VIRTUAL URBANISM: A USER-CENTERED APPROACH

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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. The decisive influence of new technologies is important for the generation of a new reality from the economic, social and urban point of view. It is a challenge for organizations and society to question the *status quo* and experiment often. To take advantage of the changes and opportunities offered by the inclusion of digital technologies, accommodation of the digital transformation into the visualization of Urbanism is required. 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 main goal of the paper is to present the use of digital transformation in processes of urban design through Virtual Reality in which specialized users can analyze, represent and transmit ideas, problems and solutions for the design of urban space. The hypothesis is based on demonstrating the following two statements: (1) the implementation of virtual gamified strategies in the field of urban design helps to critically evaluate the result of urban design, make decisions and understand the location conditions, dimensions and relationships of urban spaces thanks to enhanced visual technologies. (2) The interactive Virtual Reality system helps for the understanding of three-dimensional space and the human scale immersive perception in Virtual Reality could be a tool to defend the arguments of urban projects.

The urban project we work on, promoted by the Barcelona City Council, aims to generate spaces that are designed to meet the needs of the users. The spaces are modeled virtually, intended to be an accessible environment where users (professionals related to the construction and design field) can interact –play– with, to recreate new spaces. These spaces are meant to have maximum realism, including the materials, textures, movements, and even sounds of the environment. The system is tested on the Barcelona Building Construmat Fair using a quantitative method. The data obtained from the assessment exemplify the effectiveness of virtual systems on the urban design process. The results obtained from inquiries to 79 citizens –specialized in the construction and design field –, showed that it is possible to empower Digital Transformation as Virtual Reality systems increase the understanding of the space. The results show that the system helps: 1) to identify the needs and requirements of the human scale and the relationship between people and the natural or artificial environment and objects; 2) to critically evaluate the result of an urban design and make decisions; 3) to transmit problems, solutions and ideas, to a non-specialized and specialized public, 4) apply formal, functional and technical basic principles to the conception and design of urban complexes; among others.

It is proven that is a system that eases the representation and argumentation of urban projects. Knowing the interactive Virtual Reality system, participants specialized in the construction and design field were motivated to change the way of working on the future. The end of the paper is to present a visualization of the results, in a way designed to be attractive and informative for users so the conducted analysis may be reproducible in other urban data contexts.

The topics that are approached on this paper are: (1) A descriptive analysis of different technologies that can be incorporated to ease the process of urban design. (2) A selection of one of these technologies to model the scenario that will be studied. (3) The exposition and evaluation of a case study and the analysis of the results. And (4) the explanation of the conclusions and next steps to take.

Keywords: urbanism; virtual reality; user experience; smart cities

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1. Introduction

Historically, visualization and understanding of 3D space are usually achieved via physical models and drawings [3]. This method is changing due to a generational change and the constant improvement and development of technology. The ways we now communicate have been adapting to new devices that mostly involve characteristics such as mobility, interaction and interconnection [19]. Reports [2] explain the openings obtainable by these developing technologies as making a new type of reality, in which physical and digital environments are combined throughout our daily lives. Even processes that are now a usual instrument, like the computer, have released a new world to the Urbanism field, through new forms, new perspectives and new ways of evaluating data. 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 creating another dimension to the practice [17].

The last decades in urban design research are distinguished by a focus on technological aspects of cities [14]. The discussion about the growing incorporation of digital technologies in the design of urban spaces comprehends several interrogates related to the complex processes of transformation that affect cities, in the economic, social, political, and environmental aspects [17]. In architecture (practice and training), until recently, the use of IT (Information Technology) was restricted to project implementation processes, where various applications such as CAD (Computer Assisted Design) and BIM (Building Information Modeling) served only as aids in the execution of one's work, not as tools for the decision making of the architecture and urban design project [15].

