Virtual Reality as a Tool for Teaching Architecture

Guilherme Valle Loures Brandão(✉),
Wilian Daniel Henriques do Amaral,
Caio Augusto Rabite de Almeida, and Jose Alberto Barroso Castañon

Universidade Federal de Juiz de Fora, Juiz de Fora, Brazil
{guilherme.loures,wilian.amaral}@engenharia.ufjf.br,
caioaugusto.arq@gmail.com, jose.castanon@ufjf.edu.br

Abstract. Every year many technologies are developed and implemented in such a way that fundamentally alters how we create, develop and interact with the environment. Virtual Reality has been broadly spread on architecture by allowing users to immerse on a digital universe or in an unbuilt project simulation. On engineering and architecture, project solutions and proposal visualization are essential for the diverse steps understanding and new project solutions development. Such tools help on speeding up processes, iterate and explore digital models faster and create the best solutions. The insertion of contents that support the student formation related to new technologies is an important step towards the qualification of future architects to new design tendencies. This paper aims to evaluate the further training methods on graphic representation and architectural design aid tools at the Juiz de Fora Federal University (UFJF). For this purpose, the use and evaluation of a VR experience used to show several architectural projects designed by the architecture students from the Federal University of Juiz de Fora presentations. The work starts from the premise that the technology applied to mobile devices such as cellphones or virtual reality goggles are reasonably cheap to acquire and become familiar to the student if presented on the first stages of learning, achieving a deep and complex status as the alumni progresses towards graduation. To conclude, it is perceived that after an initial adaptation period there was a perceivable acceptation and architectonic design comprehension by students.

Keywords: Architecture · Design process · Teaching · Virtual reality Technology

1 Introduction

Broadly, virtual reality (VR) is a digital tool that transports the user to an environment in which one is not physically present but receives sensorial stimuli that lead to the sense of real presence in those spaces. Through computational modeling and simulation, it allows the user to interact with a three-dimensional (3D) artificial space, through visual perception and/or other sensory stimuli.

The VR application immerses the user in an artificially generated environment that simulates reality using devices that allow interactivity such as headsets, goggles, gloves

© Springer International Publishing AG, part of Springer Nature 2018
A. Marcus and W. Wang (Eds.): DUXU 2018, LNCS 10919, pp. 73–82, 2018.
https://doi.org/10.1007/978-3-319-91803-7_6

and clothing that exchange information with a computer. In its typical format, the user has coupled to the head a set of goggles or a helmet with stereoscopic screens that allow visualizing animations and simulations of an environment (Virtual Reality 2010).

Computer graphics, computer visualization and user interfaces enable new challenges upon shapes and concepts under the creation processes. Although the computer use as a project tool is widespread among the architectural offices, there are still unexplored and emerging forms of representation and visualization such as VR and augmented reality (AR), which can help and modify the built environment's production mode.

In the engineering and architecture fields, the design solutions and proposal visualizations are essential for understanding the various stages and new design solutions development. The VR allows the user visualization of elements, generating significant evolutions that affect all production stages, from the conception to building and interior materialization plus city elaboration and development.

Rebelo et al. (2011) affirm that VR has been applied in architecture to allow interaction between internal and external virtual environments, with different levels of realism. In these environments users can move freely and, in some cases, make modifications such as color changes, lighting and furniture placement in many different scales. In the field of applied ergonomics, VR has been developed for increasing environmental quality and training for the task executor, in addition to the general gain on product, environment and productive systems overall quality (Grave et al. 2001; Rebelo et al. 2011).

Digital modeling and analysis tools allow for greater control over creation and visualization on complex models, in which the drawing by hand has greater difficulty and time spent in representing. The time spent developing a work in the virtual environment is reduced in addition to allowing a greater amount of potentially relevant information and its visual and performance comparison, especially in cases of architectural projects and its spatial and ergonomic relations (Borgart and Kocaturk 2007).

Borsboom-Van Beurden et al. (2006) affirm that the use of virtual models, compared to the use of technical drawings, can contribute to greater efficiency in project communication. According to the authors, virtual models have a greater connection with the way that a human being perceives real objects, facilitating the identification and understanding of the object conceived. For Cross (2007, p. 33), designers need means which "allow ideas in the conception process to be expressed and reviewed, developed and corrected according to the design process" in an integrated way within the expected temporality.

According to Tversky (2005) when constructing external or internal representations, designers are involved in a spatial cognitive process in which the representation of the medium serves as cognitive auxiliaries for memory and information processing.

