, information can be found everywhere given Internet access. Academics must offer that which information available on websites does not, meaning that they must share their knowledge, a structured set of patterns that have been identified through observation followed by reflection and abstraction (Kuhn, Cooper, Cooper, & University of Chicago Press, 1970). It is important then, to help students see the difference between information and knowledge and to put into practice the critical-thinking structures that the architectural discipline uses (Boys, 2010; Burkhard, 2004; Eppler, 2006). These thinking processes will help students identify conceptual similarities, differences, and interrelationships while reducing the material to fewer, more manageable pieces (Nilson, 2010). When the mind has fewer independent pieces of knowledge to learn, it can process and retain more knowledge.

Students are typically more motivated to engage with material that interests them or has relevance for important aspects of their lives (Cetin-Dindar, 2016; Pintrich, 2012; Wentzel & Brophy, 2014). It is better to assign problems and tasks with relevance to their current academic lives that the students can see (Klegeris & Hurren, 2011; LaForce, Noble, & Blackwell, 2017; Pintrich & De Groot, 2003; Zhou, Kolmos, & Nielsen, 2012). Extensive study has been made of the relationship between student motivation, degree of satisfaction, and the user experience or student perception of the interaction with and teaching of applied collaborative works and methodologies, with recent contributions helping to design new digital experiences or dislocated teaching methodologies using information technology (IT) (Afzal, Ali, Aslam Khan, & Hamid, 2010; David Fonseca, Martí, Redondo, Navarro, & Sánchez, 2014; Friedman & Mandel, 2011; Hung, Sun, & Yu, 2015; Meece, Anderman, & Anderman, 2006).

Which methodologies can universities profit from concerning the current profile of students and the technologies available to update the methodologies of learning? (Vrebos, Nielsen, & Styve, 2019). Interactive virtual systems have begun to be used in multiple sectors, including the professional and educational sectors, as they allow users to be close to the recreated space while allowing a rapid flow of changes and updates to the models (Calvo, Sánchez-Sepúlveda, et al., 2018; Simpson, 2001). In the framework of urban and architecture studies, the designs must be assessed before they are built (Hisham El-Shimy, Ghada Ahmed Ragheb, & Amany Ahmed Ragheb, 2015; Kamel Boulos, Lu, Guerrero, Jennett, & Steed, 2017; Sidiropoulos, Pappas, & Vasilakos, 2005). This situation compels educators to rethink how students learn and represent, as it is important for students to become skilled in multiple representation technologies so they can incorporate the latest technologies into their design process to better communicate their proposals (Hai-Jew, 2010; Wu, He, & Gong, 2010) and facilitate critical reasoning on the spaces they conceive (Suwa & Tversky, 1997).

For these reasons, and considering the project development described in the paper, we address the following research questions.

RQ1. Is there a significant difference between students in their first and last phases of studies related to the potential of virtual, interactive and gamified systems for the visualization of their projects?

RQ2. What are the main characteristics of the proposed interactive system used by students that are useful for their professional careers?

In this regard, this article aims to understand how students, specifically undergraduate architecture students, learn, and it tests this process relationship in a case study using student profiles. The article is organized in the following way: Section 2 includes learning processes and methodologies, revealing the characteristics of the undergraduate student profile, better ways of teaching according to that profile, and the profile and characteristics of architecture students. Section 3 presents the case studied and the methodology used to assess our proposal. Sections 4 and 5 discuss the data obtained from the results of the qualitative evaluation. Finally, Section 6 summarizes the main conclusions of this work.

2 Learning Processes in Undergraduate Students

2. Construction of Knowledge

Good teaching, according to Biggs, is helping the maximum number of students use the higher level cognitive processes that the majority of students use spontaneously (Blair, Steiner, & Havranek, 2011). What is the cognitive process of undergraduate students? William G. Perry (Perry, 1970, 1988) and Baxter Magolda (Smith & Baxter, 1994) separately derived theories on the cognitive development of undergraduates. The stages can be summarized into four types based on how students begin university with a dual perspective. They may, based on their instruction, progress through stages of relativism, multiplicity and commitment as well as the four levels of knowing: independent, absolute, transitional and contextual (Table 1).

Perry's Stages of Undergraduate Cognitive Development	Baxter Mogolda's Levels of Knowing
3. Relativism: All opinions equal • Standards of comparison	Independent Knowing

1. Duality: Black and white thinking; authorities' rule • Uncertainty	Absolute Knowing
2. Multiplicity: Poor authorities or temporary state • Uncertainty as legitimate, inherent	Transitional Knowing
4. Commitment (tentative) to the best theory available	Contextual Knowing

Table 1. Stages/Levels of Student Cognitive Development (Nilson, 2010).

At position 1, students perceive the world in black and white. They choose what to accept as true and how to act according to the standards of right and wrong. Authority figures, such as instructors, theoretically know and teach absolute truths about reality. Knowledge can be enumerated, such as exact answers on a spelling exam. At position 2, students enter the stage of multiplicity. They realize that, since instructors do not know everything, a discipline permits several views to compete for acceptance. Students do not give these views much credibility, believing that they are simply an instructor's exercise intended to lead students to the one correct answer (Nilson, 2010). At position 3, the stage of relativism, students abandon their faith in the instructor's capacity to recognize the truth and are left with no hope of the existence of a true explanation or solution. Students at position 4 feel the need to position themselves in their relativistic world by making a personal commitment to one posture or another. They experience and study the effects of their election of responsibility, understanding individual and intellectual growth.

Knowledge is constructed based on personal experiences and hypotheses about the environment. Learners continuously test these hypotheses and have different interpretations and constructions of the knowledge process. A reaction to didactic approaches such as behaviorism and programmed instruction, according to (Piaget, 1970) and (Valero García, 2013), states that learning is an active, contextual process of constructing knowledge rather than acquiring it. People learn by inserting information into their cognitive structures and reorganizing these structures if necessary. Form (a) represents the cognitive structure each person has. Each node is information, and the bridges are the relationships that people establish among this information from their living experience. Learning occurs when someone (teacher, book, television, etc.) throws a ball of new information against a learner's cognitive structure. A simple way to explain the construction of learning is shown in Figure 1.

