Souphanouvong University Journal of Multidisciplinary Research and Development
2024, Vol.9. No. 1, 149-159
https://doi.org/10.69692/SUJMRD0901149

Design of Virtual Reality System for 3D Visualization and Interaction

Kalaphath Kounlaxay[1*], Vialakone Manyvanh[1], Sommany Pathoumxay [2], Sinlapaxay Sengdala[3], Kim Soo Kyun[4]

Department of Computer Engineering, Faculty of Engineering, Souphanouvong University, Lao PDR

[1*]***Correspondence:*** *Kalaphath Kounlaxay, Department of Computer Engineering, Faculty of Engineering, Souphanouvong University, Laos, 020 55672266, kk_koun@hotmail.com*
[2]*Department of Architecture, Faculty of Architecture, Souphanouvong University, Laos*
[3]*Information and Technology Center, Souphanouvong University, Laos*
[4]*Department of Computer Engineering, Faculty of Engineering, Jeju National University, Republic of Korea*

Article Info:
Submitted: Nov 03, 2022
Revised: Feb 11, 2023
Accepted: Feb 27, 2023

Abstract

Nowadays, a virtual environment or metaverse environment is becoming more popular and can be used for various purposes. There are many computer games and more applications for them such as for training, learning and planning. Currently the presentations of 3-Dimensional (3D) models using mixed reality (MR) technology can be used to avoid misinterpretations of oral and 2-Dimensional (2D) model presentations. As an independent concept and MR applications, MR combines the best of virtual reality (VR) and augmented reality (AR). Therefore, this research aimed to present the descriptions of MR systems, which include its devices, applications, literature reviews and create 3D models that were then implemented in Unity 3D using VR applications for 3D architectural visualization. In addition, the assessment results of the VR application showed that the mean score of 2.85 and 3.45 (“neutral”) indicated that the VR application was a new one for the students and they had never used it before, but they certify that learning with VR is not as difficult as with other simulations. The mean scores of 4.55, 4.70, and 4.75 (“strongly agree”) indicated that the use of the VR application’s 3D objects in the scene was beautiful, clear, and realistic. Besides, the student also enjoyed the immersive experience and the learning was very interesting and they felt that they were in the real world.

Keywords: *Mixed Reality, Virtual Reality, Augmented Reality, Application, Oculus Rift*

1. Introduction

MR is the art and technology of merging the real and virtual worlds. It can create new scenes and visualizations so that physical and virtual objects can coexist and interact in real-time. The head-mounted MR device is able to present virtual 3D objects on a see-through display, enabling virtual world observation (Yilei, 2020), which depends on the concept mentioned in the reality-virtuality continuum as shown in Fig. 1., which can be used as an independent concept or used to distinguish the spectrum of reality technology (Milgram et al., 1994). MR not only overlays but also attaches virtual objects to actual-world objects and permits the user to interact with them together. As an independent concept, MR has combined the advantages of both VR and AR. When used to distinguish a wider range of reality technologies, it represents a range of all viable forms and elements of actual and virtual objects. MR may additionally be a solitary notion or used to refer to the whole spectrum of conditions between AR and VR while trying to mix the high-quality of each VR and AR. When each real and virtual world was combined, new environments and visualizations emerged as feasible places physical and virtual objects could cohabit and interact in real-time. MR wants to be better used in daily life, but it also has to overcome too many diverse peripherals and difficult technical coordination problems (Ting et al., 2017).

Figure 1. Mixed reality continuum

The MR spectrum covers all feasible types and elements of actual and virtual objects. Inside the spectrum starting from the far left is a natural world without computer generation. At the far right of the spectrum is a computer-created virtual environment (Carlos et al., 2019). VR seeks to grant customers the biggest stage of immersion probably complete immersion. VR can be defined as a simulation that gives the user a similar or different experience than the real world (Ninad et al., 2019). This deepened immersion is great from different reality technologies. Immersing in VR requires all the sensory stimulation of the user for the perfect experience as long as the brain accepts the virtual environment as the actual environment. In a VR environment, users living in a synthetic world may also or might no longer imitate the features of a real environment as shown in Fig. 2. In addition, some VR environments can be considered motivating factors as they provide individualized learning opportunities (Gurkan et al., 2018).

