ON HOW TO EMPOWER ARCHITECTURAL STUDENTS THROUGH THE USE OF IMMERSIVE TECHNOLOGIES

C. Lorenzo, E. Lorenzo

CEU University (SPAIN)

Abstract

Technologies considered immersive, Augmented Reality (AR) and Virtual Reality (VR) are the most likely candidates to head a new digital revolution. The worlds that open to interact virtually with objects, people and places to which we do not have physical access are a source of applications for the scientific field, business, medicine and also architecture. In fact, the teaching of architecture offers a favourable space for the introduction of immersive technologies and novel methodologies that integrate digital paradigms. The traditional architectural learning methodologies present multiple approaches in common with what is understood as digital teaching, as for example, learning by doing, the approach to problems through trial and error, the emphasis on the creative and discovery aspects, or the conception of professors as a counsellors and facilitators rather than as mere transmitters of knowledge

Furthermore, learning Architecture using immersive technologies is becoming essential in the education of future architects, as they must learn new tools that will be required during their professional career that helps to promote a better understanding of architectural projects. This paper describes some project based learning approaches to teach Architecture at the Madrid-based CEU University's Digital Fabrication Laboratory (Fab Lab Madrid CEU), that raise students to use VR and AR technologies to explain their architectural projects and to analyse in depth buildings that they do not have access to or that are physically away from them. These technologies have also been used to teach how to use digital fabrication tools (3D printers, laser cutters, vinyl cutters and milling machines), that are needed to make architectural models that help students to visualize in 3D complex architectural projects.

Keywords: Virtual Reality, Augmented Reality, Architecture.

1 INTRODUCTION

Technologies considered immersive as Virtual Reality (VR), that involves getting immerse in a parallel environment and Augmented Reality (AR), which incorporates virtual entities to our reality, seem to be emerging with a great impact in many different fields, as scientific research, Business, Medicine, Education, Design and also Architecture. In fact, these technologies are the most likely candidates to head a new digital revolution in the next years, although nowadays they have not reached yet the critical mass of users that are needed to drive its exponential dissemination. According to some studies (Braud *et al*.) [1], there are some facts that are delaying the massive use of immersive technologies nowadays, as the fact that computers that allow generating and visualizing VR and AR content are still too expensive for the average user. There are also problems related to the lack of adaptation of the human body to immersive technologies, which leads many users to suffer dizziness when using them. Furthermore, more stable networks with greater bandwidth than current ones are needed to improve the experience in virtual worlds. All these trends are necessarily based on a network capacity much higher than currently available, as the fifth generation (5G) of wireless communications.

Besides all this, researches (Klimova *et al*.) [2] exist on the fact that immersive technologies are growing stronger, although the teaching competence and exchange of good practices in education are still very fragmented and there is a lack of literature that primarily concentrates on teaching aspects of AR and VR. According to this study, understanding learning methods, learning objectives, assessment criteria, and required knowledge, skills, and competences in the field of immersive technologies will help to suggest trends, perspectives and the opportunities for further development of innovative programs. Despite of all this facts, Englund *et al*. [3] affirm that teaching with immersive technologies is central for the successful implementation of educational technologies, especially in higher education. Furthermore, according Cipresso *et al*. [4], Augmented Reality, which is a more recent technology than Virtual Reality, shows an interdisciplinary application framework; in

which, nowadays, education and learning seem to be the most field of research. Indeed, Augmented Reality allows supporting learning in many different ways, for example, increasing-on content understanding, memory preservation and learning motivation.

Regarding the application of Virtual Reality in Architectural Design, it is worth to mention the research conducted by Song et al. [5] that proposes an interactive system based on Virtual Reality technologies to provide users a close-real experience in the development of open-architecture products using immersive technologies. The system provides an interface through which users can review a product design by virtually operating and evaluating it. Milovanovic *et al*. [6] provided an overview of applications of VR and AR in the field of Architectural Design, affirming that although a high diversity of devices and systems have been developed in laboratories, in real practice, there are still few studios or firms benefiting from those technologies. Nevertheless, user studies showed the potentials of Virtual and Augmented Reality applications in term of ideation, collaborative design, building management and design education. Lütjens *et al*. [7] investigated advantages, limitations, and possible applications for immersive and intuitive 3D terrain visualizations in VR developing a workflow to present large scale terrain datasets in Virtual Reality, where terrain textures could also be altered and measurements conducted to receive necessary information for further terrain analysis.