It is true that the new technologies that model in 3D, Virtual Reality and even videogames, correspond to progress to enhance the capacity of spatial and graphic vision and therefore ease the process of project conception [12, 23]**.** Recent approaches in the use of gamified methods for the visualization of real urban spaces to improve or generate dynamic experiments:

- "Blockholm" (Stockholm, 2014), founded on Minecraft that has invited 100,000 users, technicians and experts in urban design to participate. The purpose of the game is based on designing a smart city of the future based on the real cartographic map of the city, including topography, streets, plots, rivers, lakes, etc.

- "Play the City", implemented throughout 2012 in different cities of Holland, Belgium, Turkey and South Africa and which was based on a Word of Warcraft type game.

- "SimCity" in its different versions, used as a basic system 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. The use of mobile devices, wearables technologies such as Virtual Reality, Augmented Reality, collaborative work, and gamified strategies are permeating our society thanks to its facility of use and effectiveness, both in training stages, as well as in professional fields [24, 26]. Using these technologies, we can work with a new way to define urban proposals interactively rehearsing various strategies of action.

Regardless of the vast sum of urban data to integrate, representation technologies take ideas into reality, letting communication between clients, designers, collaborators and contractors [10]. Recent approaches in the use of this kind of methods for the visualization of real urban spaces to improve or generate dynamic experiments [18]:

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- 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 different type of tools:

  1) 2Dimensions - 3Dimensions CAD (Computer Assisted Design) Systems: The CAD methods allow a fast representation and modelling of the architecture and urban data. Support for technical modeling software allows you to add specific modules on more powerful graphics platforms such as AutoCAD for manipulating 3D figures and spatial comprehension of the projects [1]. The ability in spatial representation capacity requires learning of spatial perception.

  2) 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 [29].

  3) BIM (Building Information Modelling): BIM applications can apply to the entire process of building construction. From the graphic conception to the physical realization. The improvement of the performance of the software has allowed the computer to be used as a drawing and also a support tool in the genesis of the project [20].

- Multimedia Systems: The contents that are based on these formats are closer to the means of everyday use. For this reason, this type of systems are more attractive, increase the motivation and favor the performance [13]. Communicating design intent and conveying space to non-technical clients has always been a challenge for architects. Immersive advancements such as virtual reality are paving the way for new ways to deal with this challenge enabling designers to jump into a 1:1, true to scale VR version of their 3D model. Interactive, spatial, real-time technologies can radically improve modelling and communication of ideas, enable participation in the design process, and facilitate planning and management at the urban scale [28].

- 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 urban designers to relate the projects to the main needs of the citizenship [25]. Through Digital Transformation, urbanists should be able to incorporate informal data obtained from the space, its functionality and the needs and the interests of citizens, to develop more sustainable projects and products adapted to more users and/or users with different profiles or disabilities.

- 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. The use of additional devices (knobs, hand wheels, glasses, etc.) is considered to be a coordination of hands and feet with mental tasks [9, 21].

- Rapid prototyping and real models: Through the mode of contact, the use of real elements that can be manipulated help the mental process of visualization. Physically you can rotate the object to see it from any point of view without having to do the mental effort [15]. You can physically rotate the object to see it from any point of view without the need for mental effort.

Nowadays, the available solutions focus on the basic ability to develop an architectural plan, rather than maximum accuracy in representing the geometry of buildings [4]. In the other hand, is necessary to consider the 3D architectural rendering, particularly because new forms and systems of visualization often exceed the possibilities of traditional CAD solutions and even

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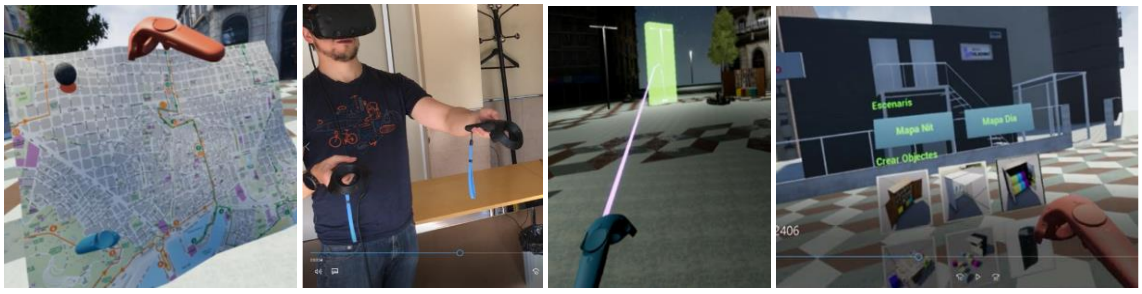
BIM. Given the approach of the project, it is important to take into account how the VR is a technology, that applied correctly, taking into account that the basis of the VR is to create an immersive experience and allow the user to interact with objects to operate in space. Some studies show that a virtual environment in which 3D objects can be manipulated from any angle allows better recognition of objects than if they are taught on paper [11].