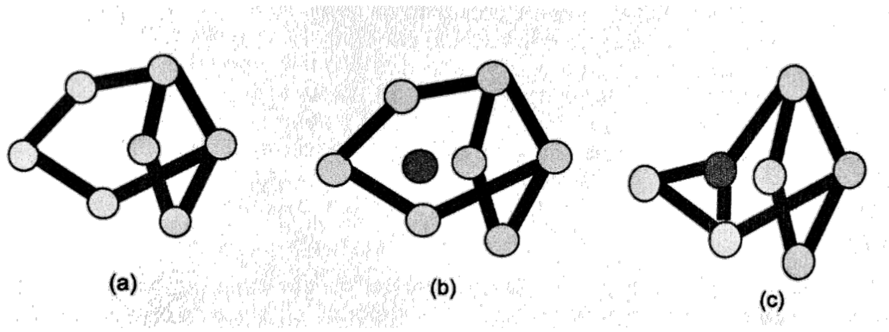

Figure 1. Construction learning theory. (Valero García, 2013)

With that ball, three things can happen:

1) The ball does not touch any element of the cognitive structure and navigates it without changing it. In this case, no learning occurs because the ball does not call into question what the learner already knows. (a)
2) The ball does not hit any element of the structure, but the learner holds it artificially, for example, until the day of the exam in case it is useful. After the exam, the learner lets the ball go. In this case, no learning occurs. (b)
3) The ball hits some element of the structure and destabilizes it. The new information calls into question part of what the learner believes and can no longer continue to believe. The learner reorganizes the structure, remakes the relationships, integrates the new information and distributes other pieces of information that are no longer relevant. In this case, some learning may occur. (c)

Many theories speak to strategies of teaching that allow the student to “grab the ball” of information and allow it to do its work on their cognitive structure. (Valero García, 2013) speak of, among others, two principles of quality teaching:

1) Stimulates active learning
2) Provides feedback on time

Other relevant concepts and ideas provided by previous studies (Nilson, 2010) also to be considered in this study focus on several characteristics of human beings. According to these studies, methodologies of learning do the following.

1) They begin where the students are, with their lifestyles. Then, they relate the new content to the students. This process helps students learn from what is familiar to them, both cognitively and experientially.
2) They make the material relevant to the students’ day-to-day experience, future careers, and real-world problems.
3) They use active learning techniques, and, when lecturing, do so interactively, with frequent breaks for student activities.

4) When possible, they use experiential methods, especially those that place students in real-life problem-solving situations, either simulated or genuine.
5) They teach in multiple modalities. They give students the opportunities to read, hear, talk, write, see, draw, think, act, and feel new material; that is, they involve as many senses and parts of the brain as possible in teaching and student learning.

Today's students want to learn differently from the ways they did in the past; they want to create, use the tools of their time, make decisions and share control. They also want to share their opinions, both in class and globally, and above all, they want an education that is both relevant and connected with reality (Prensky, 2010). For them, the new era of an information society (IS) is simply their era; therefore, the acquisition of skills (both general and specific) and knowledge must be related to the use and control of information and communication technologies (ICT) (Paes, Arantes, & Irizarry, 2017).

In general, and especially for architecture students, graphic visuals are powerful learning aids because they provide a ready-made, easy-to-process structure for knowledge. (Gantt, 2011) asserted that human beings have a short-range retention capacity of 20% of what is heard and 75% of what is seen and done. Considering previous recommendations and logical premises based on such cognitive studies as this one, the traditional master class (in which students are limited to taking notes about what they hear and see) must be migrated to a learning system in which students are active content generators. This new paradigm is desirable as an optimal learning model, allowing student involvement in the subject and content as well as the ability to study collaboratively. For students, this process is easier to accomplish with visuals than with text (Nilson, 2010). People learn best when they receive new material in different ways, that is, through multiple senses and modes that use different parts of their brains in a multiple-method instructional style. Specifically, in the fields of architecture and building engineering, space visualization and conceptualization are essential aspects that students must master before initiating their professional careers (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. Teaching to multiple methodologies can help revitalize lesson plans that have become routine through repetition (Abdullah, Kassim, & Sanusi, 2017; Dinis, Guimaraes, Carvalho, & Martins, 2017; David Fonseca, Villagrasa, Martí, Redondo, & Sánchez, 2013; Wang, Wu, Wang, Chi, & Wang, 2018).

The ways in which we now communicate have been adapting to new devices that mostly involve characteristics such as mobility, interaction, and interconnection (Sánchez-Sepúlveda et al., 2018). Studies (Bower, Cram, & Groom, 2010) explain the openings obtainable by these emerging technologies as making a new type of reality in which physical and digital environments merge in our daily lives (Doyle, Dodge, & Smith, 1998; Redondo, Fonseca, Sánchez, & Navarro, 2017). However, architecture education is still in the process of adapting to these changes. In many examples, the traditional lecture class is given as the predominant system, although it does not make use of this generation's ability to adapt to and quickly use all types of devices and applications for their purposes (Bennett, Maton, & Kervin, 2008).