Figure 2. VR Applications [Hunter Library's VR work stations (WCU), 2021]

The VR design focuses on communicating the functionality of the virtual world, the control of that world with objects, and the connection between the users and the content that allows them to become a part of this virtual world or be immersed within its environment, as well as manipulate objects or operate a series of actions. Therefore, VR is a 3D computer simulation environment that uses devices to allow users to experience their existence in the environment. It causes feelings that can be perceived but do not exist in a virtual simulation scene. In a VR scene, users can experience real-world experiences in parallel and interact with 3D objects through the transition to an avatar, the digital avatars that work through a synthetic brain system. In addition to visual immersion, the perfect VR environment is notable for sound, touch, smell, and unique perception. The essential functions of VR are defined by three things: immersion, interaction, and imagination (Burdea and Coiffet, 2003). Another feature of VR is that it can enable immersion in a synthetic environment instead of viewing the environment from an outside perspective (Earnshaw, 2014). The immersive experience that takes place through VR depends on the potential of 3D images, head movement tracking, hand movement tracking, and stereo sound.

VR technology is mainly used to improve product development in the entertainment industry, such as games and movies. VR can also generate sensory experiences that consist of virtual flavors, images, smells, sounds and touches. VR technology uses VR environments built with computer software, while VR technology built with computer hardware provides the experience of having moved to another 'world', a virtual world. At the end of the set, these immersive devices have been developed with tracking tools and navigation devices that allow through simulation space, and head-mounted displays (HMDs) that enable the virtual world to be seen through the eyes of a person (Joshua, 2017). The HMD design is extremely important to the immersive nature of early VR. In addition to bringing the visuals closer, HMD also excluded the visuals of the actual world, creating insulated areas that the simulated world can play without being a reality. While the VR era has been used in the last decade by most game developers, educators and moviemakers no longer use HMDs, it is an alternative to flat-screen that is prevalent in front of users.

VR is an immersive experience with simulated environments that permits us to change the enclosed environment while cutting off most of it from the actual world. MR, in the continuous spectrum from VR to AR, is still an active pursuit. With the popularity of smart devices among the public, access to instructional content has become ubiquitous. For instance, Billinghurs (2012) reviewed and validated the use of an inexpensive device to furnish immersive VR experiences at some point in unique study scenarios. However, the information provided is still static and does not often offer to interact with users, which makes it very similar to a regular textbook. Although the prospect of pervasive computing remains an active research challenge (Santos et al., 2014), current trendy teaching methods do not integrate educational information with their scene.

