Collaborative Design of Urban Spaces Uses: From the Citizen Idea to the Educational Virtual Development

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Abstract. The paper is concerned with the design of virtual environments for collaborative design. The interests of citizens are coming to the forefront nowadays with the awareness that a livable city does not only consist of good infrastructure and sustainable energy supply but also citizen input and feedback. The project consists of a transversal research at the intersection between computer science, the teaching of future architects and multimedia engineers and the urban policies of the cities of the future in which citizen participation is fundamental. The hypothesis is based on demonstrating the following two statement: (1) The implementation of virtual gamified strategies in the field of urban design will generate an improvement in citizen participation by being a more dynamic, real and agile collaborative environment thanks to enhanced visual technologies and immersive. (2) Gamified strategies for the understanding of three-dimensional space improve spatial competencies of students generating greater motivation in their use and a degree of satisfaction high. First, we studied the contemporary student profile and better ways of teaching according to it. Second, rehearse and evaluate the teaching of the urban project incorporating collaborative design, immersive ICTs, gamification and citizen participation. Third, the data obtained from the quantitative assessment, exemplify the role and use of technologies, in the educational processes to improve the students' motivation, involvement and way of learning.

Keywords: Higher education · Information and communication technologies · Architecture schools · User experience · Urban spaces · Virtual reality

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1 Introduction

Both, education and the cities in which we live are changing rapidly, presenting the scenery to debate future visions of transformative education and its impact on the city. In order to take advantage of the changes and opportunities offered by the inclusion of digital technologies, an accommodation of the digital transformation into the visualization of Urbanism is required. It is a challenge for Higher Education and society to question the *status quo* and experiment often. This sometimes means walking away from long-standing conventional processes that universities and citizens were built upon, in favor of relatively new practices that are still being defined. The integration of digital transformation in Urbanism consists in balancing the creative act required to generate receptive environments and the social and environmental responsibilities that should be integrated into this act. It is about understanding how knowledge is produced, what the components of that knowledge are and which are the learning processes and social practices that can be used to transmit it.

The main goal of the paper is to present the use of digital transformation in the teaching and processes of urban design and citizenship, through innovative concepts and practical methodologies. The objective is to promote the use of digital technologies, in particular to evaluate the inclusion of virtual reality in various formal and informal teaching environments of collaborative urban design, in order to improve it, speed up and increase its positive social impact. The results will show that it is possible to empower digital transformation, to improve public motivation, implication, and satisfaction in urban decision-making processes.

The paper describes the role and use of technological innovations involving the social re-appropriation of urban spaces and contribute to social inclusion in the city of Barcelona. It is focused on studying the motivation, engagement, and overall experience of the participants (citizenship and the students). The general objectives (or research questions) of this paper is to approach the following topics:

- Combining model with real-scale proposals using Virtual Reality in open spaces makes is it possible to define a new space-participation model, guided, on the local scale, by single citizens, and by a local community.
- It is infer that these initiatives could facilitate public decisions through the social re-evaluation of spaces, real and virtual, in order to respond any needs.
- Organizations can be able to incorporate informal data obtained from citizens, urban and architecture professionals, students, and consequently, designs can be executed with a suitable design, adapted to space and combining the functionality, needs, and interests of all of them.

2 New Generation of Students - Adapting the Profile to Innovative Supporting Technologies

How is the generation of nowadays? This generation is called the Generation Y that comes after the Millennials. This generation are the students that were born in the mid-1990s, early 2000s. They were raised, combined with the school experience, along with their heavy mass media exposure, made them self-confident, extremely social,

technologically sophisticated, action bent, goal oriented, service or civic minded, and accustomed to functioning as part of a team, but on the other side, they are also impatient, demanding, stressed out, sheltered, brand oriented, materialistic, and self-centered [1]. This characteristic has a lot to do in the way they perceive the instructor, the institution and education. This generation has an increased use and familiarity with communications, media, and digital technologies, something older generations did not. However, it must be said that the characteristics of this generation do not apply an entire generation but a portion of its members, as the characteristics vary by region, depending on social and economic conditions.