2.2 Technologies Used by Architecture Students

Architects are trained to build abstract relationships and to understand the impact of ideas based on research and analysis. This training includes having a facility with a wider range of media used to think about architecture and urbanism, including writing, research skills, speaking, drawing and model making. Linked to these skills are visual communication skills (Cho & Suh, 2019; János & Kem Gyula, 2019; Lobovikov-Katz, 2019; Salerno, 2018). Architecture students tend to express their work primarily by visual representation. Moreover, throughout their academic careers, they learn to represent their work through various representation technologies, incorporating these technologies into their design processes to better communicate their proposals. Technologies that model in 3D, virtual reality and even video games represent progress in enhancing the capacity of spatial and graphic vision; therefore, they facilitate the process of project conception (Martín-Dorta, Saorín, & Contero, 2008; Torner, 2009). Architects should be able to use appropriate representational media, such as traditional graphic and digital technology, to convey essential, formal elements at each stage of the programming and design process (Malcolm Champion Taylor, 2008).

The use of ICTs in educational methods is defined in the courses of many undergraduates and master's students, including the architecture degree (Reffat, 2007; Sariyildiz & Veer, 1998). From an educational perspective, these methods are applied to enhance the acquisition of spatial competences to analyze the visual impact of any architectural or urban project (Villagrasa et al., 2017). Architecture students must learn to be proficient in the following representation technologies throughout their studies (Navarro, 2017; Monica V. Sanchez-Sepulveda, Marti-Audi, & Fonseca-Escudero, 2019):

- Basic systems that allow 2D representation (based mostly on CAD technology)
- BIM systems capable of integrally managing the 2D and 3D information of a project
- New interactive systems based on video game platforms, such as Unreal or Unity, capable of managing a visualization through augmented reality (AR), or virtual reality (VR) in real-time, as they have advantages over CAD/BIM systems.

For this article, we focus on the new interactive systems based on video games. Video games/gamified systems have tasks with a high spatial component (rotate, move, scale, etc.), such as those present in video games as well as in serious games applied to the visualization of complex models, where we can find actions in which the user must move the character in a multitude of possible combinations (Gagnon, 1985; Sedeno, 2010).

These interactive applications have favored the performance and speed of learning as well as the personal and intrapersonal skills of students. Content based on these formats is closer to the means of everyday use for students and end-users. For this reason, this type of system is more attractive, increasing motivation and favoring performance (Martín-Gutiérrez, Saorín, Contero, & Alcaniz, 2010). A few of these examples can be found in the compilation of (García, 2015). The study of material outside the classroom is promoted through multimedia systems, interactive tutorials, animation, hypermedia systems, and new visualization methods, such as augmented and virtual reality (AR/VR) (Alvarez Rodríguez, 2007; Campos, 2016; Salmerón, Rodríguez-Fernández, & Gutiérrez-Braojos, 2010).

3 Case Study

3.1 Project description

We design an educational activity based on a project-based learning (PBL) method to evaluate student behavior, motivation, and adaptation to pedagogical innovations that involve the use of different work technologies and the visualization of complex 3D models, an approach with excellent previous results (Campanyà, Fonseca, Martí, Amo, & Simón, 2019; Pons, Franquesa, & Hosseini, 2019; Suwono & Dewi, 2019). The perspective of PBL is easily adapted to the training of architecture students, who work with real exercises and initiatives from the start of their coursework. This method includes creating a real presentation of a selected urban project. The selected project is based on the implementation of virtual gamified strategies in the field of urban design for the understanding of three-dimensional space to improve the spatial competencies of students (Monica V. Sanchez-Sepulveda, Torres-Kompen, Fonseca, & Franquesa-Sanchez, 2019).

The urban project on which we work, promoted by the Barcelona Metropolitan Area, aims to generate spaces that are designed to meet users' wants: spacious, pleasant spaces with vegetation and dynamic uses; spaces for children's games; urban gardens; lighting; and recreational and cultural activities, among others. The site selected is part of the *Superilles* (Super Squares) concept, where the streets are closed to vehicles for pedestrians and outdoor activities of neighbors. The aim is to create a large public space that prioritizes the people instead of the vehicles of the Eixample Esquerra District (Mónica Sanchez-Sepulveda, Fonseca, Franquesa, & Redondo, 2019). By closing the street to vehicles and opening it to pedestrians, the program to be situated there is designed according to the residents' criteria. Collaboratively with the neighbors, the following conditions were stated:

- Focus the street primarily on the pedestrians
- Provide spaces for tourists and residents to coexist
- Increase low vegetation while maintaining the typical alignment of trees
- Increase the surface of rainwater catchment on the terrain
- Establish criteria for the location of furniture and services

3.2 Technologies

We created a virtual reality game in which, through interactive elements, the students shaped the urban public space following previous case studies focused on similar approaches

(Stauskis, 2014). The students were in charge of modeling the space with different software and then analyzing the proposed methods, their profiles and learning experiences. The students were first introduced to emerging technologies such as augmented and virtual reality in a course that focused on using video game technology for architectural representation (Calvo, Fonseca, et al., 2018), taking advantage of improvements in real-time rendering to produce interactive content.

This virtual three-dimensional scenario becomes an environment with which users can interact to recreate new spaces. These spaces are meant to show maximum realism, including the materials, textures, movements, and even sounds of the environment. Using VR glasses, the users experimented with and shaped the urban public space. Now, neighbors and the city council can visualize the scale, the textures, and the lights and shadows, among other elements, in the context of the needs and uses of citizens. The VR glasses allow users to understand in an immersive way how their actions and changes affect the environment in real time. The focus of the evaluation of this project is to study the motivation, engagement, and overall experience of the students with the used methodology, not the effectiveness of the approach, as the complete urban design process is still ongoing.

3.3 Sample and methodology

We worked with two groups of students. The first group was composed of students from the 4th-year course Multimedia Tools 1 at the Superior Technical School of Architecture of Barcelona, Polytechnic University of Catalonia (UPC) (Figure 2). The group was composed of 21 males (mean age of 28.57 years with a standard deviation (SD) of 4.46), and 13 females (mean age of 24.30 years, SD of 2.01). They used Sketch Up for modeling and Unity for creating the interactive virtual environment of the space. The second group was composed of students from a 2nd-year course (Computer Tools 2) at the Superior Technical School of Architecture of La Salle, Ramon Llull University (Figure 3), where the students used 3DMax and Unreal to reproduce the same spatial area as the first group. The group was composed of 12 males (mean age of 21.58, SD of 1.83) and 17 females (mean age of 20.94 years, SD of 1.56).

