Using Virtual Reality to Improve Visual Recognition Skills of First Year Architecture Students: A Comparative Study

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Abstract: The use of virtual reality (VR) technologies is getting widespread throughout the world in the last years. Architecture as a prominent discipline in using digital technologies has a lot to promise about the use of VR in different areas of the profession. It can be used as a design or a representation instrument, as well as a tool in the construction processes. Accordingly, as architectural education needs to keep itself up-to-date about new technologies, the implementation of VR technologies into the architecture curriculum is supposed to be a subject to be studied by researchers working in the educational domain of architecture. This paper presents a comparative study on the use of VR technologies in the first year of architectural education to improve the visual and spatial recognition skills of students. The findings of the study indicate that VR technologies can be beneficial in various aspects like the perception of certain physical characteristics of a model, and students' enthusiasm to participate in the design studio courses.

1 INTRODUCTION

The strong relationship between technology and society is an undeniable truth nowadays. Technology has become a major force that transforms and adds new dimensions to people's lives (Dugger Jr., 1993). 20th century has been the era of digitalization where the knowledge of humanity was transferred to digital devices and the 21st century is being the era of digital communication as every entity is connected to others through a global web of networks. Digital technology has entered most things in everyday life and it increasingly determines the activity of people (Rückriem, 2009). Computers, phones, other smart devices, even household tools that are connected to the internet transform society into a massive organism that depends on technology for its improvement. Children of the last decade who are born into such a society are significantly talented in using those technological devices, and in that way, they contribute to the broader and further development of digital technologies throughout the whole world.

However, the reflections of technological improvements in society are not emphasized enough in the fields of education and teaching. Technology has had very little effect on our conceptions of teaching and learning (Schank, 2007). The reasons for this situation may be varying from the conservative approach of the educators to the phlegmatic structure of education policies, but its results are mostly seen in struggling curricula that try to keep up with the emerging needs of the society but are bound to conventional approaches in education. Bates and Poole (2003) argue that it does not make sense to use technology unless it makes a difference in learning and teaching.

In higher education, especially in disciplines where the connection between the practice and academy is strong, the mechanism for the digitalization of educational content works slightly faster. Emerging developments in technology briskly become a part of vocational education through some exercises and implementations. In architectural education, emerging technologies like automation in construction, building information modelling (BIM) and artificial intelligence have already started to become a part of the curriculum. Various researchers and educators have begun to address the need to integrate digital design in architectural design education (Oxman, 2008). Among the different ways to integrate digital technologies into architectural education are computer augmented design studio,

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CAD-plus studio, virtual and web design studio, cyberspace design studio, intelligent building studio, and toys and tools studio (Do & Gross, 1999). Virtual reality (VR) and augmented reality (AR) are other emerging technologies that are started to be employed in architectural design and representation processes and they already started to find a place in education as well. However, they mostly serve as representational tools rather than design instruments, and they are utilized in the advanced phases of the education instead of first years. This paper presents a case study that questions the use of virtual reality technologies in the first year of architectural education as a supportive tool to improve students' visual and spatial recognition skills.

1.1 Aim of the Study

This study aims to examine the benefits of the use of VR technologies in the first year of architectural education by comparing them with different representational techniques in architecture such as physical and digital models. It is assumed that VR technologies' use in education is beneficial from various aspects such as visual recognition and student motivation. The first year of architectural education is the period when the spatial and visual recognition skills of students start to develop. Any tool that can be useful to support this development needs to be integrated into the education process to get better outcomes. VR as an emerging technology can easily be adapted to the first year of architectural education by forming several exercises for students.

Another aim of the study is to examine several representational methods to find out the advantages and disadvantages they provide for the students with their spatial and visual recognition processes. Physical scaled models, digital models and virtual models have their unique characters and features, enabling certain perception skills to be activated in the human brain. The case study aims to reveal those features to formulate a structure for future exercises in the first years of architectural education.

1.2 Research Questions

Through this research, it can be determined if and how the use of VR technologies contribute to primary levels of architectural education. To find out in what extents it contributes and how it performs compared to other methods of representation, the following research questions are asked:

RQ1: How are different representational methods in architecture compared with each other in terms of spatial and visual recognition of first-year students?
RQ2: To what extent and how does the use of VR technologies contribute to the spatial recognition of first-year architecture students?
RQ3: Is the use of computer-aided tools necessary and beneficial for first architecture students?