VR has numerous advantages over other forms of education. In comparison to textbooks, videos, computer programs and video games, VR is more immersive, interactive and lifelike, respectively. It can be used as a one-to-many medium for lectures and practicum alike, and each experience is repeatable without using new resources, allowing every student to learn and grow. It places educational concepts in context and works in tandem with the imagination to expand possibilities for students from pre-school to Ph.D. Not only is VR more engaging, but it also improves long-term retention of information and simulated skills. Given the latest commercial applications of VR, it is not surprising that research on its use in classes has been limited (Potkonjak et al., 2016). There is literature about using VR in higher education, particularly in science and engineering, some of these applications may affect the use of VR in schools. For instance, Makransky (2017) and the project team reviewed the advantages of virtual laboratories in science and engineering then focused on the prospective value of high-quality virtual laboratories and how multiple students access virtual devices that are different from physical devices that are resistant to damage. It also suggests that virtual labs can reveal the ‘unseen’ things because the device cover can be easily removed or made transparent to visualize the functioning of internal structures. However, there are concerns that the development of virtual labs is often time-consuming. Moreover, students may not value simulator proficiency as much as that of real people, and in the final or advanced stages of learning, there is nothing to replace experience with actual equipment. The results of a recent scientific experiment were that college students compared learning with desktop VR and the results show that even if students enjoy the experience of VR, they experience overload awareness problems that reduce test efficiency (Ke and Carafano, 2016). Interestingly, the problems of cognitive load and an extremely realistic simulator were explored in experiments whit children age 14 and 15 years, some of whom had desktop computers and had experience with space flight simulators in classes as lower immersion, while others could use a custom truck for large-scale realistic space flight simulations as higher immersion (Fotaris et al., 2017). The study found that the degree of immersion does not impact learning issues, but a higher level of sensory immersion may hinder the processing of concepts. Although its number is very small, the method of using desktop VR in STEM schools (Science, Technology, Engineering, and Mathematics) has been rigorously studied. In STEM classrooms, it has proven that technology can help increase the abilities to ask questions (Monicha et al., 2017). The majority of the literature on immersive VR in schools is about nature. In a research team survey, Olmos-Raya et al. (2018) discovered that using Google Expeditions in the classroom has a small experimental benefit for education. For example, when some conditions such as mood induction and immersion levels change during short term storage measurements (Bowor and Sturman, 2015). The issue was found in an international learner survey of the learning possibilities of portable technologies such as HMDs. These things include privacy; the potential to shift learner values; equipment costs; the fear that the novelty of using new ‘gadget’ will replace the need for teaching and learning design; and a lack of appropriate educational software (Southgate et al., 2018). Observational data on the use of VR in school research indicates that some students are so indicated to virtual effects that they avoid monitoring the system designed to protect users from warnings when they leave a determined safe area. It also revealed that continuous monitoring by the researchers or other students is necessary for safety. Moreover, the measure of helping students turn on/off VR devices has resulted in the development of a child protection protocol that is proper for touch-sensitive students. The data also exposed that girls were less likely to experiment with VR than boys, and a few girls initially wore HMDs embarrassingly and were seen by them: it was not obvious in boys. The study also found that by integrating a game into the curriculum, students needed more time to become familiar with the benefits of VR experiences and technical learning (Chang et al., 2013). There are many branches to using VR for education as shown in Fig. 3

(a) VR for chemistry

(b) VR for kindergartens

(c) VR for designing

(d) VR for anatomy

Figure 3**.** VR in education

Some of the benefits of VR in education include transcending physical boundaries, both in connecting people from all over the world and allowing them to visit places and times that are not possible. Displaying high-quality images can foster emotional connections and a deeper understanding of complex concepts. Hazardous situational training can be safely simulated and reproduced, and sessions in the VR space take remote action to the next level. Realistic learning can increase participation and have the potential to reduce disparities in access to quality education. Therefore, this research aimed to create 3D models that would be then implemented in Unity 3D using VR applications for 3D architectural visualization.

2. Material and Method

2.1 Material

In recent years, there have been sizable advances in customer VR devices such as the Oculus Rift, HTC Vive, Leap Motion controller, and HoloLens, conducting immersive VR experiences into consumers' homes on demand. Cost and space are lower than previous VR devices. These new devices also reduce the limitations of VR engineering applications (Jerald, 2016). This research focuses on reviewing the categories and components of VR, such as the **Oculus Rift**, which is released on March 28, 2016. It is a type of VR headset developed and manufactured by Oculus VR, a division of Facebook Inc. The company's first product is the Oculus Rift VR headset. VR is known as the technology that creates a virtual environment by using computer simulation and allows a 3D pseudo-experience within that environment (Karthika, 2017). VR uses VR environments built with computer software and VR technology built with computer hardware to make it feel like one has moved to another 'world', a virtual world. The environments are run on computer software, and the Oculus Rift headset is connected to the computer via a USB port and an HDMI cable, after which the user experiences a 3D world as shown in Fig. 4. Therefore, this research used the Oculus Rift as an experiment.

Figure 4. Oculus Rift VR head set

2.2 Method

The purpose of this research is to propose a method of using VR technology for rendering 3D houses and interacting with them. First of all, we designed a house as a 3D model in the SkechUp program then exported it into the Unity 3D program and created 3D objects for the Oculus HMD with a hand controller to interact with those 3D objects that we could move or patrol through the house. The system will allow users to look around the scene and enter the house with the immersive experience of VR interaction as shown in Fig. 5.