Figure 2. UPC students' work.

Figure 3. La Salle students' work.

We selected these two samples because they were working with the same project and with the same typology of exercise: starting from the modeling, illumination and texturization of a basic stand in a public square and finishing with the visualization and discussion of the proposals using VR engines. Before conducting the exercise, the students completed a questionnaire to assess their knowledge of and motivation in using different technologies. This questionnaire gave us information about the student technological profile (and the homogeneity of the samples) and helps us answer RQ1. After the experiment, students completed a survey focused on assessing the experience and the technology used in relation to the improvement of urban projects (to answer our RQ2).

To analyze the proposed methods, we used a system for data extraction that was earlier proven in educational studies in the same field (David Fonseca, Redondo, Valls, & Villagrasa, 2017; David Fonseca, Valls, Redondo, & Villagrasa, 2016). An initial questionnaire was created to obtain the student's profile and level of familiarity/motivation regarding the use of selected technologies. This questionnaire was given at beginning of the course, and the students were asked to estimate their degree of knowledge of, use of, and interest in technologies, specifically in the use of informatics devices and mobile technology, the Internet, and serious games. The objective of this initial questionnaire was to evaluate the extent of their similarities to validate the differentiation of the experiment and its results.

At the end of the course, a survey was given to evaluate the level of usability of the technologies used and their possible relation and uses with the students' studies and future projects. We brought the virtual reality technology to the neighbors so they could participate in defining the uses of the public spaces of the city of Barcelona, such as the Urban Mobility Plan Superiors (PMU) 20132018, and help build the city everyone wants in a participative way (Paes et al., 2017). This methodology includes participants as an active element of the project, allowing them to preview the space and propose changes that can help the designer in the process (Portman, Natapov, & Fisher-Gewirtzman, 2015). The core of this survey is the assessment of the students' perception of the utility of the systems executed and used in their studies, future deliveries and professional undertakings. The objective is to evaluate the students' satisfaction when completing the experience at the end of the course.

4 Results

4.1 *User profile: Questionnaire*

We created an initial user profile questionnaire in which the students were asked 35 questions about diverse topics (Figure 4). The first block asked about personal information (age, gender, and nationality), followed by information about the technologies the students have, types of connections, location, etc. To estimate the probability that profiles by group are significantly similar, we used Student's t-test (Gosset, 1908) using a null hypothesis (H_0) that had no differences in scores between groups. The statistical significance (two-tailed) obtained was 0.4985, which exceeds the threshold of 0.05. This result indicates a low probability that the digital profile of both of the student groups is different with respect to their skills and previous technological uses. The null hypothesis, which states that there is no significant differences between the groups, is accepted, as we can see in Table 2.

	Questionnaire with scientific objectives in order to improve the Architecture and Urbanism education					
	The present questionnaire is carried out in the framework of a research (2016-2020) that is underway with the aim of improving teaching linked to architecture, town planning and techniques of representation. The research project is framing the challenges program of the Spanish Ministry of Education and Competitiveness. All data will be treated confidentially and will only be used for statistical purposes and correlation of variables.					
	Name and Surname (for correlation with post-test)					
1	Year of Birth					
2	Gender (Male / Female)					
3	City and Country (Birth)					
4	Finished studies (Primary/Secundary/Bachellor/Professonal studies/Degree/Postg/Master):					
5	Nowadays studies (Initial year):					
6	If you are working: profession, position, , profesión / cargo / company:					
	Technological Data Profile:					
	From (1 Never, 2 occasionally, 3 weekly, 4 daily, 5 very frequently), indicate the use of the following devices and technologies	1	2	3	4	5
7	Desktop Computer					
8	Laptop					
9	Mobile Phone (no smartphone)					
10	Smartphone					
11	Tablet					
12	GPS					
13	Physical activity control device					
14	Smartwatch					
15	Video Digital Camera					
16	Photo Digital Camera					
17	Other:					
18	Social Network					
19	Search services related to study/profession					
20	Information in general / News / newspapers					
21	Download services					
22	Video/Series watching services					
23	MP3/Audio listening services					
24	Other:					
	Internet connectio: (1 Never, 2 occasionally, 3 weekly, 4 daily, 5 very frequently)	1	2	3	4	5
25	ADSL at home					
26	WIFI at home					
27	Cable at home					
28	Phisic connection at the place of work/study					
29	WIFI connection at the place of work/study					
30	Public WIFI					
31	Data mobile services (for mobile or tablet)					
	Frecuency of use: (1-Never / 2- less than 1h a day / 3- between 1h - 2h a day / 4- between 2h - 3h a day / 5 - more than 3h a day)	1	2	3	4	5
32	Internet in smartphone, mobile device or tablet					
33	Internet in fixed places: PC					
34	Videogames in mobile devices					
35	Videogames in fixed places: PC, Game Consoles, TV, etc...					

Figure 4. Profile Questionnaire

Independent Samples Questionnaire.

PROFILE QUESTIONNAIRE	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Difference
Equal variances assumed	-0.6834	37	0.4985	-0.001	0.29913

Table 2. Null Hypothesis Results

We descriptively highlighted the following items: 91% of the students use laptops for studying and working, and only 48% also have a desktop computer. Ninety-seven percent have smartphones, and only 24% also have a basic mobile phone. Only 55% have a digital camera, and devices such as tablets or fit bands have a percentage of use between 35% and 45%.

The main connection types used by our students are Wi-Fi (94% home, 91% university, and 44% public) and data plans for smartphones (91% mobile devices and 48% desktop devices). In summary, 93% of the students use the Internet in their mobile devices compared with 62% who use desktop devices. Finally, asked about their use of video games and serious games on mobile devices, only 32% answered positively, the same who play frequently using desktop interfaces.