If comparing this generation with past ones, Biggs mention two types of students: the "good" student—intelligent, well prepared, goal oriented, and motivated to master the material, that came to college with solid thinking, writing, and learning skills. This type was about 75% of the students in 1980 and only about 42% are like that today [2]. The 58% are less academically talented, college ready, and motivated to learn, that just wants to get by with the least amount of learning effort, so they can parlay their degree into a decent job. This type of student will rely on memorizing the material rather than reflecting on and constructing it [2]. In different generations, there are the both types of students that Biggs describe. The only thing that change is the percentage.

Over the last decade, European Higher Education Area (EHEA), and institutions have been involved in a transformation process with the aim of creating a common framework for mobility and generating a knowledge-based competitive society [3]. As an objective of the educational reforms, it is promoted in these contexts that: "Higher education institutions should train students to become knowledgeable and deeply motivated citizens with a critical sense and capacity for analyzing the problems of the society, finding solutions for those who oppose to society, applying them and assuming social responsibilities".

In Spain, universities are in the process of redesigning and verifying their qualifications in accordance with the new guidelines established for the EHEA. This change aims to put the student at the center of the teaching-learning process, focusing on the competencies that the new graduate should possess, enhancing students' know-how, initiative and autonomous learning, according to Dublin descriptors [4]. This new scenario creates a suitable context for the use of new ICTs in higher education, key tools in the development of these new competencies. As already predicted [5], the digitalization of information has changed the primordial support of knowledge and with it our habits and customs in relation to knowledge and communication and, in the end, our ways of thinking. In this sense, new ICTs are changing the way to learn and the type of materials [6]. If we analyze the incorporation of ICT in teaching [7, 8], we can observe how universities are increasingly implementing new technologies as support for teaching, but still there is a gap between the potential of ICTs incorporation in classrooms and the unusual renewal of pedagogical processes. This is because the ICTs have been incorporated into our universities are often associated with individual teaching practices and not as a methodical change.

According to EHEA, within the basic competences and training that must be acquired in engineering and architecture degrees, we can identify the "Capacity of spatial vision and knowledge of graphic representation techniques, both by traditional methods of metric geometry and descriptive geometry, such as through computer aided

design applications" [9]. In Spain, the academic abilities and competences for the architecture and the urbanism profession were defined by the White Book for Architectural and Building Engineering studies, promoted by the National Agency for Evaluation and Accreditation. The main competences identified to develop are:

- Basic skills in computer use
- Application of graphics procedures in the representation of spaces and objects
- Representation of visual attributes of objects dominating proportion and computer techniques
- Skills with spatial representation systems
- Skills with graphic lifting techniques in all its phases

These competences must be developed in a formal educational context: learning typically provided by an education or a training institution, structured and leading to certification [10]. But in the architectural and urbanism courses is easy to work with a real Project-Based Learning (PBL). Under the guidance of a tutor, students are required to develop a proposal, usually in a given location, in a process that mimics the workflow of an architectural studio. Adding to this training, architects and urban designers learn about their discipline in a continuous and informal way, because the subject of their craft surrounds them almost anywhere and anytime. Under the guidance of a tutor, students are required to develop a proposal, usually in a given location, in a process that mimics the workflow of an architectural studio. Adding to this training, architects and urban designers learn about their discipline in a continuous and informal way (Learning result from daily life activities related to work, family or leisure), because the subject of their craft surrounds them almost anywhere and anytime [11, 12].