In relation to the application of Augmented Reality in Architectural and Urban Design, Lin *et al.* [8] proposes an integrated system with a special focus in architecture students, in which 3D modeling, procedural modeling and VR platform are integrated, aiming to support architectural design education. Lahoz [9] highlighted that Augmented Reality technologies reached mass consumption when the Augmented Reality mobile game Pokémon Go became a mass phenomenon without an unprecedented success. From the point of view of the Urban Design, this turned out to be very interesting because thanks to it, once again, playing on the street, in the urban public spaces of the city was encouraged through the AR game. Lahoz emphasized the fact that initiatives as Pokémon Go were part of a broader trend in which digital technologies were helping to reintroduce ludic practices in public spaces through new augmented reality technologies.

2 METHODOLOGY

Nowadays, empowering architectural students through the use of immersive technologies is becoming essential in the education of architects, as they must learn new tools that will be required during their future professional career that helps to promote a better understanding of architectural projects. Furthermore, the traditional architectural learning methodologies present multiple approaches in common with what is understood as digital teaching, as for example, experiential learning, trial and error approaches, emphasis on the creative and discovery aspects or the conception of professors as a counselors and facilitators rather than as mere transmitters of knowledge.

Taking advantage of immersive technologies and innovative pedagogical approaches, the Madrid-based CEU University's Digital Fabrication Laboratory (Fab Lab Madrid CEU) [10] is implementing the use of Augmented and Virtual Reality in architecture and design courses. This paper describes two cases studies to show project based learning approaches and immersive technologies to teach Architecture and Design. During these courses, students were encouraged to present architectural projects using Virtual Reality technologies, as well as to analyze in depth buildings that they do not have access to or that are physically away from them. Augmented Reality was also used to teach students on how to use remotely digital fabrication technologies (3D printers, laser and vinyl cutters, and CNC machines), that are used to make design products following the criteria of Universal Design.

2.1 Virtual Reality Technologies

One of the greatest challenges faced by architectural students is working to improve their design during the classes, receiving valuable feedback from professors and classmates that can be integrated into the finished design. During architectural design courses, through critical sessions and workshops, multiple people are asked for their input on diverse aspects of the architectural project's design. Sometimes, plans, elevations, sections and views (including 3D renderings) are not enough to effectively communicate ideas and Virtual Reality technologies can be helpful to involve students into a fully interactive 3D environment, allowing them to visualize, analyse and explore a virtual representation of a particular space, floor plan or architectural design as a whole. Furthermore, VR technologies could also impact in architectural student's workflow, because they allow students fully interaction with an architectural model moving around the architectural spaces and interacting with

different architectural elements as structure, construction and mechanical facilities, allowing the comparison between the architectural project and the finished architectural design.

The first case study presented in this paper describes a project based learning approach to integrate Virtual Reality technologies in architectural courses of the Advance Diploma of Digital Fabrication in Architectural Design taught at the Madrid-based CEU University's Digital Fabrication Laboratory (Fab Lab Madrid CEU). In order to do so, new classes have been implemented in one of the modules: Building Information Modelling.

Building Information Modeling (BIM) is a new work environment supported by various tools and technologies that allows three-dimensional modeling for architectural design. BIM not only facilitates three-dimensional modeling and renderings in realistic environments in a simple way, but it is a very powerful tool for managing the architectural project that substantially reduces errors in the documentation by implementing the planning of the entire project process, from the design to the maintenance of the building once finished.

Regarding the integration of BIM with virtual reality, it is worth to mention a study [11] that reports the improvement of BIM uses with the addition of interactive capacities allowed by Virtual Reality technology. The bibliographic and software research that was made to support this study confirms that the fundamental base of BIM combined with VR improves the presentation of architectural design projects as a first step, and that the possibility of consult data while walking through the building improves the use of BIM in design, construction, maintenance and management.

