Future Generation Computer Systems 91 (2019) 371–381

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Virtual interactive innovations applied for digital urban transformations. Mixed approach

Mónica Sanchez-Sepulveda [a,*], David Fonseca [a], Jordi Franquesa [b], Ernesto Redondo [b]

[a] Technology Enhanced Learning Research Group, La Salle, Ramon Llull University, 08022 Barcelona, Spain
[b] Barcelona School of Architecture, Polytechnic University of Catalonia, 08028 Barcelona, Spain

HIGHLIGHTS

- Integration of Digital transformation into the visualization of Urbanism.
- Virtual Reality systems for participatory design.
- Technological innovations to improve motivation in urban decision-making processes.
- Informal data generated by the citizenship.
- DT in governmental urban design projects.

ARTICLE INFO

Article history:
Received 31 May 2018
Received in revised form 13 July 2018
Accepted 7 August 2018
Available online xxxx

Keywords:
Digital transformation
Virtual reality
Urbanism
Participatory design
Mixed method assessment

ABSTRACT

The cities in which we live are changing rapidly, presenting the scenery to debate future visions of transformative designs 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 organizations and society to question the *status quo* and experiment often. The discussion about the increasing integration of digital technologies in urban spaces involves a number of questions relating to the complex processes of transformation that impact cities, like economic, social, political, and environmental. The main goal of the paper is to present the use of Digital Transformation in processes of urban design through technological innovation in which the diverse forms of active citizenship operate from below as agents of innovation, inclusion and social development. The results showed that it is possible to empower Digital Transformation – as for example the use Augmented and Virtual Reality (AR/VR) systems in collaborative urban design – to improve public motivation, implication, and satisfaction in urban decision-making processes.

1. Introduction

In Urbanism there are four significant themes: (1) is for and about people; (2) the value and significance of 'place'; (3) operates in the 'real' world, with its field of opportunity constrained and bounded by economic (market) and political (regulatory) forces; and (4) the importance of design as a process [1]. It is about constructing a scenario for urban evolution, imagining the conditions of transformation and proposing a process capable of incorporating new experiences into the human–environment relationship. Using technological innovation have an effect on the mode through which social movements and the diverse forms of active citizenship operate from below as agents of innovation, inclusion and social development [2].

In the last decade, there have been various initiatives conducted by researchers as well as all type of organizations to explore methods and technologies to foster the public participation in the design and implementation processes of social projects. One of the strategies, increasingly used, has been the implementation of these projects through new digital media. However, the use of new tools has not generated a digital transformation (DT) as was expected, among other things because of the novelty of the proposals, or even because of the use of technologies that are not commonly used by users [3]. This lack of success in technologically innovative proposals is due in part to an insufficiency of motivation on the part of the user, which, together with a lack of experience in the use of tools, condemns the proposals for transforming organizations into innocuous efforts. For this reason, technological innovations must

* Corresponding author.
E-mail addresses: monica.sanchez@salleurl.edu (M. Sanchez-Sepulveda), fonsi@salleurl.edu (D. Fonseca), jordi.franquesa@upc.edu (J. Franquesa), ernesto.redondo@upc.edu (E. Redondo).

https://doi.org/10.1016/j.future.2018.08.016
0167-739X/

be accompanied by a methodological innovation, which above all, generates greater motivation on the part of organizations and users. In this sense, it is increasingly common to find proposals that base their initial efforts on methods such as gamification, to adapt content and technologies to the needs and requirements of users.

Taking advantage of technology from the visual simulation and virtual reality, provide a delivery system for organizations to get closer to final users. Virtual reality has rapidly become one of the most exciting new computer technologies — exercising a strong hold on the popular imagination, attracting hundreds of researchers, and spawning a booming industry [4]. Working on the spatial transformation virtually is a supporting dimension of the overall process of a structural change. We are in the need of new collaborative design processes, adapted to the new social, technological, and spatial context in which we live.

This article describes the role and use of technological innovations in DT 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 with the technology. For this purpose, we have designed a mixed evaluation method (using quantitative and qualitative data), which allows us to identify the positive and negative aspects in a more objective way. The general objectives (or research questions) of this paper is to approach the following topics:

- Combining model with real-scale proposals using Augmented and 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 inferred that these initiatives could facilitate public decisions through the social re-evaluation of spaces, real and virtual, in order to respond to unsatisfied 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.

The Section 2 of this article, analyzes the framework related to the way Urbanism is practiced to see later on how technologies are incorporated. Section 3, includes the explanation of citizenship participation in the inclusion of digital technologies inside of an organization and exemplified the use of digital transformation in Urbanism through new ways of Urbanism. Section 4, presents the project. Section 5, discusses the data obtained from the mixed assessment, leading to the conclusions and future work of the study, which are discussed in Section 6.

2. A new challenge for Urbanism

Urbanism theoretical maturity was reached in the twentieth century from a combination of different disciplines that merged to rethink the city. It was a time when specialists in the field started to study more about the problems of our cities adopting new methods of research and analysis, emphasizing more in the scientific phase than the artistic one. "This may be due to a natural reaction against past practice when city planning was based on the superficial *city beautiful* approach, which ignored the roots of the problems and attempted only window- dressing effects". – Jose Luis Sert [5]. Urbanism developed as a new science; concerned with the structure of the city, its process of growth and decay [5]. The physical, social and cultural changes that we are experimenting force the contemporary urbanist to a practice open to the processes of socially responsible participation and the conscious interaction of the culture that live- in each place.

In Urbanism current technology-driven implementations, while being an important step is important to understand that the main actors are the people and the human dimension of cities. For this, the conception of a participatory innovation system in which citizens and communities interact with public authorities and knowledge developers is key. This collaborative interaction leads to a co-designed user-centered innovation models of governance. The urban transformation in which citizens are the main "drivers of change" through their empowerment and motivation ensures that the major city challenges can be addressed, including sustainable behavior transformations [3].

To merge the main actors of the cities with the spatial forms and processes it is understood to be necessary to adapt to the new social, technological, and spatial context in which we live. Technologies, methodologies and tools for these urban processes are various. Even processes that are now a common instrument, like the computer, have opened a new world to the Urbanism, through new forms, new perspectives and new ways of analyzing data. Psychosocial and post-occupational studies, new communication media and ways of collecting data and technology that can detect social, economic and environmental patterns of the urban spaces, is supporting the discipline and bringing another dimension to the practice. Also in the visualization aspects, the approach of Visualization and understanding of 3D, which typically accomplished via the classical view is changing due to a generational change and the continuous improvement and development of technology [6].

Present and future changes that are leading to the necessity of a faster utilization of a DT strategy, can be brought by several causes like users' behavior and expectations, new economic realities, societal changes and emerging digital technologies [7]. For this, DT has the capability to renovate a sector's activities, processes, competencies, and models to force the changes and opportunities of a mix of digital technologies and their accelerating impact across society in a strategic and prioritized way, with present and future changes in mind. Sectors that are involved in tackling societal challenges such as urban deterioration and unpractical city spaces, can take advantage of one or more of the existing and emerging technologies. Using technological innovation have an effect on the mode through which social moves and the diverse forms of active citizenship operate from below as agents of innovation, inclusion and social development [2].

