JOURNAL LA MULTIAPP

VOL. 05, ISSUE 06 (946-955), 2024
DOI: 10.37899/journallamultiapp.v5i6.1639

Design of Earthquake Disaster Evacuation Route Simulation in a High-Storey Building Using Virtual Reality

Bagus Wahyu Masdhana[1], Tranggono[1]

[1]*Universitas Pembangunan Nasional "Veteran" Jawa Timur*

**Corresponding Author: Bagus Wahyu Masdhana*

Article Info

Article history:
Received 11 September 2024
Received in revised form 5 November 2024
Accepted 5 December 2024

Keywords:
Earthquake Evacuation
High-rise Buildings
Simulation Design
Virtual Reality

Abstract

Indonesia is a country located in the Pacific Ring of Fire, because of this Indonesia is vulnerable to earthquakes because it is located at the meeting point of several colliding tectonic plates. In addition, the presence of active volcanoes is also an additional factor. The construction of high-rise buildings in Indonesia has continued to increase in recent years along with the growth of urbanization and the need for more efficient space in urban areas, this has increased the risk of accidents in high-rise buildings. With these problems, a disaster simulation is needed which can be the right step to understand the correct ways to handle and evacuate from disasters. The right simulation for this problem is to use Virtual Reality (VR)-based learning because this simulation can increase the effectiveness of disaster management education by experiencing firsthand a realistic and interactive earthquake scenario simulation. The results of the pre-post test processed using the Wilcoxon signed rank test method obtained a result of 7.5 where 7.5 ≤ 52 (critical value) concluded that this simulation provides a significant change in knowledge of earthquake disaster mitigation in high-rise buildings. And from the SUS (System Usability Scale) Questionnaire, the score obtained was 78.875 which is included in the category 70-85 which means that this system is quite good in terms of usability. Users generally feel comfortable using the system.

Introduction

The earth is round like a ball but flat at the poles. The earth has an internal structure that is almost the same as an egg. In dealing with disasters, preparedness is the key to safety. This shows the need for a preparedness plan in the field of disaster nursing, especially earthquakes, so that it can minimize the losses that will occur (Cahyo et al., 2023). The slowing down of movement causes a buildup of energy in the subduction zone and fault zone. As a result, pressure, tension, and shear occur in these zones (Leutualy et al., 2023). The types of earthquakes are volcanic, tectonic and collapse earthquakes (Maharani, 2020). The risk of this earthquake disaster is that in addition to loss of life and mental health, losses and damage to property cannot be avoided, damage to office buildings, factories and others. This causes a lot of losses, therefore it is necessary to have earthquake risk mitigation that can be taken or proper evacuation routes (Kosim et al., 2023). Self-rescue from an earthquake can be done in various ways. One way is disaster mitigation by providing training in schools or the like (Qurrotaini & Nuryanto, 2020). One of the rescue efforts during a disaster is to take shelter under a table, turn off all electrical equipment and others.

A multi-storey building is a high-rise building with a unique and attractive shape. The characteristics of a multi-storey building are that it has many floors, a strong and stable structure, a complete and good safety system, and complete supporting facilities (Makhrus &

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Hakim, 2023). Multi-storey buildings must be strong in supporting loads in order to comply with the function of the building and can survive an earthquake. The response of the building when experiencing a combination of loads also needs to be evaluated so that the building provides good comfort (Pramesti, 2018; Saruni et al., 2017). The risks of multi-storey buildings include structural damage, fire risk, and others (Tampubolon et al., 2022).

Evacuation route is An evacuation route is a route or path designed and designated for use by occupants of a building or a particular area to exit safely and quickly (Mandela & Torang, 2022). Evacuation route signs include assembly point locations, emergency exit markers (Fire Protection Association, 2019).