Among all the tools available right now the classes involved both, non-immersive experience VR content through the desktop, and also immersive experience VR by using head-mounted displays (HMD) that allowed students to be immersed in the 3D architectural model. During the class, student's smartphone devices were used along with the virtual reality applications that were easily downloaded and installed onto their phones. The latest smartphones are powerful enough to support high resolution images, and thanks to the accelerometers, they detect movement as students navigate through the virtual environment.

Three activities were carried out during the classes. First of all, VR glasses were used to visualize and experience a 360° panorama picture that was prepared by students in Revit, the Building Information Modeling software used during the course. To do so, students used the 'Render to cloud' tool, selecting the option 'All views' before moving on to the 'Render gallery' to create the stereo panorama picture, that was preview in their mobile phones after scanning the QR code to visualize it using the VR glasses.

Figure 1. Students using VR head-mounted displays to navigate through a 360 º panorama picture of an architectural project previously generated in Revit.

The second activity involved the use of Enscape, a virtual reality and real-time rendering plugin for Revit that allowed students to walk through their fully rendered project. The aim of the use of this plugin was to give students the option to evaluate possible changes of their architectural projects in Revit, which were immediately available to evaluate in Enscape. They were able to quickly explore different design options and present them in real time even in VR. Students also explored the option to create a standalone file of their architectural projects, so that they could send an Enscape file to their classmates and professors for quick visualizations. Finally, the third activity was focused on the use of Lumion, a visualization software for architects that allowed students to quickly turn their designs into videos, images and online 360º presentations. Thanks to it, it was possible for them to add environment, materials, lighting, foliage and compelling effects to create impressive visualizations after using a free Revit plugin to export directly to Lumion their Revit models.

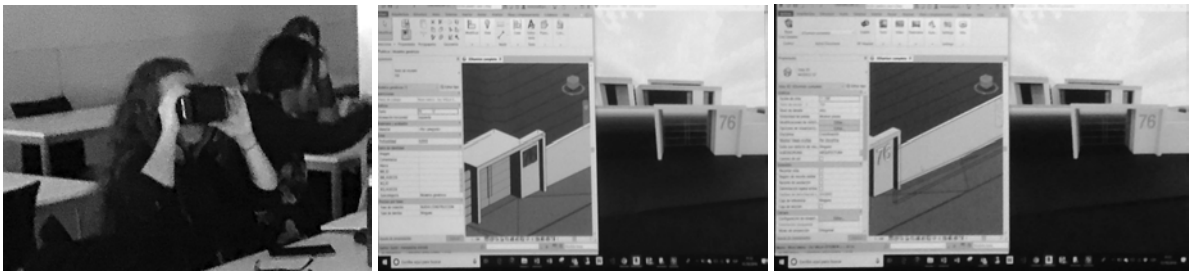

Figure 2. Virtual Reality and real-time rendering plugin to evaluate possible changes of students' architectural projects in real time.

2.2 Augmented Reality Technologies

Augmented Reality Technologies have been used as a support tool to teach Universal Design (UD). The course aimed to improve research and practice in Universal Design putting universal design methods into practice. To that end, fifteen students between eighteen and thirty years old enrolled in the Advance Diploma of Universal Design taught at the Institute of Technology at CEU University were requested to design small merchandising products according to the precepts of Universal Design. These precepts are related to promote easy user hand manipulation of products designed for low physical effort. They were trained on the use of Rhinoceros and Ultimaker Cura to create and prepare 3D designs to be 3D printed. After that, they learned how to remotely use the Fab Lab machines (3D printers) to fabricate their products without the need of being physically in the Fab Lab. They learned how 3D printers work thanks to Augmented Reality applications and then, how to remotely monitor the 3D printers through the Cloud Hub app, [12] an application designed by CEU University for the NEWTON project [13, 14] that allow students remote access to Fab Lab facilities in order to fabricate the products previously designed.

Augmented reality was used as an assistive tool to provide a deeper understanding on the 3D printer procedures. It is worth to mention that students did not have any experience in the use of 3D printers. Moreover, they did not even know how a 3D printer works, as well as their components or materials needed. Therefore, it was absolutely necessary to show students 3D printers in operation allowing them the possibility to interact with them for a clearer and more precise understanding.