With the characteristics of the VR system, we can test our hypothesis based on demonstrating: (1) the implementation of virtual gamified strategies in the field of urban design helps to critically evaluate the result of an urban design, make decisions and understand the location conditions, dimensions and relationships of urban spaces thanks to enhanced visual technologies. (2) The interactive VR system helps for the understanding of three-dimensional space and the human scale immersive perception in Virtual Reality could be a tool to defend the arguments of urban projects. Using new technologies, as VR, we can work with defined urban proposals interactively rehearsing various strategies of action and evaluate public spaces.

2. Methodology

The urban project we work on, endorsed by the Barcelona City Council, aspires to create spaces that are designed to meet what the users' wants, that are spacious, agreeable spaces with vegetation, with dynamic uses, spaces for children's games, urban gardens, lighting, recreational and cultural activities, among others. The aim is to diversify the road network based on the connectivity of the streets: basic network (connection at the city level), local network (at district level) and neighborhood network (of origin or final destination, to get home, to a trade, to work, etc.). For this, we virtually recreate urban areas of the city of Barcelona and its surroundings to be an accessible environment where users can interact –play– with, to shape and recreate new spaces. These spaces are meant to have maximum realism, including the materials, textures, movements, and even sounds of the environment (Figure 1).

Figure 1. **Examples of user's interaction with space for its modification**



Note: Two-hand joystick with different options: map to indicate your location in the site, grabbing objects to move or rotate and a catalog with urban furniture. Source: Authors.

The purpose is to view and think 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 permits creating more aware and precise project decisions and warranting much more measured results.

We used this system to validate the effectiveness of virtual gaming application in the urban design projects proposing to enhance the spatial perception and urban skills, due to the immersive visual technologies. As such, will detect essential elements to encourage initiatives in both urban transformation and designing processes. [8]. We put importance to evaluate the motivation and usability of the users of the gamification platform.

The first urban project we work on is in Sant Boi de Llobregat in a short urban development of Plaça de la Generalitat. Neighbors asked for an intervention on the part of the Administration

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due to some reasons: the perception of insecurity of the neighborhood, the need to promote the commerce of the surroundings and the degradation of the uses in general. The challenge was to design a new place from citizen input to improve and renovate the square corresponding to their needs and requests [18].

A second project we work on, aspires to make a large public space that prioritizes the people of the Eixample Esquerra District instead of the vehicles [17]. By closing the street to vehicles and allowing it to pedestrians, the program to be placed there is design according to the neighbors' criteria. Collaboratively, they stated the following conditioners:

- Carry out the street mainly to pedestrians
- Promote spaces for stay and neighborhood coexistence
- Increase the amount of vegetation while maintaining the alignment of typical trees
- Increase the surface of rainwaters' catchment on the terrain
- Establish criteria for the location of furniture and services (garbage bins, zone of loading/unloading, bar terraces, etc.)

The third project we work on is in the area of the Plaça Baró, in Santa Coloma de Gramanet. The basis was to create a collaborative design with a gender viewpoint from the design phase to the intervention. The goal is to generate a specific space adapted to the needs of children between 6 and 12 years old. A participatory process was conducted with students of the fifth grade of the Torre Balldovina School, neighbor of the square, as well as sessions open to the whole neighborhood. The sessions were complemented by a process of education in architecture and urban planning with a gender perspective for children. All activities have been supported with approaches that permit children to contribute with their realities and needs related to the specific public spaces of action. Subsequently, children analyze spaces with a critical eye and suggest enhancements with an inclusive perspective and through collective debate and agreement.