We detected small differences in the behaviors of the male and female students regarding the use of mobile devices (smartphones/laptops/digital cameras). Smartphones are more commonly used by the females (98% vs. 93% for the males, following the results of previous studies (David Fonseca et al., 2014)), as were digital cameras (71% vs. 58%), and desktop computers (47% vs. 33%). All of these devices led laptop devices, which were more frequently used by the males than the females (99% vs. 96%, respectively). When we analyze by gender the type of the connections, we also see significant differences based on “mobility”. The male students (57%) more commonly used a physical connection (not Wi-Fi) than the females (44%), and both groups had a rate of 81% for using Wi-Fi connections (at home, public, university, etc.).

To evaluate the possibility that profiles by gender are considerably similar, we used Student’s t-test with a null hypothesis (H_0) that had no variances in scores between the groups. The statistical significance (two-tailed) was 0.2416, which corroborates that a low probability indicates that the results by gender are different. When we consider the results of both of the groups in the profile questionnaire (by age, course and gender), our sample is consistent and allows us to compare the results of the experience.

Regarding the main topic of the research and surveyed in the profile questionnaire, where the video games and serious games play an important role, a 5% difference was found in the use of video games between groups B and A (B: 35% vs. A: 30%). When we analyzed the data of each group by gender, in Group A, the male students had an average of 33% use compared with the female students’ average of 27%. The distribution is similar in Group B, which has a more extreme distribution of 45% use for the male students compared with 26% for the females.

These data can be associated with the major use of desktop systems for the male students, considering that video games and serious games are too complex to play on mobile devices, which are used more by females. Following our assumption, we analyzed the intrinsic motivation (using the Intrinsic Motivation Inventory [IMI], previously validated and used in similar works (Mónica Sanchez-Sepulveda, Fonseca, et al., 2019)) of the students as a function of the following seven indicators:

- IMI-1: I enjoy playing and using virtual environments. I think this kind of experience is very amusing and entertaining.
- IMI-2: Using 3D viewing, I can acquire better architecture skills related to the 3D space in front of the traditional systems (print sheets, posters, etc.).
- IMI-3: I believe that the use of virtual and gamified proposals needs less effort than traditional systems.
- IMI-4: The use of interactive-virtual proposals generates less stress that systems based on panels and mock-ups.
- IMI-5: I think that using virtual proposals I can change the future way of working, understanding, and showing the architectural and urban projects.
- IMI-6: Serious games and virtual interactions and navigation are systems useful for my future and can benefit me.
- IMI-7: Interactive and gamified systems help me in the collaboration with other users/partners/friends/colleagues, expanding my social relations.

The results of the seven IMI indicators, separated by groups, are as follows:

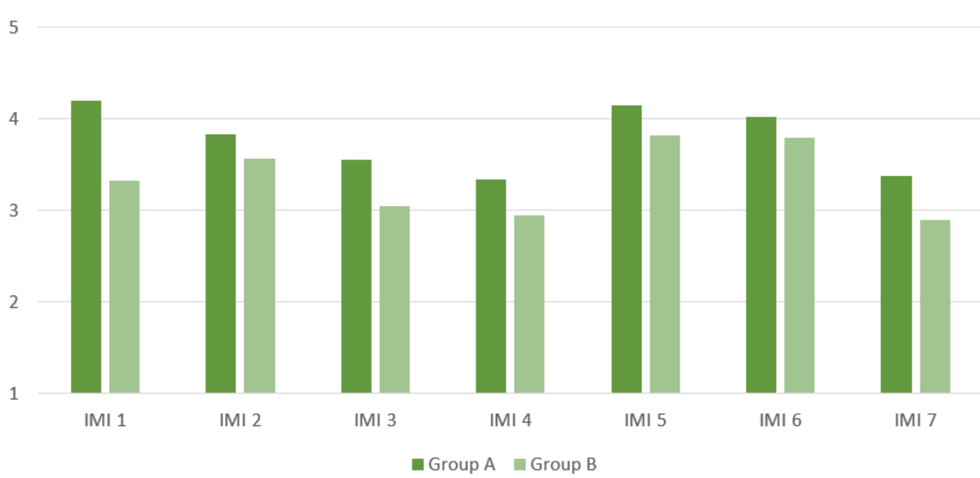

Figure 5. IMI indicators by group, using a Liker scale from 1 to 5.

When we analyze the global IMI data (Figure 5), the average obtained is 3.78 (SD: 1.17) by Group A and 3.34 (SD: 1.06) for Group B. The lowest IMI level identified by Group A was IMI-4 (3.34, SD: 1.22), followed by IMI-7, with an average of 3.37 (SD: 1.66). Conversely, the best indicators, 4.20 (SD: 1.01) and 4.14 (SD: 1.27), were, respectively, IMI-1 and IMI-5. In the case of Group B, the lowest value was obtained for IMI-7 (Av: 2.90, SD: 1.18), followed by IMI-4, both previously identified by Group A as the lowest indicators (Av: 2.95, SD: 0.96).

The major positive indicators for Group B were IMI-5 and IMI-6, (Av: 3.81, SD: 0.88, and Av: 3.79, SD: 1.03, respectively), making IMI-5 the most common positive indicator. To estimate the probability that the results of IMI indicators by the groups are significantly similar, we used Student's t-test. The statistical significance is 0.050 (two-tailed), which means that there is a high probability that the IMI global perception by the groups (the initial motivation for using gamified and interactive 3D systems) are different.