In order to do so, two applications were used as new mediums for immersive learning, the School Fab Lab app and the SFL AR app, [15] both created by Nader Shaterian and Simone Amber, founders of Fab Lab Connect. Fab Lab Connect is a platform that brings resources to technology innovators from the digital Fab Lab community to scale up their solutions for social change. It is part of a movement initiated at the Massachusetts Institute of Technology (MIT) to address global issues and locally fabricate solutions. [16, 17] Both apps, offered access to learning for students who never have had access to Fab Lab machines, so they could experience technologies in a virtual way. Students experimented with placing 3D printer machines in the classroom and saw them function in a customized space. Thanks to it, it was possible to bring realistically scaled Fab Lab machines into a conventional classroom, set multiple machines in the space to design and create a virtual Fab Lab layout and finally, operate 3D printers in augmented reality to learn about the digital fabrication process and capabilities of each machine.

Figure 3. Students using SFL AR and School Fab Lab Augmented Reality applications to operate 3D printers and vinyl cutter machines.

The aim of the use of SFL AR and School Fab Lab Augmented Reality applications was to bring realistically scaled Fab Lab machines into other space in need of Fab Lab machines for educational purposes, in order to teach how digital fabrication machines work. Augmented Reality technologies allowed students setting multiple machines in a space to design and finalize a layout, operate machines in mixed reality to learn about the digital fabrication process and capabilities of each machine and take video walkthroughs of the space and record the machines in operation.

3 RESULTS

This paper addresses the application of Virtual Reality and Augmented Reality as new educational tools, implemented during architecture and design courses to get students more deeply immersed in their computer based architectural models and to use them as educational experiences not possible using other methods. The paper provides an overview of some devices, systems and applications of VR and AR that have been used during architecture and design classes to analyse the potentials of immerse technologies in terms of collaborative architectural design using Virtual Reality, and design education using Augmented Reality.

Results of using Virtual Reality during the class show that this technology seems to be efficient to enhance the quality of student's presentation of their architectural designs. The immersion in the virtual model of students, tutors and classmates during critique reviews augmented their spatial comprehension and improved the design evaluation and feedback from tutors and colleagues. During the critique session, students showed their design navigating in the scene to support their ideas, allowing tutors and classmates to be immersed in the architectural space and receiving background from all. The aim was to prove the potential of VR technologies to communicate, analyse and discuss an architectural project encouraging students to address local collaborative design activities in a pedagogic setting. As design is a collaborative process, the VR tool enhanced the presentation of the ideas and allowed all participants to freely explore and interact with the model in order to analyse and critique. However, we have also discovered certain weaknesses, as for example the fact that all participants were wearing virtual reality glasses made the communication among them difficult during the presentation. In order to solve this lack, after the visualization of the model in VR, students and tutors discuss the experience and propose improvements using also the technical documentation printed out in paper (sections, plans and elevations). VR was used as a new tool to add to the conventional material used during critique sessions, and not as a substitute for other materials commonly used during the classes.

Regarding the use of Augmented Reality, results show that it is useful as a tool that allow design students to learn how to monitor 3D printer machines remotely, as this technology is a good medium for free explorations learning by observational experience. It also allowed to pull students inside the simulation and made them active participants, as they were responsible to monitor the machines. The 3D virtual objects created by the virtual 3D printed were also useful to show students the relationships of the mathematical concepts they used to design the products in a computer based software with the physical appearance of the virtual 3D printed products. It also allowed students to produce different objects and easily visualize them in order to compare and contrast the benefits of each one, getting background from the rest of students and tutors. Finally, results show the usefulness of this technology to learn skills that are difficult to learn by studying and need practice, such as monitor safely 3D printer machines of a digital fabrication laboratory by students with no previous experience.

4 CONCLUSIONS

It is difficult to imagine a future Architecture that is not sustained in one way or another in the new technologies of a digital world in full expansion. Staying ahead of the technological advances won´t help students, who will have to deal with new technologies in their future career. It seems that the use of immerse technologies will become an integral part in the education of future architects, not just of presenting a project, but of the design process as well. The present paper shows that these technologies could have a great potential for architectural students, from initial design mock-ups to architectural design project presentations. They seem to be also useful as educational experiences, not possible using other methods. The project is still on-going, but results are promising and it seems that offering students training on Virtual Reality and Augmented Reality technologies offer them the possibility to face this great challenge.

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