Combining the innovative technologies to reach citizen participation in decision-making about the construction of the city is an essential condition for urban ecological regeneration. The act of "urbanizing" a project through DT requires a vision for what parts of the process need to be transformed. In face of the enormous amount of urban data that is needed to develop a proposal, the field of Urbanism is yet to incorporate many sources of information into their workflow. Whether it is in the way students are trained and professionals work and collaborate, the way processes are executed, or in the way, it relates to the users, digital technology provides a meaningful opportunity. Regardless of the enormous amount of urban data to incorporate, representation technologies bring ideas into reality, allowing communication between designers, clients, contractors and collaborators [8]. This is the same as for the professionals in the field and organizations should commit to incorporate these technologies.

3. Social in DT

Currently, the ways we communicate have been changing and adapting to new devices and applications that mostly involve characteristics such as mobility, interaction and interconnection. [9] describe the opportunities offered by these emerging technologies as "creating a new kind of reality, one in which physical and digital environments, media and interactions are woven together throughout our daily lives''. Informal data related to a public space that analyze semantic, temporal and spatial patterns, aspects generally overlooked in traditional approaches, improve the process of urban designing and management in order to relate the projects to the main needs of the citizenship. Through DT, organizations should be able to incorporate informal data obtained from the space, to develop more sustainable projects and products adapted to more users and/or users with different profiles or disabilities. The need to incorporate an informal approach to projects used by the public is essential. For this, the use of the gamification of a real space generates a virtual space and an urban environment of simulation in which it is possible to make dynamic experiments of participation and generation of ideas, uses or changes that improve that space [10].

Gamification has been put forward as a tool to support the process of civic participation that leads to sustainable civic engagement through a process of collective reflection [11]. This tool citizen enables citizens to observe their environment and reflect collectively on spatial issues in their daily environment. There are references to the use of gamification in urban planning processes linked to other citizen participation such as the ''Blockholm'' - Stockholm, 2014-, a game based on Minecraft promoted by the Swedish Center for Architecture and Design of Stockholm that has invited 100,000 users, technicians and experts in urban design and citizens to participate. Other examples are the ''Play the City'', from the Play the City Foundation implemented throughout 2012 in different cities of Holland, Belgium, Turkey and South Africa and which was based on a Word of Warcraft type game, or the use of the ''SimCity'' game in its different versions in urban planning workshops, highlighting the case of Cape Town in 2013.

They are basic proposals for zoning, for general uses at the level of an entire urbanization, or for large-scale digital work. In the significant case of Blockholm, informal teaching model is applied since it is the citizen who generates a series of opinions or suggestions for change that reaches the students externally since the whole process is outside the academic scope. The same happens in the cases of SimCity or Play the City, where part of the results revert to contents of informal use in the student's training but are more focused on specific practices of professional projects. In this sense, this experience is the closest to our approach, given that we have defined challenges to be solved by users and that generate complementary information prior to the generation of the project, knowing the type of participants, their opinions modifying the scenario and it can be interpreted as the support or rejection of a proposal.

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. It is important to take into account how the VR is a technology, that applied correctly, can be a tool to involve society and democratize decision making in complex projects, like urban ones. Taking into account that the basis of the VR is to create an immersive experience and allow the user to interact with objects.

4. Case study

The urban project we work on, promoted by the Barcelona City Council, aims to create a large public space that prioritizes the people of the Eixample Esquerra District instead of the vehicles (Figs. 1 and 2). They want to generate spaces that are designed to meet the needs of the users: spacious, pleasant spaces full of vegetation with dynamic uses and according to the needs at all times. According to their criteria and collaboratively, configuring elements such as spaces for children's games, urban gardens, vegetation, lighting, recreational and cultural activities, among others. 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 of the Eixample
- Increase the surface of rainwater catchment on the terrain
- Establish criteria for the location of furniture and services (garbage bins, cargo download, bar terraces…)

For this, we created a virtual reality game in which through interactive elements, the participants shaped the urban public space. We exposed to the public to use ''wearables'' technologies such as RV glasses and RA in Tablets to know how virtual reality can help us to participate in a city-planning restructuring project in our city, such as the Superilles (super squares) in Barcelona (Fig. 3). The testing of this technology includes both, quantitative and qualitative techniques, with the variable of a gamified proposal and the use of visual technologies, aspects that brings innovation, and immediacy. The focus of this testing is to study the motivation, engagement, and overall experience of the participants with the technology, more than the effectiveness of the approach, as the whole urban design process has not been completed, and still ongoing.

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 of the city of Barcelona such as the Urban Mobility Plan Superiors (PMU) 20132018, and help to build the city that we all want in a participative way. At the end Barcelona City Council (organization interested) wants to create a space that prioritizes the people, designed to meet the needs of the users, then is the people who have to collaborate to achieve this goal. This methodology brings the participants as an active element of the project, able to preview the space, propose changes and be part of what later on will be a livable space.

The virtual reality allowed participants to see in an immersive way the changes and actions that happen in the environment in real time (Fig. 4), 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. The procedure that the participants followed was:

1. The explanation of the project was exposed and so the description of the experiment, the technology and the way they would take part in the project;
2. The way to use the tool was to explain, for example, how to use the controls, how to move on the space, how to grab objects, how to move and rotate the objects, how to choose them from a catalog and how to see the cost of each object;
3. The controls and the helmet are given to the participant to start the using the tool, get immersed in the virtual world and start to get familiar with the navigation system;
4. The participant is exposed to a pre-built environment, with all the existing buildings already in the site, and they get to see the catalog with all the options of objects;
5. Participants have already identified their necessities. In our case, taking into account the limited time of the test, we have proposed one challenge: to create a summer cinema in the street, choosing objects that are organized in categories with a limited budget;
6. Participants start to interact in the space, moving to the specific place they want to propose a use and grab the objects they want, drop then in site and move and rotate them to the exact position they want;
7. When participants are choosing the objects they get to see the price of each object.

Fig. 1. Urban project first proposal.

Fig. 2. Comparison of present state and future proposal.

Fig. 3. Fair Research in Direct 2018. Multimedia gallery. https://recercaensocietat.wordpress.com/galeria-multimedia/. Accessed on May 7, 2018.

An interesting feature of this tool is that participants get to see what they are proposing in real time. Objects throw shadows, the participant get to choose if the environment is seen in daytime or nighttime and see in real time the lighting being put on any section of the street and how it is affected by the color, intensity or type of light being used, they get to see a real-time map while they are moving through the space to see their situation within the city and have a visible pointer that select the objects and select the options in the menu (Fig. 5). This method allows the participant to see in a very immersive way the changes and actions that happen in the environment in real time. The rendering engine, Unreal Engine 4, allows the calculation of these features in a space to show a very dynamic and realistic result.