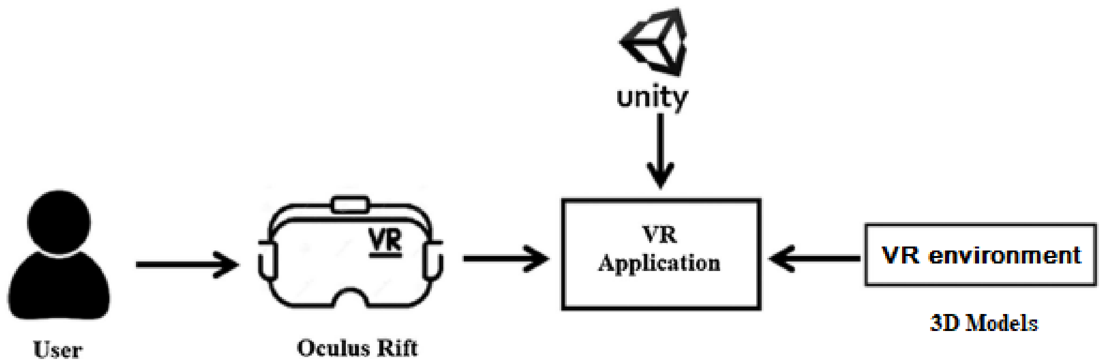
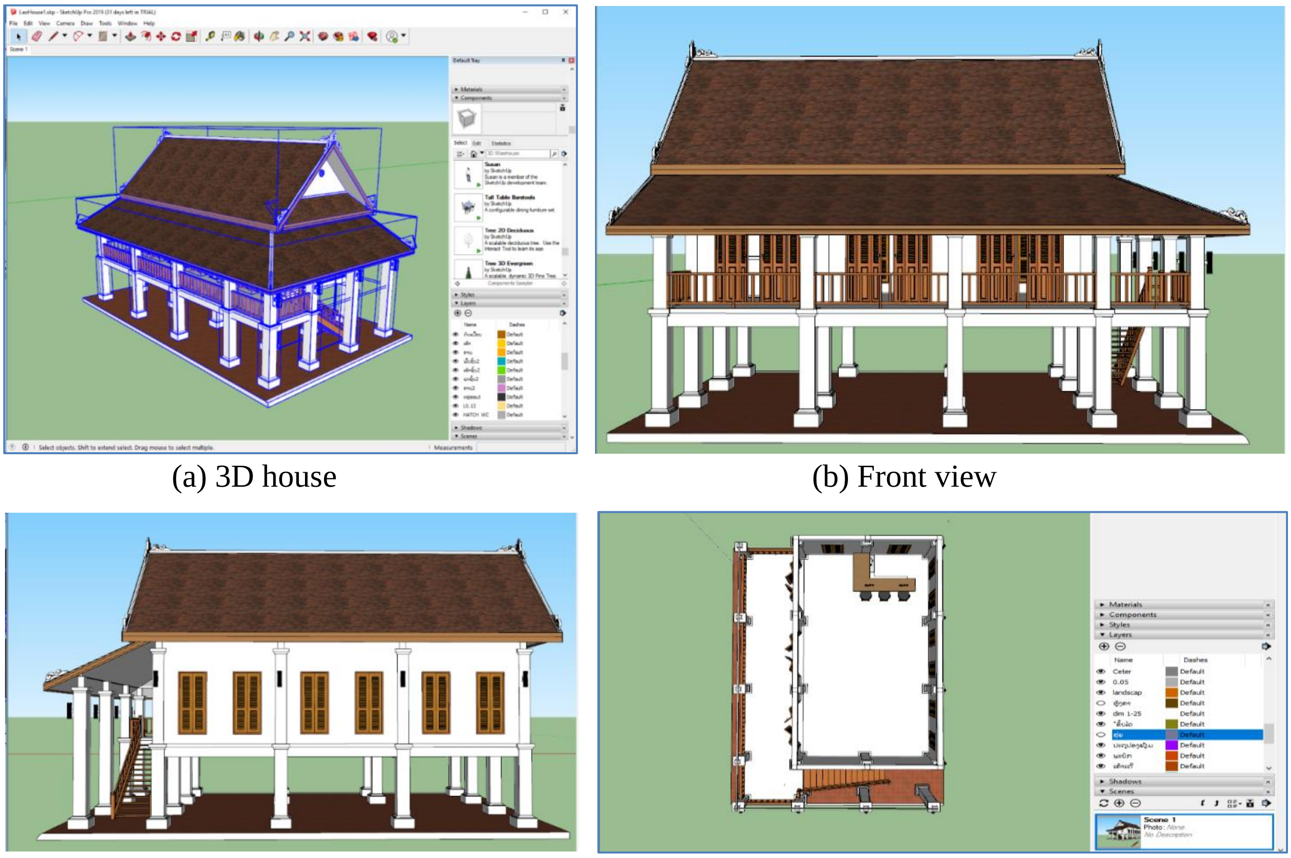