Virtual reality (VR) is a multimedia technology application that has the advantage of depicting a situation or an object where the simulation displayed can not only be seen from one point of view, but can also be seen from any angle, because it produces 3-dimensional visualization (Lubis & Rahayu, 2023). Virtual Reality is a technology that allows users to interact with the environment in cyberspace that is simulated by a computer, so that users feel like they are in that environment (Riyadi et al., 2023). With the interaction between the user and the virtual, VR is an interactive media (Fitriya et al., 2022). The uses of VR include entertainment, education and training, health (Fitriyani et al., 2021).

Oculus Quest 2 is a virtual reality (VR) headset device developed by Oculus (Ridha et al., 2022). The advantages of this device are that it does not require additional devices such as computers or consoles so it is more practical, high visual quality, ease of use, affordable price (Mardoyo et al., 2022). Unity software has various features (Mardoyo et al., 2022). Unity is one of the most popular and widely used game development platforms for creating Virtual Reality (VR) applications and content. With Unity, developers can create immersive and interactive VR experiences for various VR devices such as Oculus Rift, HTC Vive, PlayStation VR, and many more. Wilcoxon Signed Rank Test (Wilcoxon Sign Rank Test) which is given the symbol T (Wiguna & Sudiarno, 2019). Another definition is a group of subjects who are treated for a certain period of time, measurements are taken before and after the treatment is given, and the effect of the treatment is measured from the difference between the initial measurement T1 and the final measurement T2.

Methods

The research method employed in this study was intended to assess the approach of earthquake disaster evacuation route simulation using Virtual Reality VR in high-rise buildings. This research was carried out at Industrial Engineering of the National Development University "Veteran" East Java during March up to the end of this research. In this study the independent variables included the learnability, efficiency and usability of the above designed simulation while the dependent variable was participants' level of understanding in disaster mitigation.

It was chosen to use a VR device called Oculus Quest 2 which does not necessitate another computer hence more effective while offering superior graphical display system. This work focused on the development of the simulation; this includes the design of the virtual conditions in high-rise buildings during an earthquake. This environment was modeled and was developed in the application known as Blender for three-dimensional visualization and the overall simulation was run in the Unity game engine to simulate the logic of object interaction of the virtual world. As for the assessment of participants' knowledge change after using the VR simulation, this study has employed the Wilcoxon Signed Rank test method in order to compare the pre-test and post-test results of the respondents.

During the study, each respondent underwent an earthquake disaster evacuation simulation and their understanding was tested before and after the simulation session. The data obtained

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

was then processed to measure how effective this simulation was in improving participants' understanding of earthquake disaster mitigation in high-rise buildings

Results and Discussion

Explain the results of the research in the form of problem-solving analyzed using relevant theories. The results of the study also revealed the findings of the research. Discussion is accompanied by logical arguments by linking the results of research with theory, the results of other studies.

Table 1. Disaster Mitigation Simulation with VR

Scene	Location	Commands	Action
when the earthquake occurs	Inside a high-rise building	There was an earthquake, what actions were taken	The action immediately came out of hiding under the table
when the earthquake stops	Inside a high-rise building	The earthquake stopped, what actions were taken	run following the correct symbol run through the wrong path (elevator, window)
when leaving the building	Outside a high-rise building	Already out of the building, what actions were taken	standing next to a tree standing next to an electric pole standing in a wide field

Source: data processing

The initial stage of creating a work safety simulation using VR is the creation of Assets or virtual environments that visualize the actual environmental conditions in each category of earthquake simulation. In this study, the environment taken was inside a multi-storey building and outside a multi-storey building. The creation of a virtual environment using three-dimensional blender software.