The behavior of a user of a new system or proposal provides information crucial for the success of its final implementation. In the experimentation and scientific research, if we work with

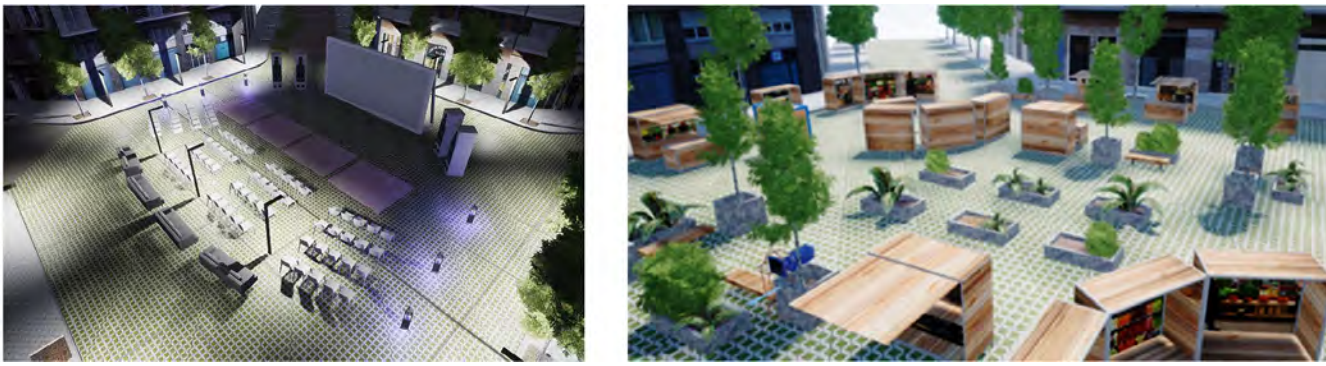


Fig. 4. Example virtual reality scene.

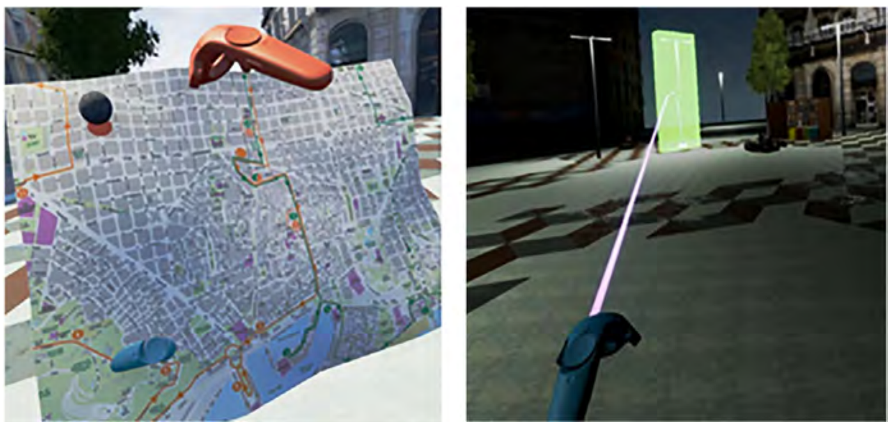


Fig. 5. Example virtual reality scene.

many samples (a minimum of 30–50 samples), we can manage collected data quantitatively and the results can be studied and compared in order to find statistical differences. With fewer users (less than 10), however, the qualitative approach has proven to be equally valid with the ability to obtain a detailed explanation of the variables of the study [12]. In this frontier, a hybrid approach to experimental methodology has emerged: the mixed-methods research approach. We can define the mixed method research as the natural complement to traditional qualitative and quantitative research [13,14]. This model is based on a pragmatic paradigm that contemplates the possibility of combining quantitative and qualitative methods to achieve complementary results.

5. Results: data and discussion

To collect data, we conducted two experiments: In phase 1, experimentation was carried out in the framework of the Fair Research in Direct 2018 (with the data discussed in Section 5.1) and in phase 2 (Section 5.2), we replied the same experiment in the framework of the Architecture School of La Salle, Ramon Llull University. The purpose of this separation was to be able to compare the results by the user's profile and identify the assessments, perceptions and needs according to this.

5.1. Phase 1

For the quantitative approach, we delivered the participants questionnaires after using the virtual, the augmented or both proposals (which is based on previous experiments done in architecture educational framework, [6,15]). In the first block, we obtained personal information (age and sex) which pointed out: 46 women under 18 years old (mean age of 15.52 years with a standard deviation (SD) of 1.17), 70 men under 18 years old (mean age of 15.18, with a SD of 1.28), 6 women over 18 years old (mean age of 25.83, with a SD of 9.41), and 13 men over 18 years old (mean age of 23.40, with a SD of 9.09), for a total of 135 participants. In the second block, we design a Likert scale where participants evaluate the answer from 1 to 5 their level of agreement with the statement exposed. The participants were consulted using 13 statements about different aspects: seven related to Intrinsic Motivation Inventory (IMI#), three questions focused on the social view of the citizens (Soc-Urb#), and the lasts three questions related architecture framework and digital skills (Dig-Sk#):

- IMI1: I like and have fun using virtual environments
- IMI2: I understand the space better with 3D visual systems rather than with plans and models
- IMI3: Using virtual and gamified systems requires less effort to understand
- IMI4: The use of interactive systems generates less stress than traditional systems
- IMI5: By knowing the new visual systems, will change my way of working in the future
- IMI6: Games and interaction are useful for my future and can benefit me
- IMI7: These systems help me to interact with other users/ friends/colleagues
- Soc-Urb1: These systems facilitate decision making in urban projects
- Soc-Urb2: The RA/RV systems allow the design and re-evaluation of urban spaces
- Soc-Urb3: They allow to identify possible unsatisfied social needs

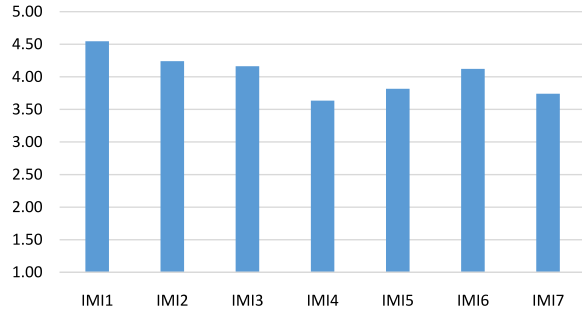


Fig. 6. Intrinsic Motivation Inventory questions about the use of virtual systems in urban spaces.