Figure 5. VR System architecture

2.3 Design of 3D house

Traditional Lao houses are made of wood or bamboo and built on above-ground stilts. People live on the ground floor of the house on the platform. Traditionally, the house has a steep thatched roof and a veranda. Therefore, the Lao house design ideas used in this section are traditional houses, especially in Luangprabang city. In this work, we prepare an asset and designed Lao House Style models in SketchUp then imported them into Unity 3D by following these steps (a) SketchUp and designed a 3D house, (b) Front view of a 3D house, (c) Back view of 3D house, and (d) Top view without the roof, shown in Fig. 6.



(a) 3D house (b) Front view

(c) Back view (d) Top view

Figure 6. Design of Lao house style by SketchUp

2.4 Import 3D model from SketchUp into Unity 3D

SketchUp is one of the most commonly used softwares for architectural modeling. Using the SketchUp 3D model for visualization in Unity 3D, the users will need to convert to a supported medium format using Unity 3D and import the converted layout into Unity 3D to solve this problem. Unity 3D now supports the import of SketchUp files directly without the need for conversion, allowing users to access certain features of SketchUp files within Unity 3D, which was not previously possible. Importing a SketchUp file into Unity 3D is comparable to importing 3D models supported by Unity 3D as shown in Fig 7. There are three methods for importing a SketchUp file:

- Import from New Asset from the menu bar in Unity 3D.
- Drag and drop the file into the project windows in Unity 3D.
- Import New Asset via the project window's context menu in Unity 3D.

Figure 7. Import 3D models from SketchUp into Unity 3D

2.5 Experiment

The experimental environment for this research is an Intel(R) Core (TM) i5-8400T CPU @ 1.70 GHz, 16 GB RAM, and Windows 10 (version 2019) Personal (64 bit) of the Unity 3D development engine. We used SketchUp 2019 to create houses as 3D Model then imported it as New Asset into Unity 3D and C# script for Unity program. We designed two houses with some facilities as 3D objects for a VR architectural interaction scene with an Oculus HMD with a handle-controller. In scene, the interior design provided for user to interact with 3D objects such as a table, desk, chair, book, bottle, etc., shown in Fig 8. Which (a) creates the main scene that includes all resources, (b) design room with add some facilities, an (c) the user use an Oculus HMD to look around the surrounding environment, (d) User used Oculus HMD with a handle-Controller to interact with the 3D object.

(a) Main scene

(b) Interior design with house equipment

(c) Used Oculus HMD look around surrounding environment

(d) Used Oculus HMD with handle-controller to interact with 3D object or house equipment

Figure 8. VR 3D Visualization and Interaction

3. Result

For the assessment of the VR application, we selected 40 students from Paichai University (20 students from the department of game multimedia engineering, and 20 students from the department of architecture) to participate in this simulation and answered the questionnaires or survey forms. A questionnaire using a 5-point Likert scale was used: 5 for “strongly agree” (4.50–5.00 during the evaluation), 4 for “agree” (3.50–4.49), 3 for “undecided” (2.50–3.49), 2 for “disagree” (1.50–2.49), and 1 for “strongly disagree” (1.00–1.49). The results from the survey responses and the analysis of quantitative data are shown in Table 1.