1.3 Methodology

The methodology used in this study is based on an exercise and a survey of first-year architecture students. Following a literature review on architectural education, VR technologies and their use in architectural education; the exercise and survey in the scope of the paper reveal the interrelationship between different representational techniques from certain aspects. The outcomes of the survey are analysed and the results are interpreted according to the needs of architecture education for first-year students. The findings of the case study are used to formulate statements in the concluding remarks and how the outcomes of the paper can be used for further studies.

2 ARCHITECTURAL EDUCATION AND DIGITAL TECHNOLOGIES

Architecture is a practice that has strong connections with other disciplines. Its vocational nature makes it also strongly related to developments in society and technology. Especially in the 21st century, technology is influencing architecture more than ever. In this era, the use of computers and other technologies in design is inevitable (Özgen et al., 2019). Thanks to technology, design became a prescriptive activity, in which models and drawings are used to foresee reality, and in which everything must be resolved before the construction process (Celani, 2012). The reflections of technology can be seen in various phases of the architecture practice such as design, representation, construction, and education.

Education is a powerful agent of social change for it raises awareness of new developments and provides training for professionals and researchers who will develop the next generation of systems and devices (Taleghani et al., 2011). Architectural education as the foundation of the profession is responsible for equipping young architects with proper tools to tackle emerging problems of society. Therefore, it needs to keep itself up-to-date and ready for upcoming challenges.

The architectural curriculum is composed of fundamental courses that develop design knowledge; courses that develop the scientific formation of architecture; courses for strengthening architectural representation; and design courses, a combination of the others and constitute the most crucial part of design education (Demirbaş & Demirkan, 2003).In the first year of the curriculum, the foundation for all the domains of knowledge is laid. In this phase, visual perception and visual language are introduced as the roots of design education (Wong, 1993). In that period, digital technologies in architecture can be potentially seen in the design and representation domains of the curriculum. However, in the current understanding of architectural education, the use of digital technologies is either completely restricted or very limited in the first year. The following chapters are about the current and potential use of digital technologies in two different domains of architectural education.

2.1 Design Domain

The design domain of first-year architectural education mostly consists of basic design or similar introductory courses. The roots of basic design course reach out to Bauhaus school where elements of design, fine arts, technology, and craftsmanship were brought together. Basic design education aims to raise awareness and provide visual sensitivity in transferring an image onto the design field (Akbulut, 2010). Design education itself has not kept up with the changes in technology and many cases do not enhance students' learning and knowledge-building skills beyond predetermined, standardized boundaries (Demirkan, 2016). Currently, in basic design courses, the use of digital technologies is mostly limited to the layout and poster presentation tools. The use of computer-aided design tools in basic design courses is only seen in a small portion of the architectural institutions.

Emerging digital technologies make it possible that digital tools can be used to support the design process in first-year architectural education by providing additional media for design activities. Important issues of design like visual perception, spatial recognition and problem-solving can be strengthened with the use of digital technologies. Current hardware and software provide solutions to easily implement digital tools into the first phases of architectural education.

2.2 Representation Domain

The representation domain of architectural education goes hand in hand with the design domain all through the course of the curriculum. Spatial information is represented in many ways, ranging from traditional methods, such as printed plans and physical models, to modern methods, such as digitally printed plans and tri-dimensional models, which allow a greater level of detail and the ability to navigate and actualize potential changes instantaneously (Fonseca et al., 2014). In the first year of education, it is more about forming a visual language to communicate with the viewer graphically. For first-year students, exercises on representation like parallel projection and different types of perspectives are quite challenging as they have no experience with the problem. Additionally, transforming a three-dimensional entity into a two-dimensional drawing on the paper is a novel form of abstraction for novice designers. New media and its forms of representation are challenging traditional skills of communication and representation (Reffat, 2007).

In their first year of training, architecture students search for concrete elements rather than abstract things around themselves. Digital technologies can aid students with the understanding of space and mass by providing a clear dynamic and interactive medium for recognition of the given subjects. While the forms of representing architectural designs (i.e. plans and sections) are remaining the same, the possible means towards these ends are increasing (Ivarsson, 2010). Computer-aided design and drafting technologies are at a very advanced level so that they can be used for alternative methods for training architecture students about ways of understanding the space and objects around them. 3D Modellers, 3D Scanners, immersive Virtual Environment, and Rapid Prototyping are used to assist both students and teachers to explore and study architectural creativity in a new way that enables a deeper involvement into design-issues (Mark et al., 2001). Consequently, emerging digital technologies in design hold great potential for the contribution to the representation domain of architectural education for first-year students.