2.1 Useful Technologies

In face of the enormous amount of urban (or architectural) data that is needed to develop a proposal, the field of Urbanism (and in a most generic view the Architecture and Building Engineering), is yet to incorporate many sources of information into their workflow, based on the tools developed in the Graphic Expression (GE) framework:

- Basic Digital Applications. The study of spatial geometry is fundamental to enhance the development of reasoning and spatial ability. In this sense we can identify clearly different type of tools:
  - 2Dimensions-3Dimensions CAD (Computer Assisted Design) Systems: The CAD methods allow a quick representation and modelling of the architecture and urban data for developing the spatial skills [13]. The ability in spatial representation capacity requires a learning of spatial perception.
  - GIS (Geographical Information Systems): One of the classical methods in the urban representation that allows linking the graphical elements with alphanumeric information to obtain an expanded analysis of the working area, for example using topologies or thematic maps [14].
  - BIM (Building Information Modelling): BIM applications can apply to the entire process of building construction [15].

- Multimedia Systems: Multimedia and interactive applications have favored the performance and speed of learning as well as personal and intrapersonal skills of students. The contents that are based on these formats are closer to the means of everyday use of students and end-users. For this reason, this type of systems are more attractive, increase the motivation and favor the performance [16]. A few of these examples can be found in the compilation of [17]. The study of matter outside the classroom is promoted through: multimedia systems, interactive tutorials, animation, hypermedia systems, and new visualization methods as for example de Augmented and Virtual Reality (AR/VR) [18–20].
- Social and semantic data: Informal data related to a public space that analyze semantic, temporal and spatial patterns, aspects generally overlooked in traditional approaches, improve the education of future urban designers in order to relate the projects to the main needs of the citizenship [21].
- Videogames/Gamified Systems: Tasks that have a high spatial component (rotate, move, scale, etc.) are 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 [22, 23].
- Rapid prototyping and real models: Physical models accelerate the spatial learning process as demonstrated by experiences in GE courses. The use of 3D printers for generating rapid prototypes in the classroom reveals that there are students who learn by touching versus traditional methods that are based on the visual aspects [24].

2.2 Technologies Between Citizens and Students

The last decades in urban design research are characterized by a focus on technological aspects of cities [25]. The concerns and interests of citizens are coming to the forefront nowadays with the awareness that a livable city does not only consist of good infrastructure but also citizen input and feedback. The city as an objective reality and as a symbolized image plays a fundamental role in the organization of space. However, the urban phenomenon that completes the urban structure is its representation as a social product, the result of human action [26]. Using new technologies, as for example VR and AR, we can work with defined urban proposals rehearsing various strategies of action in an interactive way and collaboratively evaluate public spaces. Taking into account that the basis of the VR is to create an immersive experience and allow the user to interact with objects [27] (See Fig. 1).

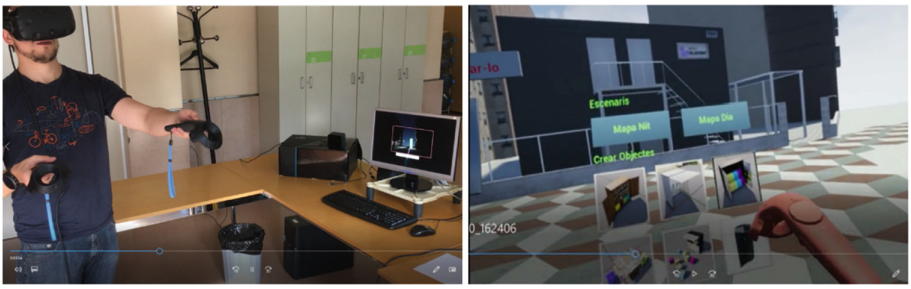

Fig. 1. Gamification for urban design.

Given the approach of the project, it is important to take into account how the VR is a technology, that applied correctly, not only can be a useful teaching tool, but also a tool to involve society and democratize decision making in complex projects, like urban ones. Some studies show that training in a virtual environment in which 3D objects can be manipulated from any angle allows better recognition of objects than if they are taught on paper [28]. By incorporating VR with informal teaching models: citizens generate series of opinions or suggestions, which help students to see different points of view. In this case study the participants are an active element of the project, and the student, will have the ability to learn in real environments and projects (PBL), allowing them to obtain and improve his spatial and social skills in a very optimal way, both formally and informally. This information improves their formal knowledge, as cases were conduct outside an academic environment.