Table 1. The assessment results of VR application

Statements	Mean	Level
1. I found the VR application scene and interface easy to understand.	4.15	Agree
2. Once I used the VR application scene, I found the 3D models are beautiful, clear and realistic.	4.55	Strongly agree
3. Once I touched the models, I found object manipulation easy and intuitive to use.	3.45	Neutral
4. I certify that the use of VR application is useful in learning architecture.	4.75	Strongly agree
5. I certify that architecture in a virtual scene and interaction with objects using Oculus Rift HMD and hand-controller is better than with keyboard and mouse controls but cause dizziness.	4.55	Strongly agree
6. I certify that the interaction accuracy is high quality.	4.05	Agree
7. I certify that the interaction by the use of VR is similar to prototypes.	4.25	Agree
8. I certify that learning with VR is more difficult than with other simulations.	2.85	Neutral
9. Overall, I enjoyed the immersive experience, and the learning was very interesting, it seemed to be in the real world.	4.70	Strongly agree
10. I think I am able to improve my learning skill with VR system for architecture.	4.55	Strongly agree

4. Discussion

For the evaluation, we prepared reference questionnaires in discussions with those who used this system to explore students' conceptual knowledge and immersion. This study involved a survey, interviews, and quantitative data collection to investigate students' attitudes toward the use of VR architecture interaction simulation. The results shown in Table 1 show that the mean scores of each statement indicate that the VR application is a new one for the students, and they have never used it before, but they certify that learning with VR is not too difficult, and the 3D objects in the VR application's scene was beautiful, clear, and realistic. Besides, the student also enjoyed the immersive experience and the learning was very interesting and they felt that they were in the real world. Despite this, the students certify that the VR application is helpful and able to improve their learning skills as the consistent of Ping Li et al. (2020) reviewed and validated that the use of VR helps to create situated learning conditions; its theoretical significance lies in its ability to provide perception-action enabled experiences to the learner, and it is these experiences that lead to positive behavioral and brain outcomes compared to traditional methods of learning. The use of VR application is useful in learning architecture as consistent of Ravi, R. & Murugesan, D. (2022) reviewed that the applications of VR in architecture allows users to freely walk around the play area of the VR area and transform physical movement from reality into a digital environment. In addition, this research demonstrated that the VR application scene and interface easy to understand and 3D object manipulation is easy and interaction by the use of VR is similar to prototypes as consistent of Leenah, F., Sara et al. (2022) indicated that the architects could use the VR to generate a digital version of the environment and buildings, which could be divided into several types, including landscape, building, interior, and exterior.

5. Conclusion

We have proposed techniques and tools for creating visual and interactive 3D models. The experimental design and related materials were implemented in 3D models to perform the experiments in a VR system, in which rendering and interaction were simulated by the Unity 3D engine with the C# script. Moreover, we have used surveys and quantitative data to investigate students' attitudes toward the use of VR device for visualization and interaction. We believe that simulating scene circumstances through a VR system can improve students' learning outcomes in 3D architecture. This research is expected to provide significant benefits to students. Students running VR simulations can perform interesting rendering repeatedly without consuming any real materials. Therefore, VR can be adopted as an easy-to-use educational tool. Experimental mistakes can be easily corrected, and students can acquire high-level competencies through this opportunity. Although some students have mentioned discomfort, such as dizziness, we plan to address it in future work.

6. Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

7. Acknowledgement

We would like to express our deepest sense of gratitude to the Department of Game Multimedia Engineering, Pai Chai University, Republic of Korea for providing resources and the computing environment for this research. This work was supported by the Research Grant of Jeju National University, Republic of Korea in 2021.

8. References

Yilei H. (2020). "Evaluating mixed reality technology for architectural design and construction layout". *Journal of Civil Engineering and Construction Technology,* Vol. 11(1), pp.1-12, ISSN 2141-2634.

Milgram, P., Takemura, H.; Utsumi, A. & Kishino, F. (1994). "Augmented reality: a class of displays on the reality-virtuality continuum". *International Society for Optical Engineering*.