3 VIRTUAL REALITY TECHNOLOGIES

Technological developments are equipping the world with new and useful instruments. One of the most recent instruments digital technologies provide for the use of humankind is the understanding of alternative realities. Different types of alternative realities such as Virtual Reality, Augmented Reality or Mixed Reality are changing the way people understand their environment. Portman et al. (2015) define virtual reality as *the component of communication, which takes place in a computer-generated synthetic space and embeds humans as an integral part of the system.* It is being used in architecture among many other fields like engineering, medicine, and gaming. The following chapters summarize the history of VR technologies, followed by their use in architecture and architectural education.

3.1 History of VR Technologies

Even though virtual reality is considered a recent technology, its roots can be followed back to the first half of the 20th century. Since the book *Pygmalion's Spectacles* by Stanley Weinbaum (1935), attempts to bring virtual reality together with daily life and different fields of studies continued. Virtual reality technologies were tried to be implemented into the daily life through devices like CAVEs (Cave Automatic Virtual Environment) and HMDs (Head-mounted Display) like the "Sword of Damocles", "Sensorama", "Sega VR", etc. (Maghool et al., 2018). Nowadays, the most widespread use of virtual reality is seen in the gaming and entertainment industries. Nevertheless, the technology of VR is developing in many domains, and architecture is one of those.

3.2 VR in Architecture

Thanks to the rapid growth of software and hardware in the field, the use of VR in architecture is getting more common every day. Its immersive technology aids the user to experience the designed product in an interactive virtual environment on 1:1 scale. Information technology is developing powerful capabilities for creating virtual contexts to be used in the field of architecture (Dede, 2000). Accordingly, numerous academic studies in the last decades address virtual reality technologies and their relationship with architecture (Witmer & Singer, 1998; Jackson & Fagan, 2000; Schnabel & Kwan, 2003; Seichter, 2007; Angulo, 2013; Häkkila et al., 2018). These and other similar studies indicate the strong influence of VR technologies on architecture.

The use of VR in architecture may vary between different phases like drafting, representation or even construction. Although it is most useful with representational purposes nowadays, the future holds great potential in terms of using VR technology in the beginning phases of design. Setting the users free from conventional architectural communication techniques like plans, sections or physical scaled models, VR technology's area of use is getting wider in architecture and connected professions, e.g. real estate where the customer can experience a property in a distant location in the VR environment before making a decision. VR in architecture has many benefits that are described as:

- *The visualization of building model;*
- *Representation of multi-dimension design space*
- *Providing real-time interactions*
- *Providing multi-user real-time collaboration for problem solutions* (Ding et al.,2003).

These kinds of benefits potentially provide a great contribution to architecture so that VR needs to be successfully integrated into the professional, as well as to the educational environment of the discipline. Educational benefits of the use of VR can touch upon many points in different phases of the curriculum.

3.3 VR in Architectural Education

The process of architectural education has always been directly influenced by the technological advancements in computer-aided drafting and design tools, enabling young architects to easily control, manage, study, visualize and evaluate their designs (Hosny & Kader, 2004). Utilization of technological tools like artificial intelligence, rapid prototyping, additive manufacturing, automation in construction and virtual reality are some of the most predominant teaching approaches in the contemporary world of education.

Virtual reality provides a suitable medium for architectural education with its immersive environment. Kalisperis et al. (2002) argue that using VR in design studios would boost architectural design education for students because of its contribution to spatial recognition and the 3-dimensional way of thinking. This contribution is especially valuable for students in their first year of architectural education to develop their design and understanding skills. The strong relationship between architectural education and the use of VR technologies are indicated by recent studies. Abu Alatta and Freewan (2017) studied the effect of employing immersive virtual environment on enhancing spatial perception within design process. Lin and Hsu (2017) developed strategies for integrating procedural modelling process and immersive VR environment for architectural design education. Other researchers also worked on the connection between VR technologies and architectural education (Camba et al., 2017; Tsou et al., 2017; Valls et al., 2016). De Vasconselos et al. (2018) state that the implications and applications of the possibilities of VR use for architecture education are obvious but still require quite an investigation. Accordingly, educators and researchers in the field of architecture must study the potentials of using VR technologies in architectural education, especially in its first year.