Schon (1992) states that with the execution of action and reflection, each level of representation makes the designers evolve in their own interpretations and ideas for design solutions. In this approach, the bias taken are the reflections caused using unconventional visualizations plus the stimuli and difficulties provided to users during the project development and reasoning, favoring the multifactorial approach and spatial experience during the preliminary phases of conception and materialization.

2 Justification

Tools that use computer aided design (CAD) and, more recently, building information modeling (BIM) help creating virtual models that increasingly resemble the final built object, with great implementation potential both in the craft as in teaching the disciplines that involve planning of the built environment (da Fonseca 2013).

In this context, Silvestri (2010) points out that virtual data and computer-generated drawings and information have quickly replaced physical and analog learning media such as hand-held drawings and mockups. Besides, these digital tools are at the center of a new way to approach the design process itself.

To Oxman (2006), expressions such as “digital design” or “digital architecture” are often used to describe contemporary architectural practices that are already assisted by these new platforms, as the latter depend on fundamentally on the first ones to conceive the project, its production and construction. The need to integrate new technologies such as VR into the product design process is generally recognized, especially in the design phase and, as such, provides new advances in CAD areas (Ye 2005).

These emerging technologies create new paradigms to overcome conventional interfaces drawbacks, such as product visualization for designer and consumer, both in conception and in understanding the object’s tridimensionality and scale. Regarding the VR applied to architecture and ergonomics, researches indicates that the introduction of these tools in different fields of education is viable, including the various design and coordination stages, integrating the various disciplines approaching design (Fonseca et al. 2013).

Specifically, in the field of architecture and urbanism, VR can be used to predict the undertaking impact on the landscape and building rehabilitation, such as changing colors, materials and textures. It also allows for project overlap compatibility, such as structures, installations, enveloping, geographical location and solar study, thus enabling interference verification between systems in real time (Sánchez et al. 2013).

This being stated, this work justifies itself due to VR presenting itself as an important and useful tool for teaching architecture and contemporary urbanism integrating design, design, analysis, spatial perception, building fabrication and assembly around digital technologies. From this integration, the professionals involved have an opportunity to fundamentally redefine the relationships between technical projects from the most diverse disciplines and the effective production, with consequent quality improvement in the final product.

3 Objective

This article seeks to verify the future architectural professionals’ perception in the use of virtual reality on teaching and developing the students holistic concept and spatial understanding skills on the Federal University of Juiz de Fora’s undergraduate course in Architecture and Urbanism.

4 Methodology

For this study's elaboration, it was studied the use and evaluation of a virtual reality experience in visualization of 3D models (Fig. 1) and in the presentation of students' architectural projects in the Federal University of Juiz de Fora's Faculty of Architecture. The work starts on the premise that the technology used in conjunction with mobile devices is familiar to the undergraduate student and, if implemented in the initial stages of training, can achieve a greater depth of interest and involvement with the content proposed in classroom.

Fig. 1. Image rendered in stereoscopic format

The evaluation relies in the feasibility of using VR through the alumni mobile devices in educational environments, investigating the relationship between tool use and student participation, through interviews and monitoring the Digital Representation discipline, besides the contribution of understanding spatiality and instrumentation after technology use.

The strategies implemented were applied during Digital Representation I and Initiation to the Process of Computer Aided Modeling classes. Two types of visualization were used: through virtual reality goggles with coupled smartphones and augmented reality through mobile devices.

First, a brief explanation was made about the concept, applications and how to use the instruments and, at first, a demonstration of models already rendered in vision 360°. Subsequently, each student would use the Kubity® software introducing a model that was carried out previously in class which, in turn, would generate a QR Code to be introduced in the smartphone application to be visualized by students in virtual reality goggles. Finally, the students answered a questionnaire about the tool's application and importance in the process of learning and visualization of the projected spatiality, as well as their interest on the subject (Fig. 2).

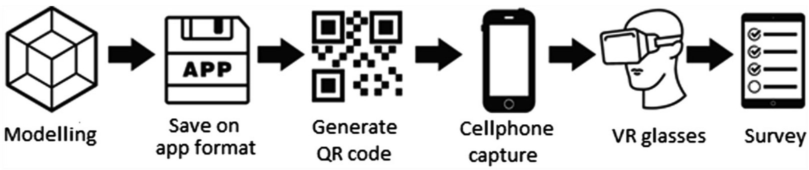

Fig. 2. Sequence used to apply the methodology

The application was performed using virtual reality goggles, coupled with smartphones with the Kubity® software installed allowing the transformation of models developed in the class by students with the Trimble SKETCHUP® 3D modeling software, on which they performed the immersion in their own models. The VR Box virtual reality goggles (Fig. 3), which allow mobile devices to couple, have several models of easy access and acquisition. Cardboard box models (Fig. 4) can also be used, with its design easily found on the internet and run by the students themselves.