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 now to asses this system with diverse users to visualize the scale, the textures, the relationship of the uses, the lights and shadows, etc. The participants use the glasses of virtual reality and through interactive elements, shaped the urban public space. According to their criteria and collaboratively, could again configure the elements.

We evaluate the use of the VR system throughout the competences required in the training of Urbanism in Spain, based on the White Paper (*Libro Blanco*), that aim of carrying out studies and useful practical cases in the design of a degree adapted to the European Higher Education Area (EHEA). These competences (Table 1) serve as the base to make the survey and assess the effectiveness of the virtual systems in the processes of urban design.

Table 1. **Competences in the curriculum for Urbanism of the School of Architecture, La Salle – URL that relates to each Survey Statement**

Survey Statement#	Urbanism Competence
1, 2 y 6	Ability to comprehend the relations among people and buildings, between buildings and their surroundings, and buildings and spaces among them based on human scale and needs
3	Capable of making decisions (in projects, construction systems, organization, etc.)
4	Capability to communicate ideas, information, problems and solutions to a specialized and non-specialized public
3	Capable of acquiring the self-critical capacity

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5	Aptitude or ability to apply the basic formal, functional and technical principles to the conception and design of buildings and urban complexes, defining their general characteristics and benefits to be achieved
7	Aptitude or ability to develop building programs, considering the requirements of customers and users, analyzing precedents and location conditions, applying standards and establishing dimensions and relationships of spaces and equipment
2	Understanding the relationships between human behavior, the natural or artificial environment and objects, according to human requirements and scale

Source: Authors.

2.1. From the Project to the Survey

In the experimentation and scientific research of working hypotheses based on participants' response, a basic issue is the correct design of methods that allow data extraction. There are quantitative methods, like profile tests, satisfaction surveys and usability tests. In the scientific investigation, if we work with various examples (minimum of 30-50 samples), we can collect information quantitatively and the results can be analyzed and compared to find differences statistically [6]. With fewer users, however, the qualitative approach has proven to be equally valid with the ability to obtain a detailed explanation of the variables of the study [6]. The classic tool in this context is the survey, which is often designed to measure the response concerning the usability of a system, his/her perception in general and the degree of satisfaction with the proposed method. The value of research lays not so much in the epistemology of the method, but in its efficiency [22] as the quantitative methods are considered objective [16, 27] and require deduction to interpret results.

To analyze and evaluate the advantages and disadvantages of the virtual systems in the process of developing an urban and architecture project we surveyed professionals in the construction field on the Construmat: International Construction Fair, on their experience of virtual systems on the design of urban environments. We exposed to the users to use RV glasses to evaluate how this method can help to design urban spaces in our city, Barcelona (Figure 2).

Figure 2. **Participation of professionals in the *Construmat*: International Construction Fair**

Source: Authors.

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With RV glasses, the participants experimented and shaped the urban public space. The RV the simulated environment let users understand in an immersive condition the actions and changes that happen in the environment in real-time with their decisions (Figure 3). For example, in the calculation of specific lighting in a space experimenting a very dynamic and realistic result and having the capacity to be in continuous interaction with the open space by moving and rotating actions.

Figure 3. **Dynamic result of the night and daylight. Work made by students of La Salle - URL**

Source: Authors.

After having the interactive virtual experience, we gave the users surveys, similar to what we have done on previous experiments in the architecture educational framework, [5, 7]. We worked with 28 women between (Age average, AA: 31.89 and a standard deviation, SD: 14.31, between 20 and 57 years old) and 51 men (AA: 33.86, SD: 14.31, between 20 and 68 years old).

We used a Likert scale for the design of the survey for users to evaluate the statement exposed from 1 to 5 from their level of agreement. The survey has 10 statements about different aspects related to the effectiveness of virtual systems on the design of urban environments (Table 2).