4 THE CASE STUDY

The use of VR technologies in architectural education is getting widespread, but it is usually seen in advanced phases of the curriculum. The use of digital tools including VR technologies is generally restricted in the first years. The reasons for that are mostly based on the intention to develop students' hand-drawing skills and improve their imagination without limits caused by any setback. It is a fact that the relationship between the brain and the hand, consequently the relationship between the imaginative and physical world is very strong and needs to be set free. However, it is also true that any contribution from external resources that support the development of students' design skills is valuable. According to Zelanski and Fisher (1996), recognition of visual sophistication is the elementary aim of basic design education. Therefore, a case study was conducted to find out whether virtual reality as an emerging technology and a potential supportive tool for design education can contribute to the improvement of visual and spatial recognition skills of first-year architecture students.

4.1 The Design of the Case Study

The study aims to find out what kind of contribution virtual reality technologies can make to the first year of architectural education. For that purpose, a comparative case study is prepared. 36 first-year architecture students are split randomly into three groups and they were expected to participate in an exercise through different representational techniques:

A- Physical scaled model
B- Digital model
C- Virtual model

All three models have similar characters: Surfaces and spaces consisting of square-based units with different colours. The reason to select square as the base unit derives from the fact that first-year students are already familiar with the shape and they have conducted some exercises with similar approaches at the beginning of the semester.

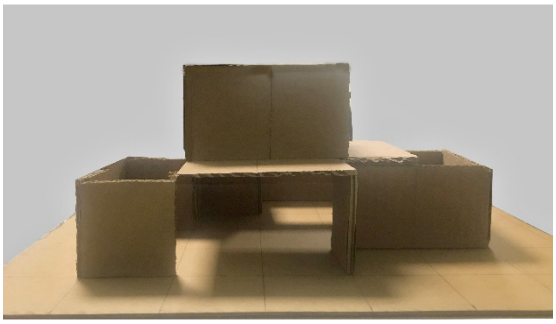

Figure 1: Sample picture of the physical model that the students worked with (source: author).

The first group of the students was given a 1/50 scaled model to inspect and evaluate (see fig. 1), as the second group was shown a digital model prepared in a 3d modelling software (see fig. 2), and the third group was invited to inspect another model in virtual reality environment (see fig. 3). Since the first-year students were not familiar with digital tools used in design and representation processes, the second and third groups of students were given short instructions about the digital and virtual software used to prepare the models before using them.

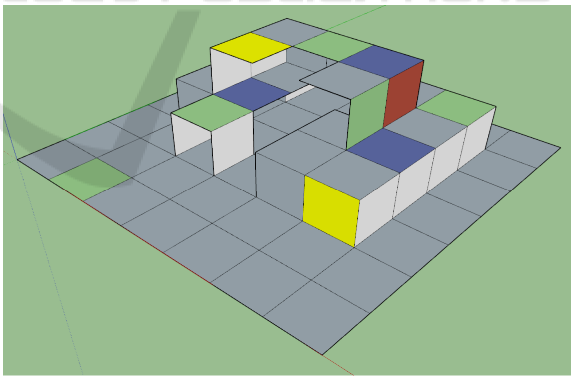

Figure 2: Rendering of the digital model that the students worked with (source: author).

The survey was categorized into 4 parts:

1- The dimensions: Length, width, height, total used area
2- Physical appearance: Solid or transparent surfaces, light and dark areas, and colours of the model.
3- Open-ended questions: Describing the model

4- Opinion question: The use of digital and virtual technologies in first-year architectural education.

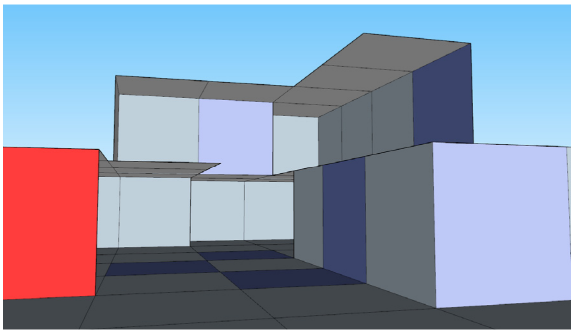

Figure 3: Screenshot from the virtual model that the students worked with (source: author).

4 categories had a total of 9 questions and all students answered them to provide input data for the study. The following data came up as the answers of the students who attended the survey.

4.2 Ethical Concerns

All students participating in the research were informed about its contents before the process started. They were asked to sign an information sheet that explains the purposes of the study and explained participants' involvement, risks they take and emergency procedures. Participants were also informed that the process was confidential and their names were not going to be revealed in the research process. Additionally, they were told that they had the right to quit participating in the research at any time.

4.3 Data Analysis

The assessment for the first and second categories of the survey is based on the percentile proximity of the students' answers to the correct values for the given questions. In the third category, a qualitative analysis has been made according to the statements of the students. Finally, the fourth category remarks students' preferences on the usefulness of various representation techniques in the first year of architectural education.