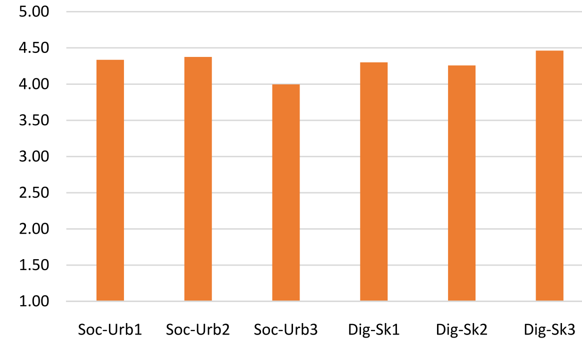
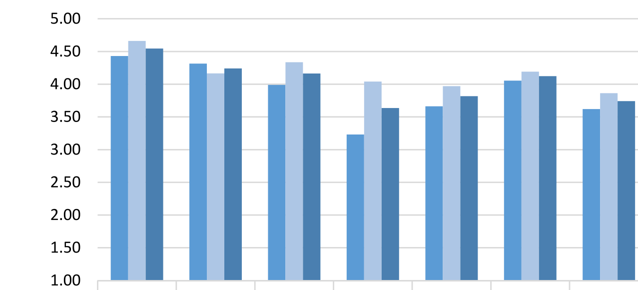


Fig. 7. Usability of Virtual Systems for Social/Urban proposes and to improve Digital Skills of the students.



	IMI1	IMI2	IMI3	IMI4	IMI5	IMI6	IMI7
Female	4.43	4.32	3.99	3.23	3.66	4.05	3.62
Male	4.66	4.17	4.34	4.04	3.97	4.19	3.86
All Users	4.55	4.24	4.16	3.64	3.82	4.12	3.74

Fig. 8. IMI results by gender.

- 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 of students

Focused on the theme of the Project (based on the design and virtual interaction of new proposals for the use of urban space and the adaptation to the space of both proposals and users), the data collection made in this article is significant as identifies a series of variables to pay attention in the process of system development. The 95% of users had never used an interactive VR system, and the remaining 5% had only used it for basic visual exercises. This data is interesting because, in previous studies (CINAIC), the absence of a previous use had been reflected with a reduced initial motivation, with an IMI of 3.0, which increased significantly once the system was used, reaching 3.9, taking into account that the sample was composed of architecture students.

By graphically analyzing the average obtained responses related to technologies used and perceptions/motivations, we observed similar behaviors in the four groups with high motivation, but with three levels below 4, with a margin of improvement IMI4 (3.64), IMI5(3.82), IMI7(3.74) (Fig. 6).

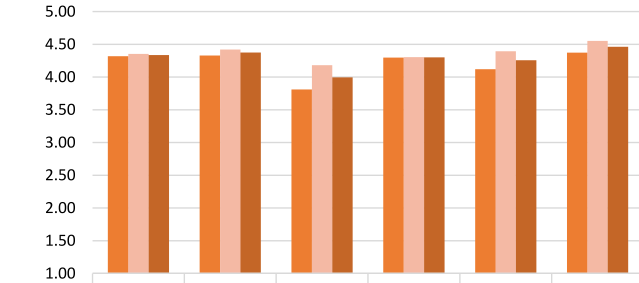
In the present study, with users outside the architectural field, the IMI average stood at 4.03, without significant differences at a global level neither by age nor by gender. This result is encouraging since it allows us to affirm that with the adequate training and practice time students can increase their degree of motivation in the use of interactive RV systems, and therefore a better preparation for the transversal use of them. Regarding the variables associated with the social/urban uses (identified with the questions marked as Soc-Urb#), and the improvement of digital skills in the students (identified as Dig-Sk# questions), the overall balance is satisfactory, all indicators are equal or above 4 (Fig. 7).

These results demonstrate a highly positive assessment by users regarding the issues designed. The average of the questions related to the utility of the system for the decision-making and re-planning of urban uses (Soc-Urb questions), have an average of 4.24/5. Higher is the result (4.34/5) related to the perception that these systems are an educational help to improve the digital and spatial competences of the students.

We have also analyzed and compared the responses by gender. To estimate the probability that the groups were significantly similar, we used Student's t-test with the null hypothesis (H_0) of no differences in mean scores between the groups. Statistical significance (two-tailed) is 0.077, which exceeds the threshold of 0.05, which means that there is a very low probability (minus that 5%), that the groups are different in their general assessment of all variables studied. The null hypothesis, which states that there are no significant differences between groups (male and female), is accepted, but in a detailed way, we find some statically differences. The most relevant are:

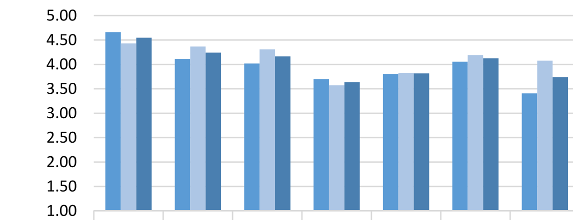
- IMI-4 *"The use of interactive systems generates less stress than traditional systems"* detects significant differences between genders. Using the same comparative system as in the previous comparison, and with the null hypothesis (H0) that there were no differences in mean scores between the groups, we found that the statistical significance (two-tailed) was 0.0001, below the standard threshold of significance of 0.05. This result indicates that there was a significant difference in the responses between young female (with an average of 3.38, and SD of 0.92), and males (average of 3.73 and SD of 1.03), as occurs with adult sample (with a female average of 2.83 and SD of 0.16, in front of male average of 4.30 and SD of 1.06), and we can see grouped in Fig. 8.
- IMI-7 "*These systems help me to interact with other users/ friends/colleagues*", detects again a significant difference (two-tailed, 0.004) between boys (average of 3.52, SD of 1.41), and girls (average of 2.92, SD of 0.91), being again better perceived by the boys. A difference that does is not endorsed in adults as in the previous case (significant difference of 0.401).

These results related to motivation and how VR generates a differentiated level of stress by gender, an aspect that in the literature is defined as Dominance [16], has been previously referenced at various levels [17–19]. Some of these studies [20–22], position this behavior due to a habitual difference in the use of technological and virtual systems depending on the users, their motivations and their "game" preference, an aspect to take into account for the possible future configurations of the Project.



	Soc-Urb1	Soc-Urb2	Soc-Urb3	Dig-Sk1	Dig-Sk2	Dig-Sk3
Female	4.32	4.33	3.81	4.30	4.12	4.37
Male	4.35	4.42	4.18	4.30	4.40	4.55
All Users	4.34	4.38	4.00	4.30	4.26	4.46

Fig. 9. Social/urban uses and improvement of digital skills using VR results by gender.



	IMI1	IMI2	IMI3	IMI4	IMI5	IMI6	IMI7
Minor 18	4.66	4.12	4.02	3.70	3.81	4.05	3.41
Major 18	4.43	4.37	4.31	3.57	3.83	4.19	4.08
All Users	4.55	4.24	4.16	3.64	3.82	4.12	3.74

Fig. 10. IMI results by age.

• Regarding the variables associated with the social/urban uses (identified with the questions marked as Soc-Urb#), and the improvement of digital skills in the students (identified as Dig-Sk# questions) represented in Fig. 9, we have found only one significant difference in the SocUrb-3 "*They are allowed to identify possible unsatisfied social needs*" (0.040), with clearly higher values for adult men (4.46 with SD of 0.76), than women (3.66 with SD of 0.66).