Fig. 3. VR Box goggles with smartphone coupled, model used. (source: VR Box)

Fig. 4. *Cardboard Box* goggles: Design and assembly with coupled smartphone (source: Google VR Cardboard)

This comparison was carried out through a workshop to collect people's perceptions on the experiment. The methodology application took place in the Digital representation I classes at the UFJF's Faculty of Architecture and Urbanism during the 2017 first school semester. For the study application were taken, to the place of the class, mobile devices with the Application Kubity® installed, virtual reality goggles, and models of the German Pavilion project from the 1929 World Fair, with architect Mies van der Rohe authorship, built in the city of Barcelona, Spain rendered in stereoscopic Vision 360° (Fig. 5).

Subsequently to the tools presentation to undergraduate students, 48 electronic questionnaires were applied to them, according to Table 1, to generate a critical analysis of the benefits and perceived limitations of the tools used.

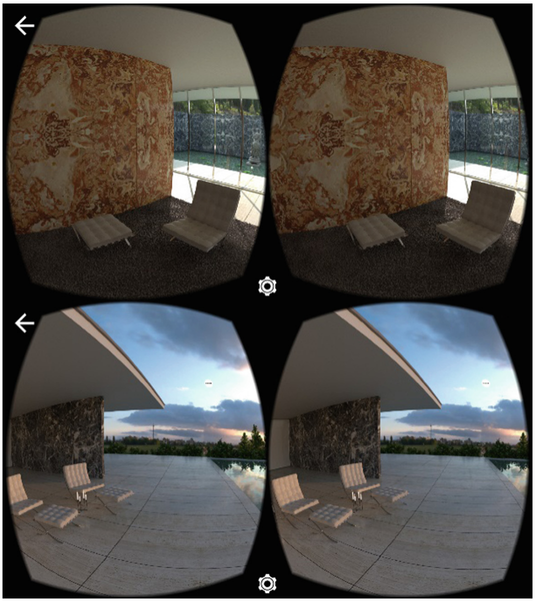

Fig. 5. German pavilion model in internal and external three-dimensional views (source: VR ArchViz Pavilion)

Table 1. Questionnaire applied to students

Question	Possible answers
Which semester are you in?	First; Second
Have you had previous contact with virtual reality?	Yes; No
Do you think that virtual reality allows you to understand a space's scale, shape, materials, distances and accesses?	Yes; No
Do you consider it relevant to use virtual reality on teaching architecture?	Yes; No
Would you use virtual reality in presentations for architectural design disciplines or other disciplines?	Yes; No

5 Results and Discussion

The compilation of the answers obtained came to the summary table presented below (Table 2).

From the respondent students, 44 are enrolled in the course's first semester and 04 are enrolled in the second semester, which was already expected since the discipline "Digital Representation I" integrates the first period in the Architecture and Urbanism course syllabus at FAU/UFJF.

When questioned about some previous VR contact, 44 students claim to have no prior contact with the technology presentation in classroom during the realization of

Table 2. Obtained answers summary table

Question	Answer	
	First	Second
Which semester are you in?	44	4
Question	Answer	
	Yes	No
Have you had previous contact with virtual reality?	4	44
Do you think that virtual reality allows you to understand the space's scale, shape, materials, distances and accesses?	48	—
Do you consider it relevant to use virtual reality in architectural teaching?	48	—
Would you use virtual reality in architectural design disciplines work presentations or other disciplines?	41	7

this work, while 04 students had previous contact. It was observed that most of the interviewed students made the first contact with the virtual reality through the performed practice, most of which had never used or knew the possibility of using the technology for digital representation in Architecture.

Asked later if the use of VR allowed the understanding of spatiality, texture and tectonic space presented, the total of the 48 students stated "Yes" and demonstrated surprise in the experimentation acuity on the object's scale. All students also recognize as important the use of digital media such as VR in the teaching of architecture and project disciplines that interfere in the built environment. Last asked about the possibility of using virtual reality in other disciplines as a form of designing and presenting projects, 41 students responded affirmatively while 7 said they would not use.

The students' responses and interest bring an indication that the introduction and application of new tools and technologies such as VR may trigger new dynamics between the parties involved in the process of design and learning, from conception to representation and presentation of the same, encompassing the manufacture of components and objects to the construction site and the building execution.