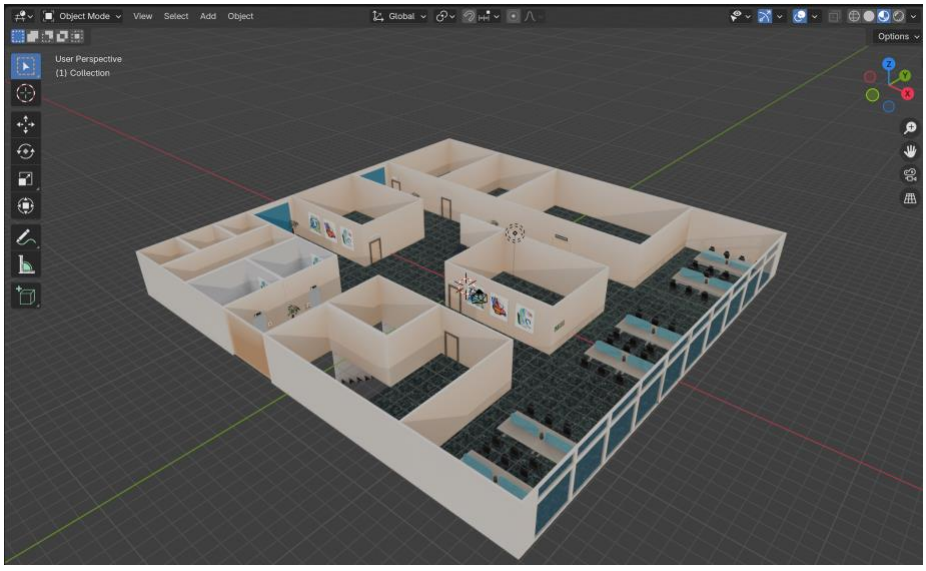


Figure 1. Assets in a high-rise building

Figure 1. is the initial layout design in the room for asset creation. This floor is a floor consisting of several rooms such as a meeting room, manager's room, ballroom, pantry, workspace and bathroom.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

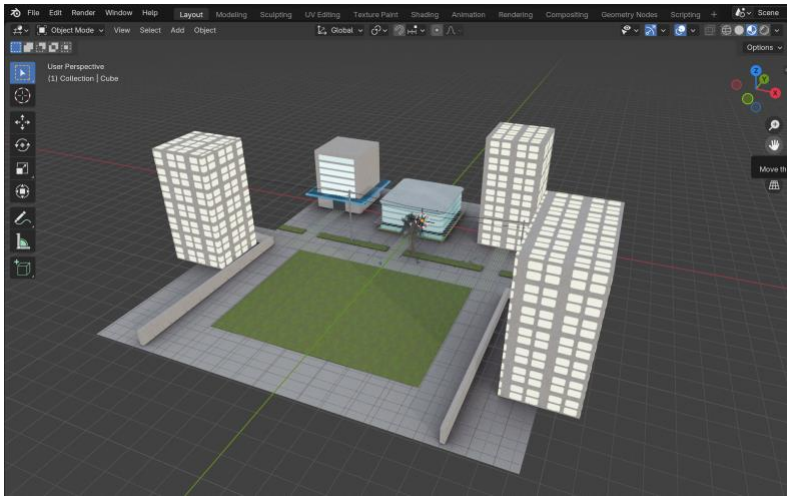
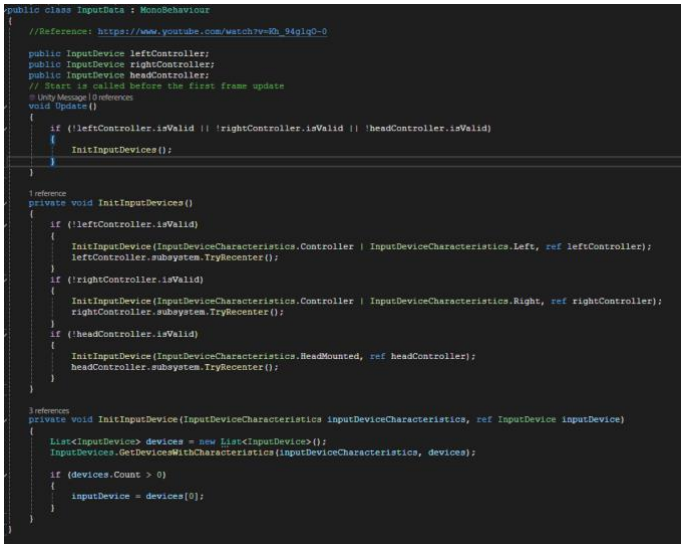


Figure 2. Assets Outside High-rise Buildings

Figure 2 is the initial outdoor layout design for asset creation. This asset consists of buildings, trees, electric poles, and open fields.