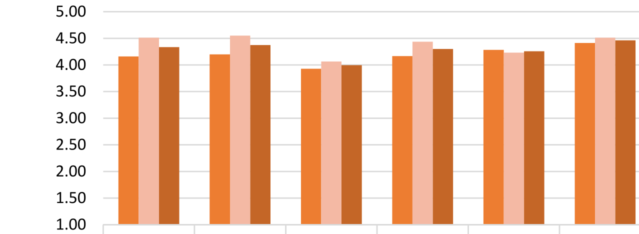
Analyzing the responses by age (Fig. 10). Focused on the IMI results, the statistical analysis revealed that:

- IMI-3 "*Using virtual and gamified systems requires less effort to understand*", reflects a significantly higher value (0.044) between adults (4.42, SD of 0.81), and young people (4.02, DS of 0.79).
- IMI-7 "*These systems help me to interact with other users/friends/colleagues*", again, indicates a significant difference by age, with a higher score for adults (4.10, SD: 1.21), compared to the kids (3.43, SD: 1.41).

These differences show how VR systems allow an easy understanding of space and are perceived as systems that can enhance collaboration among users. This feature is clearly highlighted by older users, and that may potentially need systems and support aids for complex activities in digital environments, due to their lack of experience [23].

Analyzing the results of the social/urban uses and digital skills questions (Fig. 11), the main differences are:

- Soc-1 "*These systems facilitate decision making in urban projects*" reflects a significantly higher value (0.0025) between adults (4.57, SD of 0.25), and young people (4.12, DS of 0.65).



	Soc-Urb1	Soc-Urb2	Soc-Urb3	Dig-Sk1	Dig-Sk2	Dig-Sk3
Minor 18	4.16	4.20	3.93	4.17	4.28	4.41
Major 18	4.51	4.55	4.06	4.44	4.23	4.51
All Users	4.34	4.38	4.00	4.30	4.26	4.46

Fig. 11. Social/urban uses and improvement of digital skills using VR results by age.

- Soc-2 "*The RA/RV systems allow the design and re-evaluation of urban spaces*", again, shows a significantly higher value (0.0021) between adults (4.63, SD of 0.24), and young people (4.17, DS of 0.77).

On the other hand, the results of the social use variables show a clear differentiation between the needs and uses perceived by young people in these systems, and the "serious game" approach perceived by adults.

Based on the results obtained through the completed quantitative surveys, and in line with previous studies with mixed approaches, we completed a series of Bipolar Laddering interviews [24], to specifically identify relevant aspects, both positive and negative, of the experience that can explain the results obtained in the quantitative phase [25,26]. The BLA method works on positive and negative poles to define the strengths and weaknesses of a product. Conducting a BLA consists of three steps: Induction of the elements, marking of elements, and element definition. The questions "Why is it a positive/negative element?" and "Why this score?" are asked. The answer must include a specific explanation of the exact characteristics that make the mentioned element a strength or weakness of the product.

In this type of analysis, the Positive/Negative Common (PC/NC) elements are the most representative because they are the most cited (Table 1). Depending on the reference rate and its average obtained value, we can identify the most relevant elements. From the analysis of the qualitative interviews through the Bipolar Laddering the results are:

In Table 2, we can observe the comments identified by only one user (particular elements), and finally, in Table 3, we have grouped the main solutions and points of improvement. All these solutions were divided according to whether they were cited for more than one person (common improvements with its mention index), or only by one person (particular improvements identified by the user).

The analysis of the qualitative approach revealed that a majority of the participants experienced good sensations of reality and quality with the designed space (1PC) and its elements (5PC), with its movements (2PC), and with the designed interactions (3PC). In general, it could be defined as an enjoyable system (4PC). At the opposite extreme, the learning process (1NC) and the first moments are not as natural as expected. This is related to the understanding of the workspace (potential need for a map and the limits of work, 5NC), usability issues such as menu location or program jumps (2NC & 3NC), and the classic effects of dizziness associated with VR [27]. These negative aspects are directly related to the quantitative variable of lower valuation (IMI-4). In line with previous studies that show the relationship between negative emotional behaviors with visual aspects of new technologies, such as lack of quality, visualization distance, etc. [28].

Table 1
Main BLA Results: Positive Common (PC) and Negative Common (NC) elements.

	Description	Av. Score (Av)	Mention Index (MI)
1PC	Very Real Sensations	8.60	54%
2PC	Free movement	9.00	46%
3PC	Good Interaction	8.30	23%
4PC	Amazing	8.50	15%
5PC	Allow to perceive details of the objects	8.00	15%
6PC	Graphics quality	7.50	15%
1NC	Interaction and initials actions	5.50	46%
2NC	Punctual locks	6.50	15%
3NC	Menu location	5.50	15%
4NC	Sickness sensation	4.50	15%
5NC	Blank spaces without collisions	1.50	15%

Table 2
Secondary BLA Results: Positive Particular (PP) and Negative Particular (NP) elements.

	Description	Av. Score (Av)	User
1PP	Perspective sensation of space	9.00	User 6
2PP	Innovation	9.00	User 7
3PP	Usable in other frameworks	10.0	User 13
4PP	Analysis capabilities	10.0	User 13
1NP	Graphics quality	5.00	User 1
2NP	Lack of quality in general (pixelation)	3.00	User 2
3NP	Low reality objects	1.00	User 3
4NP	Static interaction, the user does not walk with reality	3.00	User 11

Table 3
Proposed common/particular improvements for both positive and negative elements.

Description	Mention Index (MI)
To improve the interaction with the objects and the space to reduce the learning time of the system	31%
To improve the quality or the graphics resolution	23%
To improve the reality of the objects	23%
More hardware/calculation powerful	User 1
Reduce the size of the location for a better understanding of scale elements and user movement	User 4
Add new interactive systems as for example gloves	User 10
Add characters in movement	User 11
Add the possibility to enter inside the buildings	User 11
Add keyword commands in a visible way for basic movements	User 12

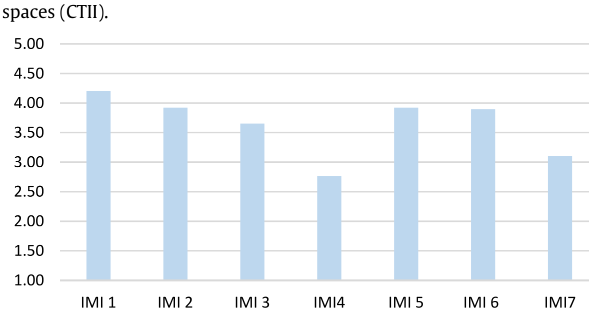
After this testing, the results clearly identified that the aspects to be improved in the proposal are (see common aspects of Table 3) the improvement of the interaction with space and objects, the quality of the graphics and the reality of the objects. All of them are aspects that can be directly linked to the variables of social and urban use Soc-Urb1 and Soc-Urb2, variables with significant differences in their broken down study.