The incorporation of new technologies in education should be considered as part of a global educational policy strategy. In this regard, several important aspects can be mentioned that must be taken into account [29]:

- There is a strong social demand to incorporate the new ICTs to education, often exercised without too much information about the real value of them.
- Strategies related to new technologies require partnerships between the public sector and the private sector, as well as also alliances within the public sector itself.
- Strategies should be considered as a priority to teachers. Relevant studies show that while the majority of teachers show favorable attitudes towards the use of new technologies, there are cultural aspects to which is important to pay attention.
- Given the diversity of situations and the enormous dynamism that exists in this field, political strategies should be based on the development of experiences, innovations and investigations that tend to identify the best paths for universal access to these modalities, which avoids development of new forms of exclusion and marginality.

The active design feedback from a city's inhabitants is an essential way towards a responsive city. We therefore propose a system to merge citizen feedback, which requires a structured evaluation process by the students to integrate for urban design and transmit it to stakeholders and public agencies (See Fig. 2).

Fig. 2. Teaching and management processes of the urban project

This aim is to look and reflect on the urban transformation of public spaces and the built context, from the direct experience with the field of intervention based on virtual reality and the modeling of the project. This direct experience of space in real time allows making more informed and accurate project decisions and guaranteeing much more controlled results.

3 Case Study

The urban project we work on, promoted by the Barcelona Metropolitan Area, aims to generate spaces that are designed to meet the needs of the users. The main intention is to generate spaces that are designed to meet what the users' wants: spacious, pleasant spaces with vegetation, with dynamic uses, spaces for children's games, urban gardens, lighting, recreational and cultural activities, among others.

3.1 Previous Works

A first urban project we work on is in Sant Boi de Llobregat in a short social/urban development of Plaça de la Generalitat. Since it was built in the 70s, the square has been remodeled. Neighbors demanded an intervention on the part of the Administration due to several reasons: the perception of insecurity of the neighborhood, the need to promote the trade of the surroundings and the degradation of the uses in general. The challenge: to design a new place from citizen participation to improve and transform the square according to their needs and desires. In order to gather ideas of improvement on the square, similar to the next projects that will be described, is to (1) Inform and inviting to the participatory process. (2) Know the opinions about the state of the current place and the proposals for improvement. (3) Carry out face-to-face surveys with neighbors. (4) Facilitation of local conferences in order to gather proposals for improvement (See Fig. 3).

Fig. 3. Plaça de la Generalitat neighbors. Collaborative design.

A second project we work on, aims to create a large public space that prioritizes the people of the Example Esquerra District instead of the vehicles [27]. By closing the street to vehicles and allowing it to pedestrians, the program to be situated there is design according to their criteria. Collaboratively, they stated the following conditioners:

- Address the street primarily to pedestrians
- Prevent spaces for stay and neighborhood coexistence
- Increase the low vegetation while maintaining the alignment of trees typical.
- Increase the surface of rainwater catchment on the terrain
- Establish criteria for the location of furniture and services (garbage bins, cargo download, bar terraces…)

3.2 Current Location

The third project we work on is in the area of the Plaça Baró, in Santa Coloma de Gramanet. The base was to produce a collaborative design with a gender perspective from the design phase to the intervention. The aim is to create a specific space adapted to the needs of children between 6 and 12 years old. A participatory process was carried out with students of the 5th grade of the Torre Balldovina School, neighbor of the square, as well as sessions open to the whole neighborhood. The sessions were accompanied by a process of education in architecture and urban planning with a gender perspective for children. All activities have been carried out with approaches that allow children to contribute their realities and needs related to the specific public spaces of action. Consequently, children analyze spaces with a critical eye and can propose improvements with an inclusive perspective and through collective debate and consensus.

In a first phase, neighborhood children participated, in the assignment and distribution of uses to the different parts of the square. In the second phase, the students of the Torre Balldovina School shaped the ideas generated from the different collaborative designs. Finally, the students presented their proposals to the people representing the council. For the realization of the final work, the collage technique on an axonometric was used (See Fig. 4).