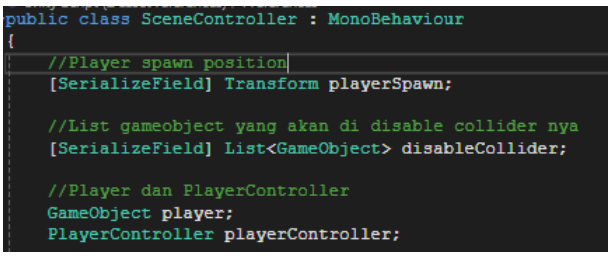
The next step is to build a logic of thinking so that the game runs smoothly. The logic of thinking here is a script used in the unity software to command everything that happens in the simulation later. Writing application scripts is made for each object in the virtual environment so that they can interact according to the desired form of interaction. Writing application scripts is done using Microsoft Visual Studio software.



```
public class InputData : MonoBehaviour
{
    //Reference: https://www.youtube.com/watch?v=Rh_94g1qO-0

    public InputDevice leftController;
    public InputDevice rightController;
    public InputDevice headController;
    // Start is called before the first frame update
    0 Unity Message | 0 references
    void Update()
    {
        if (!leftController.isValid || !rightController.isValid || !headController.isValid)
        {
            InitInputDevices();
        }
    }

    1 reference
    private void InitInputDevices()
    {
        if (!leftController.isValid)
        {
            InitInputDevice(InputDeviceCharacteristics.Controller | InputDeviceCharacteristics.Left, ref leftController);
            leftController.subsystem.TryRecenter();
        }
        if (!rightController.isValid)
        {
            InitInputDevice(InputDeviceCharacteristics.Controller | InputDeviceCharacteristics.Right, ref rightController);
            rightController.subsystem.TryRecenter();
        }
        if (!headController.isValid)
        {
            InitInputDevice(InputDeviceCharacteristics.HeadMounted, ref headController);
            headController.subsystem.TryRecenter();
        }
    }

    3 references
    private void InitInputDevice(InputDeviceCharacteristics inputDeviceCharacteristics, ref InputDevice inputDevice)
    {
        List<InputDevice> devices = new List<InputDevice>();
        InputDevices.GetDevicesWithCharacteristics(inputDeviceCharacteristics, devices);

        if (devices.Count > 0)
        {
            inputDevice = devices[0];
        }
    }
}
```

Figure 3. C# script

This Input Data contains code used to set the connection between the device and the player object if the device is disconnected and also to set the position back according to the device.



```
public class SceneController : MonoBehaviour
{
    //Player spawn position
    [SerializeField] Transform playerSpawn;

    //List gameobject yang akan di disable collider nya
    [SerializeField] List<GameObject> disableCollider;

    //Player dan PlayerController
    GameObject player;
    PlayerController playerController;
```

Figure 4. C# script

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

This Input Data contains the code used to give the object the will to interact with the player via the VR controller.

At this stage all objects that have been created are combined with a script containing interaction commands using a game engine software called Unity. This stage is an important process in the development of a simulator software, if at the time of execution the object cannot be manipulated according to what is ordered then there is a big possibility that there is an error in the script/code that has been created.