Ting P., Yuchen Z. & Tong Y. (2017). "Inquiring the Application of Mixed Reality in the Traffic Safety Education". *International Journal of Engineering Innovation & Research,* Vol. 6, Issue 5, ISSN: 2277-5668.

Carlos F., Sergio I-S. & Carlos O. (2019). "The impact of virtual, augmented and mixed reality technologies on the customer experience". *Journal of Business Research, 100,* 547-560.

Burdea, G. C. & Coiffet, P. (2003). "Virtual Reality Technology". *John Wiley & Sons: Hoboken, NJ, USA.*

Earnshaw, R. A. (Ed.). (2014). "Virtual Reality Systems". *Academic Pres. London, UK.*

Joshua, Q. C., Ian, F. & Salmon, J. L. (2017). A review of the capabilities of current low-cost virtual reality technology and its potential to enhance the design process. *Journal of Computing and Information Science in Engineering,* vol. 17, no. 3.

Billinghurst, M. (2012). Augmented reality in the classroom. *Computer,* vol. 45, no. 7, pp. 56-63

Santos, M. E. C., Chen, A., Taketomi, T., Yamamoto, G., Miyazaki, J. et al. (2014). Augmented reality learning experiences: survey of prototype design and evaluation. *IEEE Transactions on Learning Technologies,* vol. 7, no. 1, pp. 38-56.

Potkonjak, V., Michael, G., Victor, C.; Pasi, M., Christian, G. et al. (2016). Virtual laboratories for education in science, technology, and engineering: a review. *Computer & Education,* vol. 95, pp. 309-327.

Makransky, G., Lilleholt, L. & Aaby, A. (2017). Development and validation of the multimodal presence scale for virtual reality environments: a confirmatory factor analysis and item response theory approach. *Computer & Human Behavior,* vol. 72, pp. 276-255.

Ke, F. & Carafano, P. (2016). Collaborative science learning in an immersive flight simulation. *Computer & Education,* vol. 103, pp. 114-123.

Fotaris, P., Pellas, N., Kazanidis, I. & Smith, P. (2017). A systematic review of augmented reality game-based applications in primary education. *Proceedings of the 11th European Conference on Games Based Learning ECGBL.*

Minocha, S., Tudor, A. & Tillings, S. (2017). Affordances of mobile virtual reality and their role in learning and teaching. *31st British Human Computer Interaction Conference, University of Sunderland's St. Peter's Campus, UK.*

Olmos-Raya, E., Ferreira-Cavalcanti, J., Manuel, C., Mariano, A., Irene, A. C. G. et al. (2018). Mobile virtual reality as an educational platform: a pilot study on the impact of immersion and positive emotion induction in the learning process. *Eurasia Journal of Mathematics Science and Technology Education,* pp. 1305-8215.

Bower, M. & Sturman, D. (2015). What are the educational affordances of wearable technologies. *Computer & Education,* vol. 88, pp. 343-353.

Southgate, E., Shamus, P. S., Chris C., Shane S., Jivvel, K. et al. (2018). Highly immersive virtual reality. *Journal for Educators*, vol. 37, pp. 130-143.

Chang, H. Y., Wu, H. K. & Hsu, Y. S. (2013). Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue. *British Journal of Educational Technology,* vol. 44, no. 3, pp. E95-E99.

Jerald, J. (2016). The VR book human-centered design for virtual reality. *Morgan & Claypool Publishers.*

Karthika, S. (2017). HoloLens. *International Journal of Computer Science and Mobile Computing.* vol. 6, no. 2, pp. 41-50.

Li, P., Legault, J., Klippel, A. & Zhao, J. (2020). Virtual reality for student learning: Understanding individual differences. *Human Behaviour and Brain 1(1),* 28-36.

Ravi, R. & Murugesan, D. (2022). Applications of Virtual Reality in Architecture. *Journal of Research in Humanities and Social Science*, *ISSN(Online): 2321-9467,* Vol. 11, pp. 70-80

Leenah, F., Sara, A., Rahaf, B. & Abdel, M. E. S. (2022). The Used and Challenges of Virtual Reality in Architecture. *Civil Engineering and Architecture 10(6): 2754-2763*.