On the other hand, when the IMI indicators are analyzed by the gender, the average obtained is 3.70 (SD: 0.95) for the male students and 3.42 (SD: 1.14) for the female students. Without a significant statistical difference between the groups ($p = 0.241$), the lowest IMI level identified by the male students was IMI-3 (with an average of 3.32, SD: 0.95), followed by IMI-4 with an average of 3.37 (SD: 1.10). Conversely, the best indicators, 4.12 (SD: 0.79) and 4.10 (SD: 0.75), were, respectively, IMI-1 and IMI-6. In the case of the female students, the lowest value was for IMI-7 (Av: 2.69, SD: 1.39), followed by IMI-4, previously identified by the male group as one of the lowest indicators (Av: 2.91, SD: 1.01). The positive indicators are IMI-5 and IMI-2 (Av: 4.06, SD: 0.95, and Av: 3.86, SD: 0.81, respectively), as we can see in Figure 6.

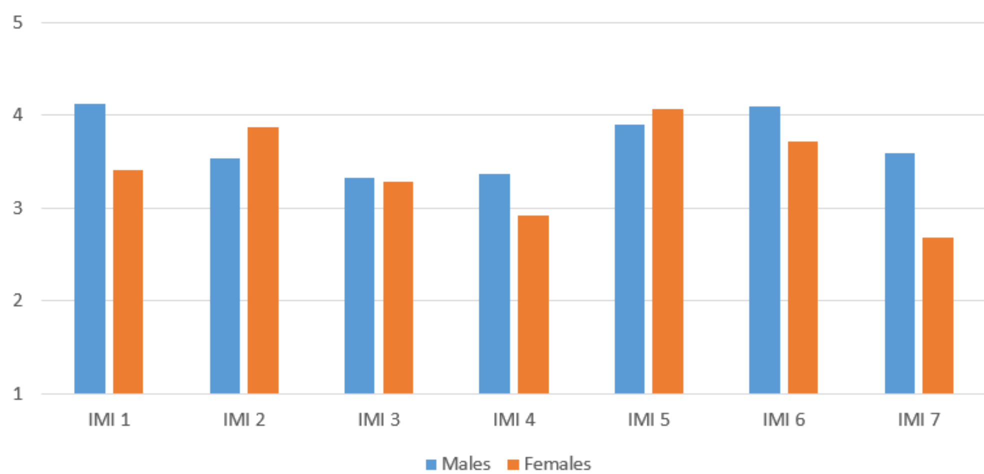

Figure 6. IMI indicators by the gender, using a Liker scale from 1 to 5.

By understanding this significant difference, found by group and not by gender, we analyzed the results by gender and by group, as we can observe in Figures 7 and 8.

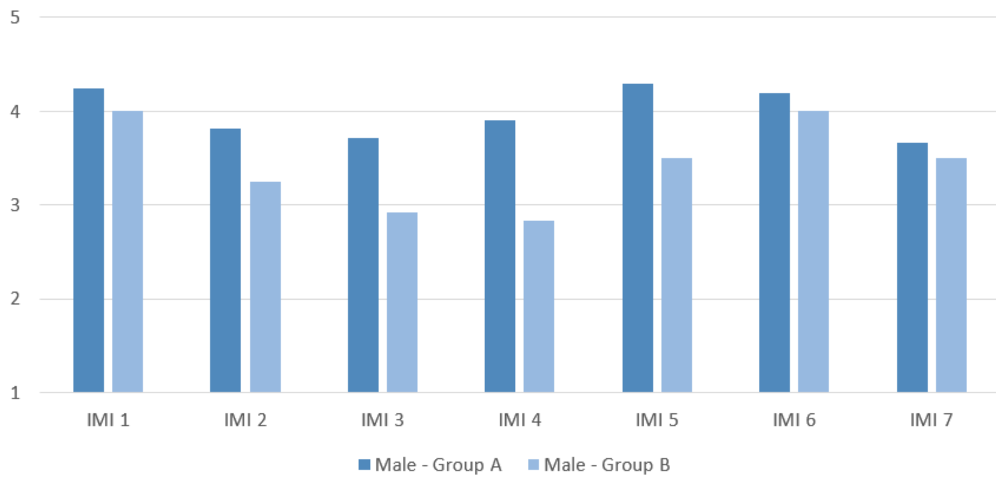

Figure 7. IMI male indicators by group.

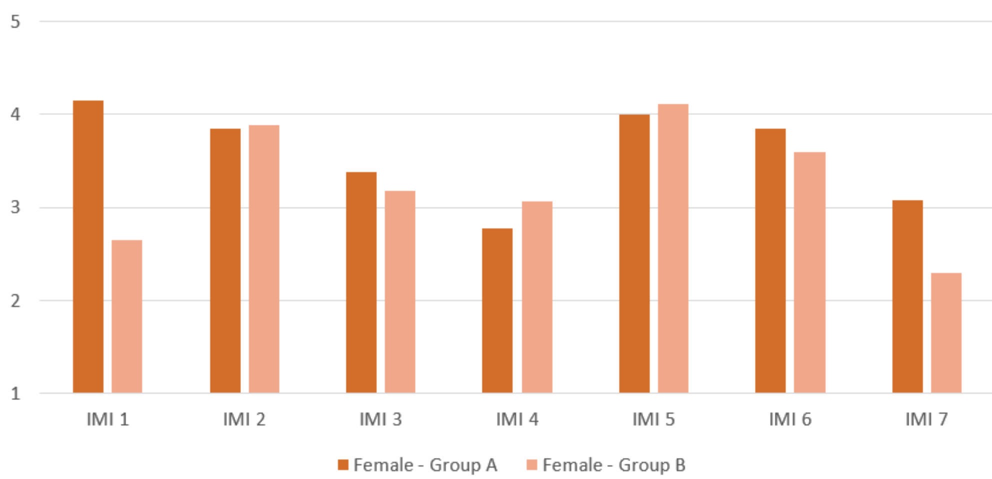

Figure 8. IMI female indicators by group.