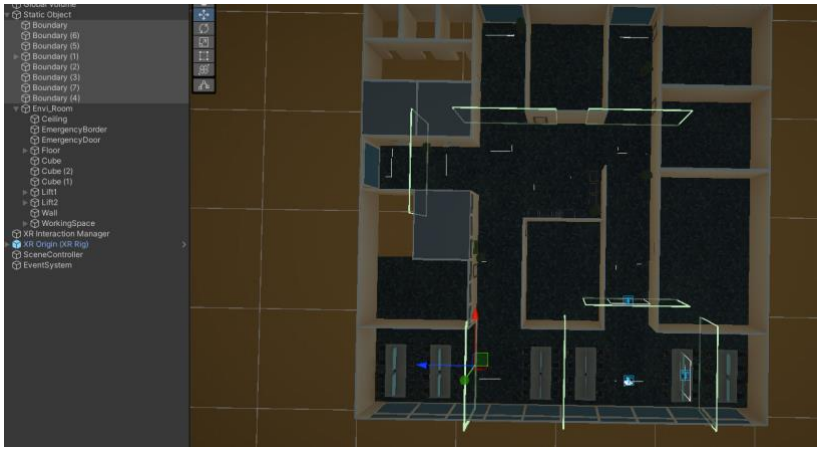


Figure 5. Simulation Boundary creation process

The purpose of this stage is to provide boundaries to the areas that can be explored by the user and to restore the player's position if the player is out-of-bound and falls.

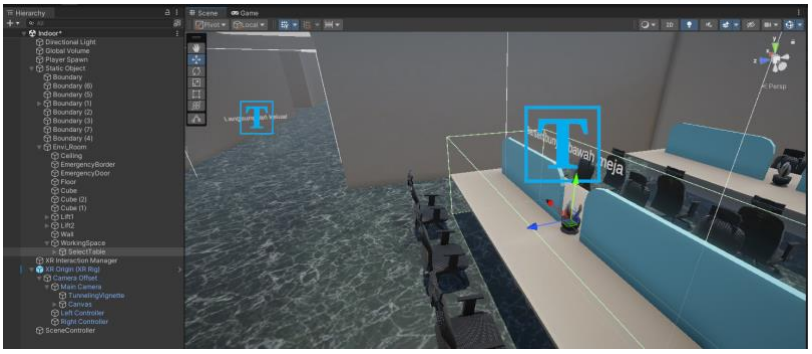
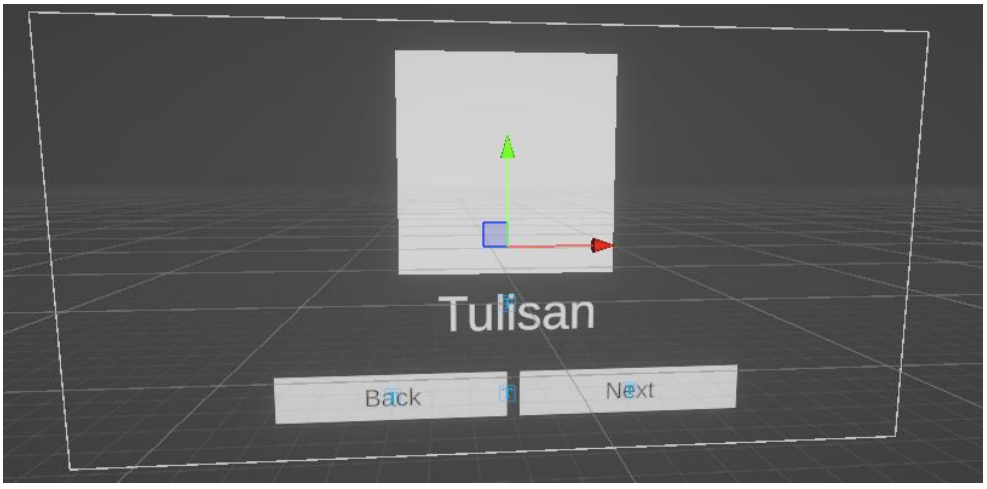


Figure 6. the process of inserting a script into an object

This stage involves inserting the C# script code that has been created into the object to make the object interactable as desired.



ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Figure 7. the process of creating the ending interface.

This stage contains the creation of an interface menu for each ending which will determine the storyline.