The first part of the survey was about the students' perception of dimensions in the given models. In this part, their prediction about the length, width, and height of the models, as well as their total area was requested. In the physical scaled model, students' percentile proximity rate for length was 84%, width 77% and height 78%. The proximity for the total area of the model the result was 81%. For the digital model, the results were; length 77%, width 69% and height 74%. The result of the total area was 74%. For the virtual model, the results were 71%, 66%, 70% for dimensions and 75% for the total area (see fig. 4).

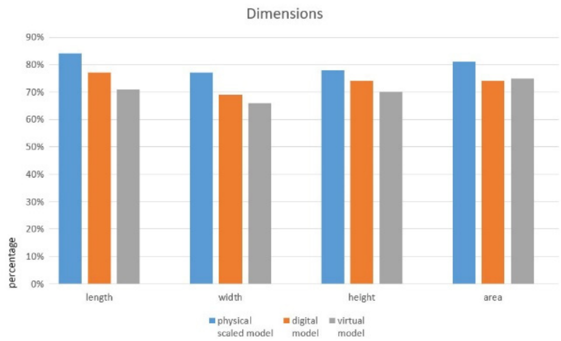

Figure 4: The results for the four questions in the first part of the survey (source: author).

The second part of the survey was about the visual and spatial recognition of the students. The first question in this part was about the solid/void balance of the given models. The result for the physical model in this question was 68%, for the digital model it was 59% and for virtual model 78%. The second question in this part was about the balance between the light and dark volumes in the models where the result for the physical model was 71%. The digital model result for the question was 61% and the virtual model result was 84%. The third question in this part was about the colours used in the models and the results for physical, digital and virtual models were as follows in order of appearance: 86%, 73% and 81% (see fig. 5).

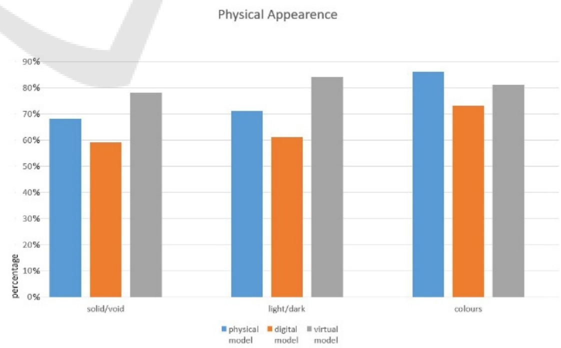

Figure 5: The results for the three questions in the second part of the survey (source: author).

The third part of the survey consisted of open-ended questions and data was analysed according to the detail level and type of written communication in the answers of the students. The first question in this part was to describe the given model and the students who described the physical model used an average of 8.6 words for the answer, mostly using keywords instead of complete sentences. The students who described the digital model used 6.4 words on average and they also used keywords to describe the model they have seen. The results of the virtual model were 16.6 words per student on average and most students, 8 out of 12, preferred to use complete sentences instead of keywords.

The fourth part of the survey was an opinion question regarding the priorities of the use of different representational techniques in the first year of architectural education. 17 students stated that the most important technique was physical model, as 11 out of 17 saw virtual models as a secondary technique to be useful. 10 students define virtual models as prior technique and 9 out of those 10 place physical models into the second position. 8 students see digital models as the primary method to be used in the first year of architectural education where 5 of them put virtual models after the digital models in terms of usefulness (see fig. 6).

Figure 6: The results for the opinion questions in the fourth part of the survey (source: author).

4.4 Outcomes of the Study

Data gathered from the survey provides important information about students' perception of space and how virtual and digital models contribute to their visual recognition.

The first part of the survey revealed that the dimensions in space are best perceived through a physical scaled model. Digital and virtual models appear to be less useful in terms of the perception of dimensions of a space. The most evident reason for it is that first-year students started to work with physical models since the first day of their education as digital and virtual models are something recent for them. Results of the virtual model were the lowest in the first part, as students observed the model only from the human eye level and from within the space instead of a higher level and distant view to perceive it as a whole mass.

In the second part of the survey, results about the virtual model came into prominence with the best scores about the recognition of solid/void surfaces and light/dark spaces. Being in the human eye level and perceiving the space from within served the purpose of sensing the space this time. The immersive feeling of being in the space was probably another reason for these high scores. In the physical model, students received the second-best average, as in the digital model the results were lowest in the second part of the survey. In terms of colour recognition, the results for all three representational techniques were quite high so that it was not possible to form a statement as a comparison between them. In response to research question 2, it is possible to claim that VR technologies contribute to the spatial visual recognition of students in terms of the physical appearance of the space.