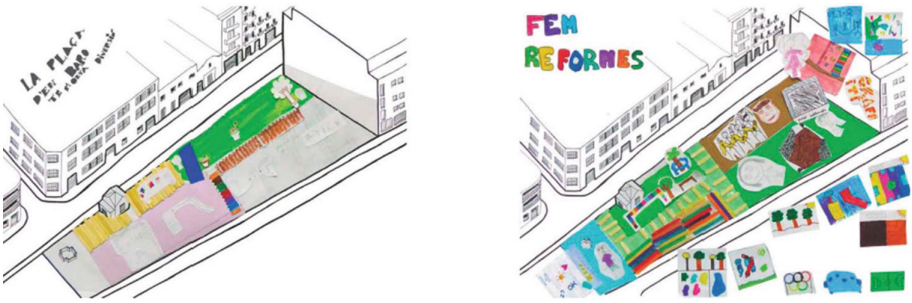

Fig. 4. Work at the Torre Balldovina School.

There have also been sessions for families and careers to share their experiences and needs. The purpose is to detect problems and virtues, a bag of desires and the fabric of the networks. Taking into account that the square is a space for coexistence between different people (age, hobbies and other preferences). Sectors and uses, vegetation and

reuse of the existing sources were defined. This is integrated with the uses and requirements of the previous phases. From this premise the most suitable pavements for each of the zones according to their assigned use (color and texture) were chosen, and the different urban elements that could be integrated into the square were imagine and draw in order to decide which of them are necessary to provide service needed and guarantee the comfort of each space.

Broadly speaking, the following areas of activities were defined: rest area and quiet activities (reading, drawing, rest, etc.), low intensity motor activity zone and symbolic game (game structures, free space for games), zone of intense motor activities (such as playing with a ball or as a team) and mediating vertical activities (cartography, chalkboard, basket, fronton…). Finally, the results were presented to the city council.

3.3 From the Citizens to the Architecture Students Education/Implementation

These proposals were passed to the University to digitalize and virtualize them in a three-dimensional way. Students and professors from the universities of the Polytechnic University of Catalonia (UPC) and La Salle - Ramon Llull University (LS-URL), work on the elaboration of taking these spaces to visualize them in real time. The idea is that now the neighbors and the city council can visualize the scale, the textures, the relationship of the uses, the lights and shadows, etc. The persons that has participated using the glasses of virtual reality and through interactive elements, the participants shaped the urban public space. According to their criteria and collaboratively, could again configure the elements. The objective is to bring all citizens the technology of virtual reality so that they can participate in the definition of the uses of the public spaces in the most realistic way before its development (See Fig. 5).

Fig. 5. UPC professors and students.

The virtual reality allowed participants to see in an immersive way the changes and actions that happens in the environment in real time, for example, in the calculation of specific lighting in a space to show a very dynamic and realistic result. Some

participants' proposals, inserted into the simulated environment, have the capacity to be in constant interaction by moving and rotating actions (See Fig. 6).

Fig. 6. Work made by the LS-URL.

With the proposals generated in urban participatory processes, based on sketches and work on paper, the students of the degree of architecture passed the project to its development phase. For this phase, we have worked with the subject Architectural Representation III, a teaching unit compulsory with five credits ECTS[1] from Architecture UPC. The main objective of the subject is to develop in the student the aptitude to value and adequately represent the visual attributes of architectural and urban elements. In this way, the concepts of the theory of form and of visual perception in the representation of urban space can be applied in a critical way. The teaching experiment has focused on evaluating the resolution of the visual simulation of the urban scenario as a whole, including all the elements of urban furniture, trees, day and night settings, in a conventional way, using classic render engines or navigating within the model using real-time render engines and VR for the inspection of it and its subsequent adjustment.

At this point, it is important to analyze the profile of students, especially to analyze their subsequent responses to the utility and uses of virtual interactive systems, especially to reveal whether or not they are prepared for a change of paradigm. This meaning, the migration of traditional systems of representation (plans and models), to new interactive and multiplatform 3D systems [30–32].