Table 2. pre-post test recap results

Responden	Pre-test	Post-test	Difference	Absolut	Ranking	Result
1	40	90	50	50	18	positive
2	70	100	30	30	13,5	positive
3	60	90	30	30	13,5	positive
4	70	90	20	20	8,5	positive
5	40	60	20	20	8,5	positive
6	80	80	0	0	1,5	negative
7	70	100	30	30	13,5	positive
8	40	90	50	50	18	positive
9	60	80	20	20	8,5	positive
10	70	100	30	30	13,5	positive
11	80	80	0	0	1,5	negative
12	70	80	10	10	4,5	positive
13	40	90	50	50	18	positive
14	80	100	20	20	8,5	positive
15	90	100	10	10	4,5	positive
16	90	80	-10	10	4,5	negative
17	80	90	10	10	4,5	positive
18	50	80	30	30	13,5	positive
19	60	90	30	30	13,5	positive
20	40	100	60	60	20	positive
			Total (negative)		7,5	

N = 20 (number of respondents)

$\alpha = 0.05$ (alpha value coefficient)

Critical value = 52 (obtained from the Wilcoxon signed rank test critical value table with N = 20)

From the recapitulation results of the Pre-Post Test calculation using the Wilcoxon Signed Rank Test method, the result was 7.5. Where through the Wilcoxon signed rank test table from N = 20, and $\alpha = 0.05$, the critical value was 52. Where it can be concluded that if $7.5 \leq 52$, there is a significant difference between before and after using this simulation in knowledge about earthquake disaster mitigation in high-rise buildings.

Table 3. SUS questionnaire summary results

Respondent	Questionnaire Results (on a Likert scale)										Result
1	2	4	5	3	3	4	3	4	3	5	40
2	4	1	5	2	5	1	4	2	5	2	87,5
3	5	1	4	1	5	2	4	1	4	1	90
4	5	1	5	1	4	2	5	1	4	1	92,5
5	4	2	4	2	5	1	5	1	5	1	90
6	4	2	5	2	5	1	5	1	5	1	92,5
7	5	2	5	1	4	1	4	2	5	2	87,5
8	5	1	4	1	5	1	4	2	5	1	92,5

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Respondent	Questionnaire Results (on a Likert scale)										Result
9	5	1	5	1	5	2	5	2	4	1	92,5
10	5	1	4	2	5	1	4	1	5	1	92,5
11	4	1	5	1	5	2	4	1	4	2	87,5
12	5	1	4	2	5	1	4	1	5	1	92,5
13	5	2	5	1	4	2	4	1	5	2	87,5
14	5	1	4	1	5	1	5	1	4	1	95
15	5	2	4	1	5	1	4	1	5	2	90
16	5	2	5	1	4	1	5	2	5	2	90
17	5	1	4	1	5	2	5	2	4	1	90
18	5	2	4	1	5	2	5	2	4	1	87,5
19	5	2	5	2	5	1	4	2	5	1	90
20	5	2	4	1	5	2	4	1	5	2	87,5
Total Results											78,875

Description:

Score 0-50: Very low usability indication. Users may experience many difficulties.

Score 50-70: Moderate usability. There may be some problems, but the system can be used with adjustments.

Score 70-85: The system is quite good in terms of usability. Users generally feel comfortable using the system.

Score 85-100: Very good usability. Users feel very comfortable and efficient in using the system.

From the recapitulation of the SUS questionnaire calculation, the result was 78.875. Which means that this simulation is quite good in terms of usability. Users generally feel comfortable using this simulation.

In this investigation, information is presented on the pre-test and post-test which was analyzed using the Wilcoxon signed rank test method with a value of 7.5 According to these finding, user knowledge before and after the use of the simulation is significantly different. The device employed in this study was the Oculus Quest 2 which enables realistic interaction with a simulated environment developed using Unity software. The SUS scale resulted to 78.875 and this falls at decidedly firmly area, which indicate that users feel at ease using the system. Hence, this study builds and corroborates earlier research that has been conducted relative to disaster prevention employing the use of VR technology. For instance, another study by Ahmadi et al. (2024) that employed the implementation of VR based interactive media for earthquake disaster actions in virtual environment yielded conclusions that also confirm the ability of VR in enhancing disaster preparedness. The findings reveal enhancement in the level of knowledge of the European users on self-rescue procedures when there is an earthquake.