As results, the need for familiarization and use of technologies aided by mobile devices, interactive methods and VR for the visualization of architectural spatialization besides a development in perception of space and its components can be highlighted. It is understood that VR was welcomed by the students, who appreciated the use of the applied methodology, and the exercises performed enabled to improve their performance and spatial cognition capacity in a more dynamic way in the development of digital models. Students' interest in emerging technologies makes them able to be used as a didactic contribution to the development of spatial and design skills in those alumni.

However, the initial difficulty to produce adequate content for the proposed dynamics is emphasized, as well as the model optimization that allow for a more reliable and detailed view, in addition to the detailing process and the difficulty on adequacy of performed models. All the students interviewed evaluated, however, that the interaction with the content in virtual reality allows to maximize the learning process, not only in the disciplines regarding graphic representation, but also in architecture's techniques, theory and history.

This study recognizes the limitation of working with a restricted number of students available in the applied discipline and stresses the suggestion for future work in which there is a comparison of similar experiences between related courses and between the student enrolment and the semester in which they gain contact within the disciplines, as well as the proper orientation to produce more complex and detailed models.

6 Conclusion

The study presented demonstrated an experiment to verify the perception of students in the initial cycle of a course of undergraduate architecture and urbanism on the use of VR as a didactic contribution, incorporated in the visualization of design alternatives of the environment Built. It was found that the use of the strategy of visualization of spaces in VR contributes to an improvement in the understanding of proposals and solutions design, with interaction between the participants and the projected environment, assisting in the decision making.

The work pointed out the way technologies that use virtual reality can offer a faster and more intuitive interaction between the designer and the CAD program, with a simple approach to the creation and evaluation of proposed concepts and tectonics. However, formal CAD systems are not fully oriented to support the project design process due in its vast majority to the traditional interaction between human and computer, usually using its peripherals (mouse, keyboard) and a two-dimensional screen for interaction with these softwares. This may lead to loss of information and visualization through the conversion of 2D into 3D elements necessary for the decision interpretation and evaluation (Ye et al. 2006).

Unlike 2D technologies, which seek to display depth and perspective on flat screens in two dimensions, stereoscopic visualization provides the user with an immersive 3D visual perception of spatiality. Stereoscopic display is also a 3D visual channel output device. This then allows stereoscopic viewing to be much easier to interpret than 2D images typically displayed on computer monitors.

VR has already been applied in the field and studied in various related disciplines such as real estate, interior design and urban planning, enabling new possibilities to exploratory studies and use of the tool aiming to complement several new forms of architecture creation and production that emerge with the digital age.

VR's potential is to allow for a natural interaction with virtual models and to increase computer support and real-time changes throughout the project process. On the other hand, the use of virtual models impacts positively on the mental formation of three-dimensional images, increasing the perception of spatial compositions and reducing mental workload, since the three-dimensional representation facilitates the understanding and needs less effort for the user to interpret.

When VR technology is applied on built environment disciplines of the when used in vocational training or in the project process, offers a new look to understand different stages of a constructive process, allowing the verification and comparison between different scenarios and proposals before the final definition. To fulfil this premise, it is important to check the ability to visualize several models to demonstrate different layers (structure, installations, furniture, etc.), textures and geographical positions.

Although VR presents many advantages in the development of consumer goods, those who often applies the technology should be aware of some disadvantages. These are not strictly associated with modeling or situation analysis, but intrinsically linked to expectations associated with the human-computer interaction inherent in VR-based projects.

One of the main problems encountered in the experiences was the 3D model display and their manipulation on mobile devices so that different interactions occur freely using open source platforms. In the case of the Kubity® application the model view in free mode is restricted to 10 min per loaded model. It is verified that a greater adherence to VR as a didactic tool as a possibility depends mainly on the technology accessibility and the programs' and applications' ease of use and interface, which go against the greater perception and usability by the students.

In this sense, the use of VR as a tool for teaching and developing analytical skills and design also presents some limitations. One of the considerations to be made when deciding to use the tool is the immersion level offered by the chosen virtual reality system, being important to select a system that allows an appropriate level of immersion to the didactic and expected task (Rebelo et al. 2011).

The results are based on the hypothesis that representation tools have a convergence in the cognition process of and space perception and, consequently, are important tools during the design and space representation phases, both in the process as in the result necessary in the context of contemporary design.

In addition to empirical activities and bibliographic study, it is concluded that emerging technologies such as VR, even with some still existing gaps, can facilitate the development of senses beyond the visual aspects of a new generation of CAD tools that introduce collaboration and cognition concepts more integrated to the space production processes.

Acknowledgements. The authors thank CAPES and the PROAC - Built Environment Graduate Programme from Federal University of Juiz de Fora for the support received during this work execution.