To carry out the study, we opted for a mixed approach based on the work sample, with 27 students that make one of the groups of the subject. Although the sample is small, it is consistent with the results obtained in previous phases of the project with higher samples of students [27]. We compared the responses of the two groups, using the Student's t-test for assessing the differences, and based on the null hypothesis (H0) of no differences in mean scores between the groups. Based on the results (Statistical significance obtained below the threshold of 0.05, which allows to affirm a guaranteed difference of at least 95%), we can affirm that there is a significance difference between

[1] ECTS: European Credit Transfer System.

the student's profile ($p = 0.124$), which discards differences between groups and demonstrates their homogeneity.

The following Figs. 7, 8, and 9, characterize the profile of our current students, separated by gender (although no significant differences are detected: $p = 0.346$), and in an aggregate form:

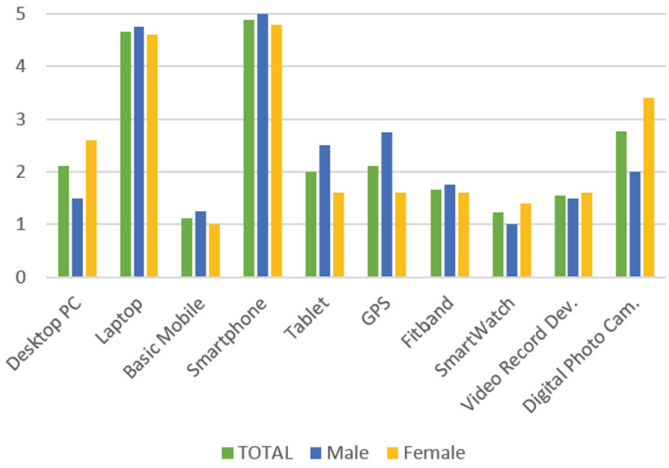

Fig. 7. Devices used daily.

As can be seen, (see Fig. 7), one of the first data that draws the attention is the concentration of use of two clearly predominant the devices: the laptop and the smartphone. This concentration reveals an important fact: the student performs tasks anywhere, and his work is mainly ubiquitous.

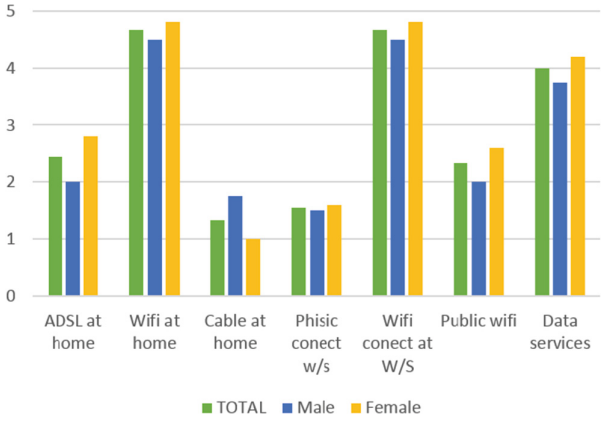

Fig. 8. Type of Internet connection.

In accordance with its ubiquitous work, the main method of connection to the Internet is through Wi-Fi networks and with a data program associated with its contracted rates (see Fig. 8), predominantly the uses centered on Social Networks, listening streaming music and search systems (see Fig. 9). These results are interesting as they predispose the student to little use of visual systems due to the mobile nature of their digital interconnection with the environment that surrounds them. This hypothesis can negatively affect the use and/or perception of utility of the systems more focused on the visual content, which need fixed and stable environments for their use, as it happens with the VR.