Figure 7: A participating student working in the virtual reality environment (source: author).

The most significant part of the survey was the third part, the open-ended questions, where the students were asked to write about their impressions about what they see in the models. In physical and digital models, students used fewer words for the description and keywords rather than complete sentences, exemplified by statements such as *open/closed space, no columns, colourful,* and *two-floor high*. However, the students who have experienced the virtual reality environment used more words on average and described their experience with more details about the space and their perception about it. One student quoted: "*When you enter the space, you become curious about what you will see around the corner.*" Another student mentioned her excitement about being a part of the space in full scale, as one other said "*You can easily understand the difference between being in a closed or open space, having a plane or the sky over your head.*" This is a sign that shows the use of new technologies can be used to increase the interest level and enthusiasm of the students about a given subject. The excitement of experiencing something novel has potentially a positive effect on the students' attitude against the subject.

In the fourth part of the survey, the opinion question, students remarked their preference about the priority of the given representational techniques. Most of them stuck to their habits and chose physical models as the primary representation technique to be used in education. However, virtual reality technologies also had significant attention from many students to reveal it as a beneficial medium for their training. Digital technologies did receive the least attention even though it is going to be the medium they will consult most frequently in the following years of their education.

Summarizing the outcomes of the case study, one can assert that every different representational method in architecture contributes to the training of first-year students in terms of spatial and visual recognition from different aspects (RQ1). VR technologies contribute to spatial recognition, especially in terms of physical appearance (RQ2). Moreover, it can be stated that the use of computer-aided tools is beneficial for first architecture students, however, the primary instrument for the representation of ideas is still the physical model for first-year students because of its ease of use and economic and practical feasibility (RQ3).

5 CONCLUSIONS

The primary purpose of this study was to determine whether the use of virtual reality technologies in visualizing models contribute to the visual recognition of first-year architecture students. The results are in line with the assumptions in the beginning that they do contribute in various aspects, but they also showed some weaknesses of VR models, especially in terms of recognizing the model as a whole object. The level of interaction between the students and the model in the 1:1 scale provided several advantages in spatial and visual recognition, reflected on the perception of solid and void surfaces, as well as light and dark spaces of the model.

Another positive aspect of using VR technologies in the first year of architectural education is based on the students' motivation. Students embrace new technologies like VR because they find it interesting, fun, pleasing and engaging in comparison to conventional methods. Enthusiasm and openness to innovations are important factors in learning, and its reflections are possible to be seen in the academic success of the students. The relationship between the academic successes of first-year students and the use of virtual reality in architectural education is another potential subject for further studies.

Digital technologies have been promoted as the almost magical agent of change for nearly all educational settings, including university schools for professionals such as architects (Wang, 2009). Accordingly, prospects provided by virtual reality technologies are quite a lot. As an improving technology, it can aid architects and architectural students in many different ways in terms of design, representation, and construction. However, an important fact about the use of VR technologies in the training of novice architects nowadays is that they should be utilized as an alternative tool and one of the different options rather than the only instrument. It is evident that VR models have setbacks and physical scaled models are still one of the most beneficial tools in terms of representing ideas.

Design studios, especially in the first year of architectural education require collaboration between the students, as well as the interaction of the students with their instructors. Regarding this, the most prominent setback of the VR technologies today appears to be the economic challenge. Although it is obvious that VR tools, just like other digital technologies are developing rapidly and are going to be economically much more accessible in the future, the current situation appears to be a challenge for them to spread out throughout the world. Physical scaled models are, and probably shortly will still be, the main representational tool in architectural education.

Speaking of the use of VR technologies getting widespread, it is also important to consider the training of the trainers. Academic institutions are the places where any innovation in technology finds its field of utilization for further development. Members of the academic institutions in architecture are supposed to show interest in the field of VR technologies to improve its use in terms of technologic advancement and knowledge transfer to young professionals who are going to be the future users of these technologies.

Consequently, the use of VR technologies in first-year architecture education proves itself beneficial. They provide undeniable benefits in terms of visual and spatial recognition, as well as student motivation and enthusiasm. However, conventional methods like sketching and physical scaled models should not be abandoned as they are still the main medium of representation in architecture. Further studies need to be conducted to come up with strategies about the implementation of VR technologies into different phases of architectural education.

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