Table 2. **Survey with ten statements about different aspects related to the effectiveness of virtual systems on the design of urban environments, using the Likert scale**

	Disagree -> Agree
The interactive VR system helps:	1 2 3 4 5
1. Easily identify the needs and requirements of the human scale	
2. Understand the relationship between people and the natural or artificial environment and objects	
3. Critically evaluate the result of an urban design and make decisions	
4. Transmit problems, solutions and ideas, to a non-specialized and specialized public	
5. Apply formal, functional and technical basic principles to the conception and design of urban complexes	
6. Understand the relationship between buildings and the spaces between them	
7. Analyze location conditions, establish dimensions and relationships of urban spaces	
Knowing the interactive VR system:	1 2 3 4 5
8. It would motivate me to change my way of working in the future	
9. I would use it to defend the arguments of urban projects	
10. I would use it to defend the arguments of architectural projects	

Source: Authors.

3. Case Study and Results

In previous work [17] we have proved that there is a significant difference between gender, background. In the present study, we only choose users that were related to the architectural/ design/ construction field, so we started dividing by gender. The statement #5 achieves the lowest value in both groups, having in common the statements #8 and #3 as the next with the

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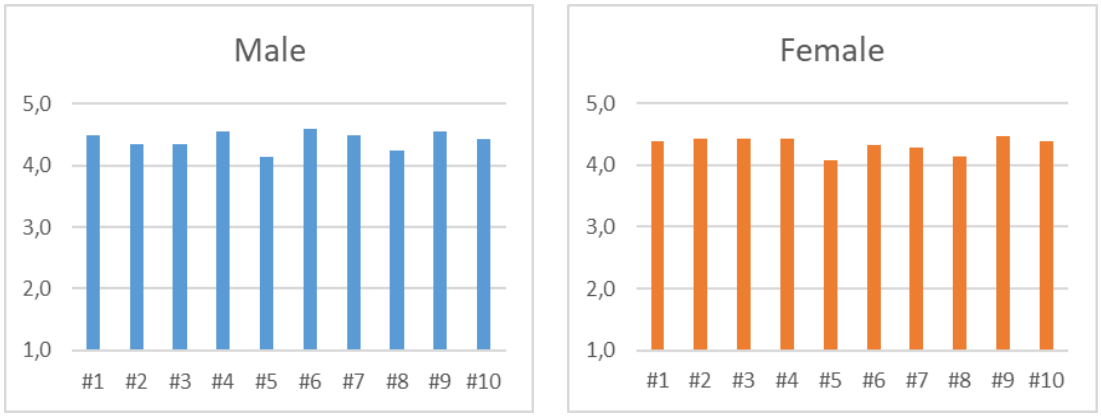
lowest value (Table 3). However, the highest values were different. The males valued statements #4, #6 and #1 as the highest (in that order), and females valued statements #9, #4 and #2 as the highest (also, in that order), having the statement number #4 in common.

Table 3. **Answers of males and females in the professionals' group**

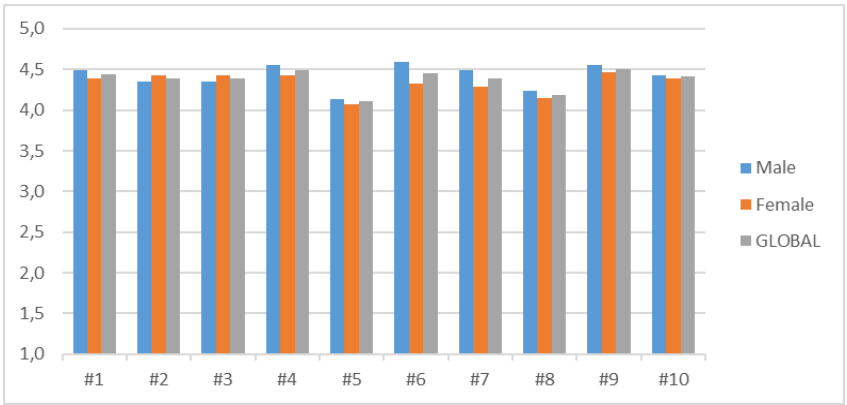


Source: Authors

To estimate the probability that profiles by group are significantly similar, we used the Student's t-test (Gosset, 1908), using a null hypothesis (H_0) that there are no differences in scores between groups. Statistical significance (two-tailed) obtained was p = 0.2812, which exceeds the threshold of 0.05, an issue that means a low probability that the responses based on the gender are different. The null hypothesis, which states that there are no significant differences between groups, is accepted.