Undoubtedly, it is demonstrated that this mixed approach allowed us to more precisely identify the positive and negative elements of a working model. We depend on the participants to show where it is necessary to strengthen the experience to improve the results in future iterations of the method. It was validated that the younger participants, born into a "digital age" and defined as Digital Natives, adapted better to a high density of technological content in the educational environment.

5.2. Phase 2

However, after collecting the results and conclusions we noticed the limited variation of participants, in terms of age, having a majority of participants were under 18 years old, but particularly with a profile not related to the urban and architecture field. To consider the opinions and feedback of a more diverse population in terms of age and including participants that are trained or with experience in the conceptualization of urban planning, and the technological uses of digital applications, we made a second test, place at Architecture School of La Salle, Ramon Llull University. These participants had the same procedure to do the test than the first group that was tested in the Museum Cosmo Caixa Barcelona, on the Research Fair in Direct. In this second group, the sample was Architecture students and faculty (identified as CTII – Computer Tools II): 15 women over 18 years old (mean age of 24.80 years with a standard deviation (SD) of 1.26), 14 men over 18 years old (mean age of 25, with a SD of 2.29), for a total of 29 participants.

Table 4
Intrinsic Motivation Inventory questions about the use of virtual systems in urban spaces (CTII).



In the second group (CTII), the IMI average stood at 3.64 (Table 4), without significant differences at a global level neither by age nor by gender. This lower result is related at first to the utility/complexity perceived by the system, based on the qualitative comments collected and not treated within this article. In summary, participants perceive a very powerful environment but with a long and complicated learning, without it being clear the immediate utility in the architectural and urban project process.

Table 5
Usability of Virtual Systems for Social/Urban proposes and to improve Digital Skills of the students (CTII).

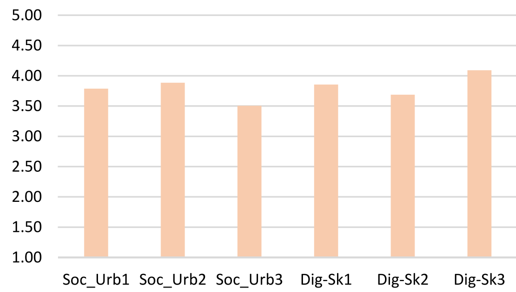
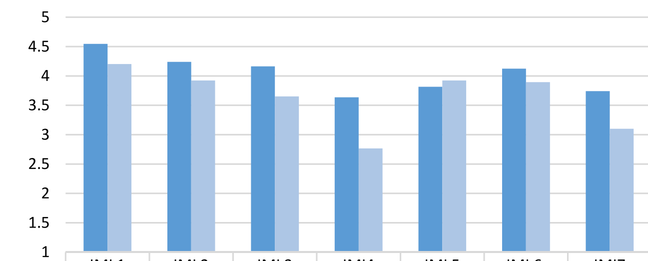
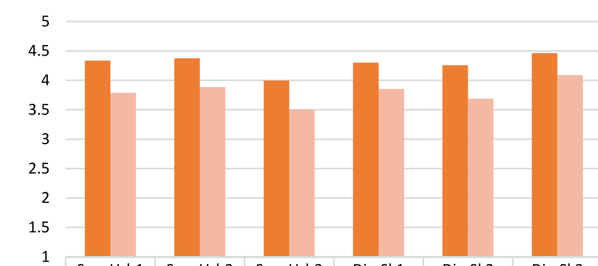


Table 6
Comparison IMI results.



	IMI 1	IMI 2	IMI 3	IMI4	IMI 5	IMI 6	IMI7
RFD	4.54579949	4.240301	4.16269709	3.63572225	3.81641185	4.12332776	3.74110129
CTII	4.20	3.92	3.65	2.77	3.92	3.90	3.10

Table 7
Comparison of Social/urban uses and improvement of digital skills using VR results.



	Soc_Urb1	Soc_Urb2	Soc_Urb3	Dig-Sk1	Dig-Sk2	Dig-Sk3
FRD	4.336068642	4.375019908	3.996181717	4.301023252	4.257310081	4.463242555
CTII	3.79	3.89	3.50	3.85	3.69	4.09

Regarding the variables associated with the social/urban uses (identified with the questions marked as Soc-Urb#), and the improvement of digital skills in the students (identified as Dig-Sk# questions) we found also lower levels in the group of CTII in front of the RFD sample. The average of the variables Soc-Urb# for the sample of the RFD is placed in a 4.27 with respect to the 3.73 of CTII, similar levels as for the variables Dig_Sk # (4.37 vs. 3.88 respectively) (Table 5).

We compared the responses of the two groups, RFD, and CTII, (Tables 6 and 7, 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 clearly differentiated behavior according to the profile of the users of the system. Regarding the variables associated with the IMI test, we have found statistical differences in the variables # 1, # 2, # 4 & # 7, but in the case of variables associated with the social/urban uses (identified with the questions marked as Soc-Urb #), and the improvement of digital skills in the students (identified as Dig-Sk # questions), we have found statically differences in all variables. In Table 8 we can observe the results of the comparison between samples using the t-Student (based on different variances of the samples).

The clearly lower averages of the users related to the architectural educational environment can be attributed to factors such as a lack of initial motivation in systems that have not been previously used and over which they have not been trained. Also, can be a perception of lack of utility in their needs of the professional activity to which they add the perception according to these systems are agents closest to leisure or external uses of the architectural professional field.

On the other hand, and at a user level, systems such as AR or VR are technologies that we could curiously say are closer and less specific than more common tools as CAD (Computer Assisted Design) and BIM (Building Information Modeling) systems, that are the main technological tools used for modeling the architectural space, due to its fast learning curve, its high degree of implementation in subjects like workshop/projects/urban planning, and its constant use. This type of interactive technologies and with a certain gamified component is found increasingly common in all types of environments, ranging from early educational phases to all kinds of applications at play, tourism, culture, etc. Undoubtedly, this aspect is what most general users perceive as part of the potential of the tools evaluated and that is demonstrated in the high result of them.

6. Conclusions and future work

It is clear that the integration of DT as a tool in the process of the urban design generated positive feedback. The main innovation of this case study is the design of a practical system to recognize the informal data generated by the citizenship, and how by using a mixed method we can extract important data that can contribute to the government of Barcelona related to Urbanism. For this, it was validated, through the results that the implementation of a method can be used as a method for organizations to incorporate the opinion of the end-user and help to execute a suitable design, adapted to space and combining the functionality and interests of citizens. Furthermore, one of the purposes of this type of research is to show that city challenges can be more effectively addressed at the scale of neighborhood and to provide an example and experience that demonstrate with the participation of the people who live, work, and play in that space and shifts the emphasis from top-down concept to a human-centric problem-solving.