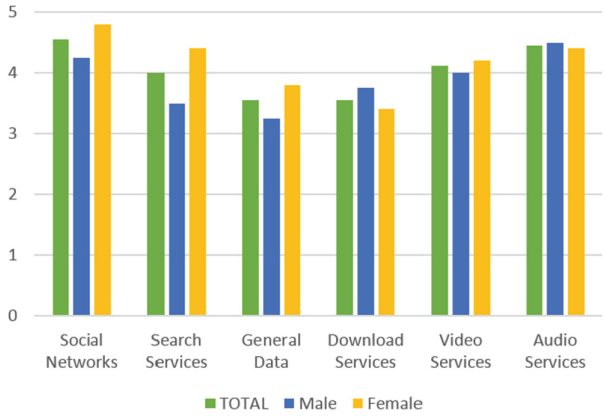

Fig. 9. Daily Internet uses.

Prior to the realization of modeling and representation of the space studied, we conducted a study based on evaluating students' motivation in the use and utility of virtual systems for their training in representation processes using the IMI (Intrinsic Motivation Inventory). The IMI is a multidimensional measurement device intended to assess participants' subjective experience related to a target activity in laboratory experiments [30]. The instrument assesses participants' interest/enjoyment (IMI1), perceived competence (IMI2), effort (IMI3), value/usefulness (IMI4), felt pressure and tension (IMI5), and perceived choice while performing a given activity (IMI6), thus yielding six subscale scores. Recently, a seventh subscale has been added to tap the experiences of relatedness (IMI7), although the validity of this subscale has yet to be established, but we have studied in order to have a general view of the system.

We conducted the same survey to the students and citizens involved in the initial participatory processes (see Fig. 10):

The overall result shows an average of 4.08 (DT: 0.08) of citizen motivation compared to 3.33 (SD: 0.27) of the students. This difference is significant ($p = 0.004$) and comes to explain how while for the end users the use of the VR and the interactive systems are methods that help to the understanding of the urban project, the same thing does not happen for the students. These results are consistent with previous studies carried out on the project [21, 27, 33, 34], and confirm the need for change in the

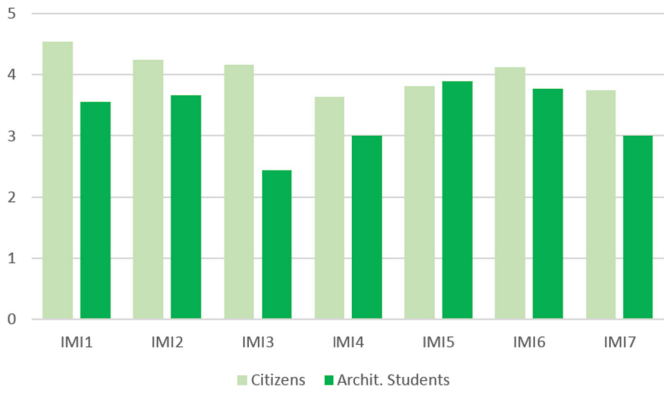

Fig. 10. IMI citizens and students comparison.

introduction of technologies in the classroom in order to improve the students' abilities and therefore society [35].

Historically, in the degree of architecture, the deliveries in subjects of projects and urbanism have focused on panels with photocompositions, sets of plans with different scales and, occasionally, representative models of the space, but without materials, textures or lighting that generate a realistic representation. While these educational systems are accepted and widely implemented, it is not the same in a non-expert environment as that of citizens, which require systems closer to the reality that they want to achieve in order to explain space and for consequently, better understand the proposed changes.

To corroborate the degree of perceived utility on the systems implemented at the educational and professional level, we evaluate the answers of a questionnaire about the perception of virtual, interactive and gamified systems (see Fig. 11). The questions evaluated have been:

- PERC1: Digital 3D visualization of architectural and urban projects is very important to understand the space.
- PERC2: The use of virtual reality (VR) to display projects is useful for understanding.
- PERC3: The use of augmented reality (AR) to display projects is useful for understanding.
- PERC4: I am motivated to use AR7VR during the presentation of projects.
- PERC5: The materials, textures and lighting of a virtual scene must always the most realistic possible.
- PERC6: The environmental sounds must always be the most realistic possible.
- PERC7: The existence of background music satisfies me in the visualization and interaction with virtual spaces.
- PERC8: The visualization device (Smartphone, Tablet, PC, etc.…) has a considerable influence in the virtual quality perception.
- GAM1: The use of gamified environment (with missions and achievements) is better than simple free navigation in a virtual space.