The IMI average for the male students in Group A is 3.97, higher than 3.42 for Group B. To complete the assessment, one-way between-group analysis of variance (ANOVA) using questionnaire IMI scores as the covariant was conducted. Significant differences between the male groups ($F = 7.236$, $p < 0.01$) has been found when compared with the female results; with averages of 3.58 for Group A and 3.25 for Group B, no statistically significant differences between the groups has been identified ($F = 1.095$, $p = 0.315$). However, in this last comparison, we find a significant difference for IMI-1 and 7 indicators, an issue that can explain the major differences by group (Figure 5) and by gender (Figure 6).

4.2 Utility perception of interactive and gamified systems: Survey

The structure of the survey is based on the International Organization of Standardization (ISO) 9241-11 and allows us to assess the usability of the VR technology and interactive-gamified methods in educational environments.

Table 3 shows the students' main perceptions (P1 to P7), including their valuations of the proposed methodology, perceived usefulness, and level of satisfaction. In addition, we incorporated their assessments of the gamification processes (G1 to G3).

Mean of perception and gamification by group and gender

VARIABLES	*Mean GA (34, 21m-13f)*			*Mean GB (39, 12m-17f)*		
Perception of the proposal	*GA*	*Males*	*Females*	*GB*	Males	*Females*
P1 - Digital 3D visualisation of Architecture/Urban projects is very important to understand the space	**4.28**	4.13	4.44	**4.28**	4.33	4.24
P2 - The use of Virtual Reality to display A/U projects is useful for their understanding	**4.08**	4.38	3.78	**4.02**	4.17	3.88
P3 - Based on the proposal used, I am motivated to use VR in my future projects for their presentation and understanding	**3.72**	4.00	3.44	**3.77**	3.67	3.88
P4 - Models scale are suitable to manipulate virtual elements	**3.73**	3.56	3.89	**4.24**	4.25	4.24
P5 - The materials, textures, and lighting of a virtual environment must always be the most realistic possible	**3.24**	3.25	3.22	**3.42**	3.67	3.18
P6 – The existence of background music is better and satisfies the user in the interaction with virtual spaces	**2.47**	2.38	2.56	**3.35**	3.75	2.94
P7 – The visualisation device has a considerable influence in the virtual quality perception	**4.08**	4.38	3.78	**3.79**	4.17	3.41
Gamification indicators						
G1 – The use of gamified environments (with missions and achievements) are better than simple free navigation in a virtual space	**3.77**	3.88	3.67	**3.28**	3.33	3.24
G2 – Playing games, I prefer one-to-one games vs. multiplayer environments	**3.16**	2.88	3.44	**2.85**	2.75	2.94
G3 – I consider that using games in educational environments can help to understand better the typology and correction of the materials used in the scenes	**3.80**	3.81	3.78	**3.10**	3.08	3.13

Table 3. Mean of perception and gamification by group and gender

As corroborated in the questionnaire, no statistically significant differences were found regarding gender within each of the groups. In this way, the average of the 7 variables of perception for the male students of Group A is 3.72, and for the female students, it is 3.58 (p = 0.70). The three gamification variables average 3.52 and 3.62 for males and females, respectively (p = 0.77). Similarly, in Group B, the averages were 4.00 (males) and 3.68 (females) for the perception variables and 3.05 and 3.10, respectively, for the gamification variables (with p = 0.18, and 0.70, respectively). Comparing the results by groups show perception averages of 3.65 for Group A and 3.84 for Group B, which fall to 3.57 for Group A and 3.07 for Group B regarding the subject of gamification indicators.

Although at a global level, there is no significant statistical difference in perception between the groups (p = 0.51), there are differences in concrete variables such as P4 (p = 0.049) and P6 (p = 0.009). Specifically, for P4 (the scale of the models is adequate to manipulate virtual elements), Group B (second course of La Salle) values this indicator more (Av: 4.24, Variance:

0.83) than Group A (fourth course of UPC), which values this indicator less (Av: 3.68, V: 1.89). The same result is found for P6, which evaluates the existence of music as a positive factor in the 3D interaction. For P6, the students of Group B value P6 with an average of 3.27, which is much higher than that of Group A, who value it with an average of only 2.44.

As with the perception of the utility, the analysis of the data of the variables linked to gamification does not reveal a significant difference between groups (p = 0.13). Thus, the variables and genres are comparable. That is, while the difference of the male students by groups is not significant (p = 0.29), a difference is found between the female students based on the two study groups (p = 0.015). With an average of 3.62, the 4th year students value the gamified dynamics in a much more positive way, highlighting G3 (using games in educational environments can help to understand the typology and correction of the materials used in the scenes).

To compare potential differences in behavior/perception according to user profile and the level of the students, the students were also asked questions based on the criteria set out in Figure 9.

- Soc-Urb1: These systems facilitate decision making in urban projects
- Soc-Urb2: The interactive virtual systems allow the design and re-evaluation of urban spaces
- Soc-Urb3: They allow identifying possible unsatisfied social needs
- Dig-Sk1: With the information obtained from the users, the students can incorporate the data to optimally modify their projects and proposals
- Dig-Sk2: The opinion of the final users helps and should serve to improve the training/competences of the student
- Dig-Sk3: These systems help to improve the digital skills in a complex representation

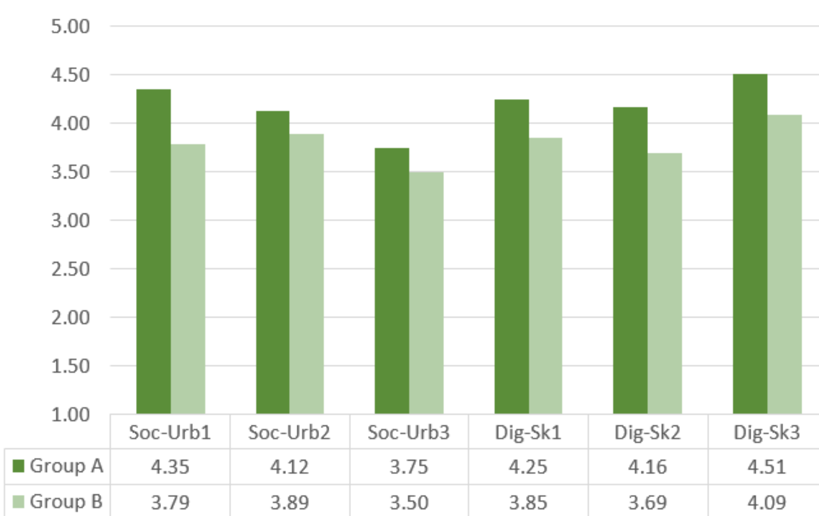

Figure 9. Social and Urban uses and improvement of digital skills using VR systems.