From this study is verified that the use of Digital Transformation in processes of urban design and citizenship, through innovative concepts and practical methodologies, such as AR/VR systems improve public motivation, implication, and satisfaction in urban decision-making processes. Participants were receptive and aware to adapt to this new paradigm using advanced visualization methods. From the results, we identify that it is a fun tool to use, that these systems help to improve the digital skills in complex representations and that they should allow the design and re-evaluation of urban spaces. This aspect reflects the usefulness of the method, the potential use in organizations and with stakeholders, and that it is possible to define a new space-participation model, guided, on the local scale, by single citizens, and by a local community. The end to show how to facilitate participatory design, the motivation, engagement, and overall experience of the participants with the technology, more than the effectiveness of the approach, as the whole urban design process has not been completed, and still ongoing.

However, an aspect to be re-evaluated is the fact that the participants gave lower point to the affirmation that this tool allows to identify possible unsatisfied social needs and to the affirmation

Table 8
T-Statistic and P (T< =t, two tailed).

Variable	*T*-Statistic	P(T< =t) two tailed
IMI1	2.676780947	**0.011235966**
IMI2	1.120234757	0.269294989
IMI3	2.041623043	**0.048367485**
IMI4	4.771683931	**2.13037E−05**
IMI5	−0.634710833	0.528569625
IMI6	0.894901021	0.376193604
IMI7	1.744822319	**0.044254121**
SOC 1	2.515225107	**0.015909398**
SOC 2	1.866614582	**0.034743524**
SOC 3	2.387306021	**0.021666007**
DSK 1	1.87053192	**0.034464041**
DSK 2	3.5101366	**0.001124552**
DSK 3	1.68816103	**0.050266944**

that the use of interactive systems generates less stress than traditional systems. For this, it would be important to improve the interaction with space and objects, the quality of the graphics and the reality of the objects. Our future experiments will be related with the study of the correlation between the interaction of the user and the visualization method and the way they can manage it to serve as a tool to satisfy their needs. In addition, we will focus our future proposals to integrate of Digital Transformation in the urban design through innovative concepts and practical methodologies to improve public motivation, implication, and satisfaction in urban decision-making processes.

Acknowledgments

This research was supported by the National Program of Research, Development and Innovation, Spain aimed to the Society Challenges with the references BIA2016-77464-C2-1-R & BIA2016-77464-C2-2-R, both of the National Plan for Scientific Research, Development and Technological Innovation 2013–2016, Government of Spain, titled "Gamificación para la enseñanza del diseño urbano y la integración en ella de la participación ciudadana (ArchGAME4CITY)", & "Diseño Gamificado de visualización 3D con sistemas de realidad virtual para el estudio de la mejora de competencias motivacionales, sociales y espaciales del usuario (EduGAME4CITY)". (AEI/FEDER, UE).

References

[1] M. Carmona, T. Heath, S. Tiesdell, T. Oc, Urban design today, in: Public Places Urban Spaces, 2010, pp. 3–19, http://dx.doi.org/10.1016/B978-1-85617-827-3.10001-X.
[2] A. Di Bella, Digital urbanism in southern Italy, Int. J. E-Planning Res. 1 (2012) 73–87, http://dx.doi.org/10.4018/ijepr.2012100105.
[3] S.K. Thiel, P. Fröhlich, Gamification as motivation to engage in location-based public participation? in: Lect. Notes Geoinf. Cartogr., 2017, pp. 399–421, http://dx.doi.org/10.1007/978-3-319-47289-8_20.
[4] R. Schroeder, Ralph Possible Worlds: The Social Dynamic of Virtual Reality Technology, Westview Press, Inc., Boulder, CO, USA, 1996.
[5] A. Krieger, W.S. Saunders, Where and how does urban design happen? Urban Des. (2009) xix, 368 p., http://mirlyn.lib.umich.edu/Record/006080724CN-NA9040.U6772009.
[6] F. Valls, E. Redondo, D. Fonseca, R. Torres-Kompen, S. Villagrasa, N. Martí, Urban data and urban design: A data mining approach to architecture education, Telemat. Inform. (2017), http://dx.doi.org/10.1016/j.tele.2017.09.015.
[7] Digital transformation: online guide to digital business transformation, I-Scoop (2016) 1–34, https://www.i-scoop.eu/digital-transformation/ [Retrieved on 20/12/2017].
[8] E.M. Horne, Margaret, Thompson, The role of virtual reality in built environment education, J. Educ. Built Environmen. 3 (2008) 5–24, http://www.tandfonline.com/doi/full/10.11120/jebe.2008.03010005?scroll=top&needAccess=true.
[9] M. Bower, A. Cram, D. Groom, Blended reality: Issues and potentials in combining virtual worlds and face-to-face classes, in: ASCILITE 2010 - Australas. Soc. Comput. Learn. Tert. Educ., 2010, pp. 129–140, http://www.scopus.com/inward/record.url?eid=2-s2.0-84870726389&partnerID=40&md5=b6ec7fc97cd2bd3078567a76289338a9.
[10] D. Fonseca, S. Villagrasa, I. Navarro, E. Redondo, F. Valls, J. Llorca, M. Gómez-Zevallos, A. Ferrer, X. Calvo, Student motivation assessment using and learning virtual and gamified urban environments, in: ACM Int. Conf. Proceeding Ser., 2017, http://dx.doi.org/doi:10.1145/3144826.3145422.
[11] O. Devisch, A. Poplin, S. Sofronie, The gamification of civic participation: Two experiments in improving the skills of citizens to reflect collectively on spatial issues, J. Urban Technol. 23 (2016) 81–102, http://dx.doi.org/10.1080/10630732.2015.1102419.
[12] S. Delamont, P. Atkinson, Editorial, Qual. Res. 10 (2010) 635–637, http://dx.doi.org/10.1177/1468794110381634.
[13] R.B. Johnson, A.J. Onwuegbuzie, Mixed methods research: A research paradigm whose time has come, Educ. Res. 33 (2004) 14–26, http://dx.doi.org/10.3102/0013189X033007014.
[14] J.W. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 2013, http://dx.doi.org/10.1007/s13398-014-0173-7.2.
[15] F.V. David Fonseca, Isidro Navarro, Sergi Villagrasa, Ernest Redondo, Sistemas de Visualización Gamificados para la mejora de la Motivación Intrínseca en Estudiantes de Arquitectura, in: CINAIC 2017 - IV Congr. Int. Sobre Aprendizaje, Innovación y Compet. Zaragoza, 2017, pp. 209–214, http://dx.doi.org/10.26754/CINAIC.2017.000001_043.
[16] T.P. Grantcharov, L. Bardram, P. Funch-Jensen, J. Rosenberg, Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy, Surg. Endosc. Other Interv. Tech. 17 (2003) 1082–1085, http://dx.doi.org/10.1007/s00464-002-9176-0.
[17] L. Annetta, J. Mangrum, S. Holmes, K. Collazo, M.T. Cheng, Bridging realty to virtual reality: Investigating gender effect and student engagement on learning through video game play in an elementary school classroom, Int. J. Sci. Educ. 31 (2009) 1091–1113, http://dx.doi.org/10.1080/09500690801968656.
[18] A. Felnhofer, O.D. Kothgassner, L. Beutl, H. Hlavacs, I. Kryspin-Exner, Is virtual reality made for men only? Exploring gender differences in the sense of presence, in: Proc. Int. Soc. Presence Res., 2012.
[19] T.D. Parsons, P. Larson, K. Kratz, M. Thiebaux, B. Bluestein, J.G. Buckwalter, A.A. Rizzo, Sex differences in mental rotation and spatial rotation in a virtual environment, Neuropsychologia 42 (2004) 555–562, http://dx.doi.org/10.1016/j.neuropsychologia.2003.08.014.
[20] R.S. Astur, M.L. Ortiz, R.J. Sutherland, A characterization of performance by men and women in a virtual morris water task: A large and reliable sex difference, Behav. Brain Res. 93 (1998) 185–190, http://dx.doi.org/10.1016/S0166-4328(98)00019-9.
[21] R. Peris, M.A. Gimeno, D. Pinazo, G. Ortet, V. Carrero, M. Sanchiz, I. Ibáñez, Online chat rooms: Virtual spaces of interaction for socially oriented people, CyberPsychol. Behav. 5 (2002) 43–51, http://dx.doi.org/10.1089/109493102753685872.
[22] N. Yee, The demographics, motivations, and derived experiences of users of massively multi-user online graphical environments, Presence Teleoperators Virtual Environ. 15 (2006) 309–329, http://dx.doi.org/10.1162/pres.15.3.309.
[23] I. Driscoll, D.A. Hamilton, R.A. Yeo, W.M. Brooks, R.J. Sutherland, Virtual navigation in humans: The impact of age, sex, and hormones on place learning, Horm. Behav. 47 (2005) 326–335, http://dx.doi.org/10.1016/j.yhbeh.2004.11.013.
[24] M. Pifarré, O. Tomico, Bipolar laddering (BLA): a participatory subjective exploration method on user experience, in: Proc. DUX 2007, Conf. Des. User Exp., 2007, pp. 1–13, http://dx.doi.org/10.1145/1389908.1389911.
[25] D. Fonseca, E. Redondo, S. Villagrasa, Mixed-methods research: a new approach to evaluating the motivation and satisfaction of university students using advanced visual technologies, Univers. Access Inf. Soc. 14 (2015) 311–332, http://dx.doi.org/10.1007/s10209-014-0361-4.