- GAM2: In the case of games, I prefer the one-to-one vs. multi-player environments.
- GAM3: I consider that using games in educational environments help to understand the typology and correction of the materials.

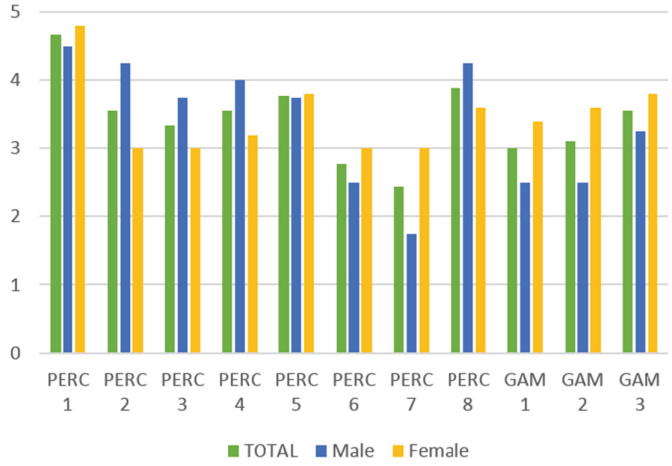

Fig. 11. Perception of the utility of virtual and gamified systems for architecture and urbanism activities.

Overall, there are no significant differences by gender in the results obtained. Likewise, the average on the perception variables stands at 3.44 (SD: 0.68), while for the evaluation of the gamification, it drops to 3.22 (DT: 0.29). The best-valued aspect is the PERC1 that affirms the importance of 3D visualization for the understanding of space (Average 4.67, SD: 0.5). Consistent with this result, the VR systems are slightly better valued (PERC2-Av: 3.56), with respect to the AR (PERC3-Av: 3.33), but the motivation of the students for their use in architectural projects can be defined as low (PERC4-Av: 3.56) [36]. Aspect that is clearly related to the difficulty of use and need to clearly perceive the quality of the model (PERC5-Av: 3.78), in mobile devices with small screens [37]. The perception of the usefulness of sound and the gamification of the interaction are the aspects least valued by the students, and that reflect as there was a lack in the need to take into account other variables of the project in the academic presentations beyond of the visual [38–42]. Just 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.

4 Conclusions: Difficulties and Opportunities

By allowing citizens new ways to co-design public spaces within their city and students to participate in the process of design helping to better visualize and understand physical projects allows to develop both the dimensional and ergonomic relationships

between elements as they see their designs come to life in real time. It is understand that virtual reality applied in design and local government contexts, might change the way we conceive the urban development and planning, even thinking in an ecological way.

Based on our hypothesis, we can affirm that the implementation of virtual gamified strategies in the field of urban design will generate an improvement in citizen participation by being a more dynamic, real and agile collaborative environment thanks to enhanced visual technologies and immersive. However, on the other hand, the gamified strategies for the understanding of three-dimensional space improve spatial competencies of students generating greater motivation in their use and a degree of satisfaction is not as high as we expected.

It is necessary to change the way to explain in our educational institutions to reduce the gap between the educational sector and the social sector. This last one seems to be more prepared to incorporate all kinds of technologies, interaction, gamification and different strategies to democratize both visualization and decision making in complex projects. At the educational level, there are few efforts to use these strategies in an active way in the classroom, generating a motivation and perception of low utility in students.

Although the profile of the current students is familiar to the used of technologies to communicate and represent ideas, there still a gap between the potential of ICTs incorporation in classrooms and the renewal of pedagogical processes. Universities are increasingly implementing new technologies as support for teaching, but not as a methodical change. However, their digital profile is fully trained to make a leap in the use of digital methods and systems of last generation in the development and presentation of its architectural and urban projects.

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