This phase seeks to complement, compare and analyze the data studied in previous phases of the project (Mónica Sanchez-Sepulveda, Fonseca, et al., 2019). The intention is to establish the training needs of the students according to the level of the subject and the available technologies at the educational level.

Based on the results (statistical significance obtained, $p = 0.016$, below the threshold of 0.05, which allows a guaranteed difference of at least 95%), we can affirm that behavior is differentiated according to the level of our students. With an average of 4.19 compared to 3.80, the students of Group A consider significantly that, for the specific case of urban projects, interactive systems are useful and allow quicker and more effective decisions to be made based on environmental problems. Likewise, and with a broader educational background, the students of Group B consider that the systems used improve the abilities and competences of the students. These results reflect the awareness of the potentialities of the method as the students are trained.

5 Discussion

The results of our study show minimal and specific differences in some indicators by gender, both in initial motivation (IMI-1, IMI-7) and after the practical implementation of the perception of usefulness of the virtual and gamified systems in the visualization processes of the architectural/urban project (P2, P3, P7 and G2). Gender was not a variable in this case, as opposed to other case studies (Mónica Sanchez-Sepulveda, Fonseca, et al., 2019)**,** in which the answers by gender showed a significant difference. These differences are not significant globally, independent of the user profiles and technological uses of our students. Therefore, we conclude that, at least by gender, our samples behave homogeneously, and gender does not cause any variations.

However, we found significant differences in the results when comparing the influence of background, similar to other cases (Monica V. Sanchez-Sepulveda, Torres-Kompen, et al., 2019). Globally, the students of Group B (2nd year, La Salle) perceived with greater utility the potential of virtual, interactive and gamified systems for the visualization of their projects, as seen from the data analysis of Table 3. This result answers our RQ1. In particular, the musical question of support for interaction (P6) stands out for the importance given it by the group of younger students, followed by P4, which relates the scale of the objects to be treated with the size of the environment. These results can be associated with the type of applications used and the programmed environment. The parametrization that allows 3D Max and the processes programmed in Unreal (the system used by the students of Group B) are clear influencers in the positive evaluation concerning the modeling work with Sketch Up and the interaction with Unity (the system used by Group A). These results and the relationship with the applications used indicate that even with a lower level of training (Group B, 2nd year vs. Group A, 4th year), the possibilities of urban and project visualization offered by the 3D Max-Unreal pack are more interesting and have greater potential for a professional future, which answers our RQ2.

The best-valued aspect is P1, which affirms the importance of 3D visualization for the understanding of space, but the motivation of the students for their use in architectural projects can be defined as low (D. Fonseca, Villagrasa, et al., 2017). The perception of the usefulness of sound and the gamification of the interaction are the aspects less valued by the students. This result reflects the absence of a need to consider other variables of the project in the academic presentations beyond the visual (David Fonseca, Villagrasa, et al., 2017; F Valls, Redondo, & Fonseca, 2015; Francesc Valls, Redondo, Fonseca, Garcia-Almirall, & Subirós, 2016; Vicent, Villagrasa, Fonseca, & Redondo, 2015). This result is the opposite of users who are not experts in the development or education of architectural or urban projects, an aspect that reflects a gap to be resolved internally in current educational plans.

Our results contrast with the results of the variables associated with the gamification evaluation, where the most positive assessment is precisely inverted for the students of Group A (4th year UPC). This result clearly explains the complexity and learning curve of the applications used. Group B used complex systems that have a slow process of creating a gamified project, although they are of a very professional quality. Group A used applications whose learning curve is very fast, which has an acceptable output quality for a representative space but does not reach a high level of realism, although it allows a very active and simple way of using a gamified system.

The knowledge acquisition and data representation method used indicate that younger students perceive a very high potential for the use of interactive systems, a perception that decreases over the years based on the repeated use of more traditional systems. However, due to the rapid learning curve of certain systems and the potential quality of virtual models, these methods are increasingly perceived as having greater use and potential work on the professional level as the studies progress, especially for exercises and concrete projects, such as in the case of tactical projects of urban planning.

6 Conclusion

The outcomes of the present study were in line with our expectations that the profile of the student was highly correlated with the motivation to use and satisfaction with the interactive educational system. The level of interaction of the students in all phases of the proposed methodology generated a high level of interest in visualization techniques and high learning perceptions. Working with a collaborative and interactive interface and the capacity to generate physical and digital expositions are activities that produced active students with significant improvements in spatial, research, and interaction skills. The overall valuations of competence, effectiveness, and satisfaction were all approximately 4. Therefore, we can validate that the students felt satisfied and motivated when using this methodology.

This study has limitations that provide some variables to improve in future studies. Some of these variables are that, first, similar experiences between different courses must be compared to ensure that students' previous experience in other architectural subjects is relevant to their understanding of how to use the interactive technology. Second, the evaluation surveys and interviews need to be improved to collect more information about experiences throughout the entire course. Our future experiments will integrate digital transformation into the teaching and processes of urban design through innovative concepts and practical methodologies, as we can confirm that the methodology used in architecture education allows for the verification of different scenarios before construction begins.

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