[26] D. Fonseca, F. Valls, E. Redondo, S. Villagrasa, Informal interactions in 3d education: Citizenship participation and assessment of virtual urban proposals, Comput. Human Behav. 55 (2016) 504–518, http://dx.doi.org/10.1016/j.chb.2015.05.032.
[27] C. Regan, An investigation into nausea and other side-effects of head-coupled immersive virtual reality, Virtual Real. 1 (1995) 17–31, http://dx.doi.org/10.1007/BF02009710.
[28] D. Fonseca, M. Pifarré, E. Redondo, Relationship between perceived quality and emotional affinity of architectural images based on the display device, in: Recommendations for educational use, RISTI - Rev. Iber. Sist. e Tecnol. Inf., 2013.

Arch. Mónica Sánchez-Sepulveda is an Assistant Professor in the Architecture Department of La Salle-Ramon Llull University. She graduated with a bachelor's degree in Environmental Design and master's degree in Architecture from the University of Puerto Rico. After gaining professional experience in Germany, the United States and Puerto Rico in the public and private sector as a Designer, Project Manager, and Urbanist, she started teaching Architecture Project Design and Urbanism at the Pontifical Catholic University of Puerto Rico (PUCPR). She recently moved to Spain and graduated with a master's degree specialized in Urbanism from the Polytechnic University of Catalonia and is currently a Ph.D. candidate researching the Methods of Teaching and Learning Urbanism in Architecture Schools. She has worked as a researcher at the Center for Sustainable Urban Development (CEDEUS) in the Pontifical Catholic University of Chile, and at the Urbanism Department in the PUCPR, and has been a lecturer at the University of Macao and Cambridge University with her research on Urban Networks and Social Integration. She has published in several journals and lectured at international conferences.

Dr. David Fonseca is Full Professor in the Architecture Department of La Salle-Ramon Llull University, with a Tenured Lecturer Certification by University Quality Agency of Catalonia, Spain. He holds a Telecommunications degree (URL), Information Geographic Systems Master by Girona University, and Audiovisual Communication degree and Information and Knowledge Society Master (Open University of Catalonia, UOC). He is working as Professor and Advisor in the Department of Architecture since 1997, and in the research framework, he is coordinating and working the GRETEL (Research Group of Technology Enhanced Learning, recognized by Spanish Government). With more than 150 international conferences and journal papers, Autodesk as Approved Certified Instructor also certifies him and he is serving as a committee member in more than 20 journals and international indexed conferences. Finally, he has served as researcher or principal researcher in ten granted local and international projects.

Dr. Jordi Franquesa: Architect, specialized in Town Planning, and he is teaching Urbanism at the University since 1996. He is also Master in Urban Planning and has taken courses on the theory of architecture in the city of Chicago. He has taught at different universities, as the University of Venice, Lisbon, Holland, Mexico DC and the University of Goiânia, Brazil, and has been a speaker in a Teaching and Learning Congress at Harvard. He has been working for years in different professional Urban Planning Projects related to the urban city growth. He has participated in several research projects and has written several articles on urban development in different publications. His PhD Thesis obtained the Extraordinary Doctorate Prize. He is the director of the GILDA (Research Group in Teaching and Learning Innovation in Architecture) and performed up to now three opened congresses about this subject, the last one with an international reverberation. Currently is a professor and Head of Studies at the ETSAB, the University of Architecture in Barcelona. This has allowed him to implement new methodological learning strategies to reorientate the way in which the future architects can learn the discipline in a better critical reasoning manner.

Dr. Ernest Redondo: Doctor of Architecture, Tenured University Lecturer, Department of Architectural. Representation and Visual Analysis I, Barcelona School of Architecture (ETSAB), Universitat Politècnica de Catalonia-BarcelonaTech (UPC), Spain. Architect (ETSAB-UPC, 1981). Doctorate in Architecture (1992). Doctorate special award (1994). Tenured university lecturer (1993), Department of Architectural Representation and Visual Analysis I (EGAI), UPC. Department of EGA-I director (1996–2003). Deputy Director of ETSAB-UPC (since 2011). He has two Government of Spain CNEAI recognized six-year increments and two Government of Catalonia AGAUR-recognized research periods. Principal researcher on the National RD&I Project EDU-2012-37247/EDUC. Assessor of the Spanish National Agency for Quality Assessment and Accreditation. Assessor of the Spanish National Agency for Assessment and Foresight (since 2006). Director of the UPC research group in Architecture, Representation and Modeling (ARM). Director of the GILDAICE-UPC executive committee. Member of the scientific and editorial boards of several publications. Author of more than 25 indexed publications, WOK, SCOPUS, Avery, RIBA, focusing on the use of ICTs in architecture. He has supervised six doctoral theses.