Furthermore, Edity (2022) whom conducted studies in 2022, on the development of flood disaster prevention simulations integrated with VR technology, has also provided evidence for this study. Editya (2022) proves that by using VR users are able to get a more effective learning experience so they will understand better the different disasters. The four studies that are most related to the study being discussed are two studies which used VR because VR can offer direct experience to the people which in return enhances their interaction and knowledge of disaster risks (Wachinger et al., 2013).

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Glauberman & Glauberman (2018) studied disaster preparedness also in high-rise buildings but the paper addressed the simulation of fire emergency for which this study is related to the study by Fajriati et al. (2021) who conduct the development of a firefighting simulation at the Faculty of Applied Sciences using the VR application. Fajriati et al. (2021) also discovered that by using facsimile manner simulations based on virtual reality, he/she was able to attain more realistic situational training, which is very significant in emergency situation where there is need for fast action.

Previous research emphasises vast possibilities of VR application in education and training particularly in the field of disaster management. The focusing of disaster management in VR simulations makes it easier for the user to practice in the area as it is hard to achieve through conventional practice. Applying VR technology also allows the necessary flexibility when it comes to constructing a variety of cases for training and the development of advanced scenarios, which can be used for individual training exercises.

This research offers a new insight in the area of disaster prevention system being implemented to high rise buildings mainly in Indonesia since the country belongs to the Pacific Ring of Fire and is regularly hit by earthquakes. Using of VR based simulations in high rising buildings is very relevant because there is a higher probability of building collapse and the evacuation process is more complicated. Thus, this simulation can be a chance to exercise through actual and interactive earthquake scenarios and find out actual ways and actions when an earthquake occurs.

It is also something practical in this study, because the Oculus Quest 2 does not require other equipment such as a computer or console, which can be conveniently used in different environments. The outcome in the form of a 33% enhancement in user's knowledge after using this simulation and fairly good SUS scores suggest that this simulation deserves wider adoption as part of disaster prevention training in high-rise facilities.

Conclusion

Based on the objectives of the study and the results and discussions obtained, it was concluded that based on the research conducted, the results of the pre-post test processed using the Wilcoxon signed rank test method obtained a result of 7.5 where $7.5 \leq 52$ (critical value) concluded that this simulation provides significant changes in knowledge of earthquake disaster mitigation in high-rise buildings. And from the SUS (System Usability Scale) Questionnaire, a score of 78.875 was obtained which is included in the 70-85 category which means that this system is quite good in terms of usability. Users generally feel comfortable using the system. Suggestions for future research using the oculus quest 2 device and the latest technology, can simulate other disaster topics besides earthquakes.

Acknowledgment

The author would like to thank the supervisor, examiners 1,2 who have provided suggestions and input in writing the research, as well as friends who provided support and input for the researcher.

References

Ahmadi, M., Yousefi, S., & Ahmadi, A. (2024). Exploring the Most Effective Feedback System for Training People in Earthquake Emergency Preparedness Using Immersive Virtual Reality Serious Games. *International Journal of Disaster Risk Reduction*, 104630. https://doi.org/10.1016/j.ijdrr.2024.104630

Cahyo, F. D., Ihsan, F., Roulita, R., Wijayanti, N., & Mirwanti, R. (2023). Kesiapsiagaan Bencana Gempa Bumi Dalam Keperawatan: Tinjauan Penelitian. JPP (Jurnal Kesehatan Poltekkes Palembang), 18 (1), 87–94. https://doi.org/10.36086/jpp.v18i1.1525

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Editya, A. S. (2022). Pengembangan Simulasi Mitigasi Bencana Banjir Menggunakan Teknologi Virtual Reality. *Journal of Computer Science and Visual Communication Design*, *7*(2), 169-178.