References

Borgart, A., Kocaturk, T.: Free-form design as the digital "Zeitgeist". J. IASS **48**(4), 3–9 (2007). http://www.iass-structures.org/index.cfm/journal.article?aID=80

Borsboom-Van Beurden, J.A.M., Van Lammeren, R.J.A., Hoogerwerf, T., Bouwman, A.A.: Linking land use modeling and 3D visualization. In: Van Leeuwen, J.P., Timmermans, H.J. P. (eds.) Innovations in Design and Decision Support Systems in Architecture and Urban Planning, pp. 85–101. Springer, Dordrecht (2006). https://doi.org/10.1007/978-1-4020-5060-2_6

Cross, N.: From a design science to a design discipline: Understanding designerly ways of knowing and thinking. In: Design Research Now, pp. 41–54 (2007)

Cross, N., Dorst, K.: Co-evolution of problem and solution space in creative design. In: Gero, J. S., Maher, M.L. (eds.) Computational Models of Creative Design Computing, pp. 243–262. University of Sydney, Sydney (1999)

da Fonseca, A.G.M.F.: Aprendizagem, mobilidade e convergência: mobile learning com celulares e smartphones. Revista_Mídia_e_Cotidiano **2**(2), 265–283 (2013)

Fonseca, D., Villagrasa, S., Martí, N., Redondo, E., Sánchez, A.: Visualization methods in architecture education using 3D virtual models and augmented reality in mobile and social networks. In: Procedia - Social and Behavioral Sciences, vol. 93, pp. 1337–1343. (2013). https://doi.org/10.1016/j.sbspro.2013.10.040. ISSN 1877-0428

Fonseca, D., Martí, N., Redondo, E., Navarro, I., Sánchez, A.: Relationship between student profile, tool use, participation, and academic performance: with the use of Augmented Reality technology for visualized architecture models. Comput. Hum. Behav. **31**, 434–445 (2014). https://doi.org/10.1016/j.chb.2013.03.006

Grave, L., Escaleira, C., Silva, A.F., Marcos, A.: A Realidade Virtual como Ferramenta de Treino para Montagem de Cablagens Eléctricas. In: Proceddings of 10° Encontro Português de Computação Grafca, pp. 147–63 (2001)

Kubity® App. https://www.kubity.com/. Accessed 15 Aug 2017

Oxman, R.: Theory and design in the first digital age. Des. Stud. **27**(3), 229–265 (2006). https://doi.org/10.1016/j.destud.2005.11.002

Rebelo, F., Duarte, E., Noriega, P., Soares, M.M.: Virtual Reality in consumer product design: methods and applications. In: Karwowski, W., Soares, M.M., Stanton, N.A. (eds.) Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques. pp. 381–402. CRC Press, Boca Raton (2011). https://doi.org/10.1201/b10950-28

Sánchez, A., Redondo, E., Fonseca, D., Navarro, I.: Construction processes using mobile augmented reality: a study case in Building Engineering degree. In: Rocha, A., Correia, A.M., Wilson, T., Stroetmann, K.A. (eds.) Advances in Information Systems and Technologies, pp. 1053–1062. Springer, Berlin (2013). https://doi.org/10.1007/978-3-642-36981-0_100

Schon, D.: Designing as reflective conversation with the materials of a design situation. Res. Eng. Des. **3**(3), 131–147 (1992). https://doi.org/10.1007/BF01580516

Silvestri, C., Motro, R., Maurin, B., Dresp-Langley, B.: Visual spatial learning of complex object morphologies through the interaction with virtual and real-world data. Des. Stud. **31**(4), 363–381 (2010). https://doi.org/10.1016/j.destud.2010.03.001

Tversky, B.: Functional significance of visuospatial representations. In: Shah, P., Miyake, A. (eds.) Handbook of Higher-Level Visuospatial Thinking, pp. 1–34. Cambridge University Press, Cambridge (2005). https://doi.org/10.1017/cbo9780511610448.002

Virtual Reality. In: Encyclopædia Britannica (2010). http://www.britannica.com/EBchecked/topic/630181/virtual-reality. Accessed 11 Aug 2017

Ye, J.: Integration of virtual reality techniques into computer aided product design. Thesis (Design Ph.D.) - Department of Design and Technology, Loughborough University, UK (2005)

Ye, J., Campbell, R.I., Page, T., Badni, K.S.: An investigation into the implementation of virtual reality technologies in support of conceptual design. Des. Stud. **27**(1), 77–97 (2006). https://doi.org/10.1016/j.destud.2005.06.002