Comparing both groups there are no significant differences at any individual level, being not noticeable that 80% of the statements got a higher valuation from the male group, where statements #2 and #3 are the exceptions, more valued by women (Table 4). The lowest values are found in the statement #5 (The VR helps apply formal, functional and technical basic principles to the conception and design of urban complexes) with a global average of 4.10 (SD: 0.79). This one is followed by #8 (Knowing the interactive VR system would motivate me to change my way of working in the future) with an average of 4.19 (SD: 0.78). While at the opposite end with averages of 4.51 (SD: 0.66) and 4.49 (SD: 0.77), we find statements #9 (The VR helps to transmit problems, solutions and ideas, to a non-specialized and specialized public) and #4 (By knowing the interactive VR system would use it to defend the arguments of urban projects).

Table 4. **Comparison between the male, female and global results in the professionals' group**



Source: Authors.

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By gender, the minimum differences are subjective, and there is no gender gap in the use and potential perceived usefulness of the studied systems. Professionals see these systems as having great potential and use them. By graphically analyzing the average obtained responses related to technology used and perceptions/motivations, we observed similar behaviors regardless of gender, stands at 4.44 (SD: 0.12).

4. Conclusions

The results of the present study are encouraging, since it allows us to affirm that the implementation of virtual gamified strategies in the field of urban design helps to critically evaluate the result of urban design, make decisions and understand the location conditions, dimensions and relationships of urban spaces thanks to enhanced visual technologies. It is clear that the integration of VR as a tool in the process of the urban design generated positive feedback helping in the understanding of three-dimensional space and could be a tool to defend the arguments of urban projects.

Regarding the urban design process, this analysis of quantitative approaches reveals an interesting aspect, that is that participants put a higher value to the statements that affirm that the interactive VR system helps to transmit problems, solutions and ideas, to a non-specialized and specialized public and that would use it to defend the arguments of urban projects. Finding this as an asset reveals that participants were receptive and help them to improve the digital skills in complex representations. This aspect reflects the usefulness of the method, the potential use in organizations, with stakeholders, and private business. It is validated, that the implementation of this method can be used to execute a suitable design. However, the formal, functional and technical basic principles to the conception and design of urban complexes is not the strength of this tool.

We can confirm through the outcomes, that the use of VR on the design of urban environments improve spatial perception and urban competences, because of the immersive visual technology experience. The application of this system can be used to help in the design process and for its representation. Through this research is shown that it adjusts with what is wanted and used on the professional field.

By concluding this, we expanded our research, willing to publish it soon, where we evaluate the use of the VR system in the learning process of urban design to help to enhance the digital skills in complicated representation and permit assessment and decision-making in the processes of urban design spaces. This second part of the research shows the usefulness of the system and the potential that it has in the competence development of the student. We emphasis to: 1) Assess the incorporation of immersive ICTs and serious games in the education of the urban project. 2) Asses the motivation and usability of the users of the gamification platform. 3) Study and link the profiles of the users with the results of the surveys. 4) Determine the relationship between satisfaction, motivation and use experience. A comparison with the professional group is made to see the gaps and opportunities of how future professionals in the field of urban design are being trained with what is demand in the professional field. The method used in architectural and urbanism education and practice is evaluated in a quantitative method, as a support in the design process and to visualize design alternatives set in existing built environments. This lets us recognize the positive and negative features in an objective way.

We cannot forget that architecture is part of the cultural heritage of humanity and access to culture is a universal right. It is then necessary to explore all those tools that make it possible. The representation of architecture, construction processes, urban planning, etc., have evolved over time to adequate to the actual user.

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