Fajriati, P., Roedavan, R., & Siradj, Y. (2021). Simulasi Penanganan Kebakaran Ringan Untuk Fakultas Ilmu Terapan Berbasis Virtual Reality. *eProceedings of Applied Science*, *7*(6).

Fitriya, Y., Satiantoro, A. F. R. N., Sari, N., & Pratama, M. D. (2022). Media Pembelajaran Tata Surya Berbasis Virtual Reality Sebagai Inovasi Teknologi Era Society 5.0. *EDUTECH: Jurnal Inovasi Pendidikan Berbantuan Teknologi*, *2*(3), 234-242. https://doi.org/10.51878/edutech.v2i3.1472

Fitriyani, J., Apriyadi, R. K., Winugroho, T., Hartono, D., Widana, I. D. K. K., & Wilopo, W. (2021). Karakteristik histori bencana Indonesia periode 1815–2019 berdasarkan jumlah bencana, kematian, keterpaparan dan kerusakan rumah akibat bencana. *PENDIPA Journal of Science Education*, *5*(3), 322-327. https://doi.org/10.33369/pendipa.5.3.322-327

Glauberman, G., & Qureshi, K. (2018). Exploratory qualitative study of fire preparedness among high-rise building residents. *PLOS currents*, *10*. https://doi.org/10.1371/currents.dis.aa27444baa486dc3d5b3fa7c28009b22

Leutualy, V., Sumah, D. F., Tasijawa, F. A., Madiuw, D., Tubalawony, S. L., Sopacua, D. T., ... & Thenu, A. A. (2023). Edukasi Tentang Mitigasi Dan Kesiapsiagaan Bencana Gempa Bumi Dan Tsunami. *JMM (Jurnal Masyarakat Mandiri)*, *7*(2), 1847-1856. https://doi.org/10.31764/jmm.v7i2.12909

Lubis, M. A. F., & Rahayu, S. L. (2023). 3D Visualization Design of Building B Case Study of Main Potential University Using Virtual Reality Based on Android 3D Visualization Design of Building B Case Study of Main Potential University Using Virtual Reality Android Based. *System Engineering*, *1*(3), 1109–1121.

Maharani, N. (2020). Tingkat pengetahuan siswa tentang kesiapsiagaan bencana gempa bumi di smpn 3 Kuta Selatan Badung Provinsi Bali. *PENDIPA Journal of Science Education*, *4*(3), 32-38. https://doi.org/10.33369/pendipa.4.3.32-38

Makhrus, M., & Hakim, A. (2023). Kemampuan Mitigasi dan Kapasitas Resiko Gempa Bumi Pada Mahasiswa Magister IPA Universitas Mataram. *Jurnal Pengabdian Masyarakat Sains Indonesia*, *5*(2), 41-44. https://doi.org/10.29303/jpmsi.v5i2.82

Mandela, W., & Torang, D. (2022). Desain Jalur Evakuasi Gedung Politeknik Katolik Saint Paul Kota Sorong Papua Barat. *Jurnal Karkasa*, *8*(1), 34-42.

Mardoyo, E., Lubis, M., & Bhaskoro, S. B. (2022). Evaluasi Virtual Reality Menggunakan Technology Acceptance Model (TAM) Terkait Dunia Metaverse. *Jurnal Sistem Cerdas*, *5*(3), 182-194. https://doi.org/10.37396/jsc.v5i3.250

Pramesti, N. R. (2018). *Analisa perilaku bangunan tidak beraturan horizontal dengan variasi dimensi kolom terhadap gempa* (Doctoral dissertation, UNIVERSITAS NEGERI JAKARTA).

Qurrotaini, L., & Nuryanto, N. (2020). Implementasi pendidikan mitigasi bencana alam gempa bumi dalam pembelajaran IPS SD. *Implementasi Pendidikan Mitigasi Bencana Alam Gempa Bumi Dalam Pembelajaran IPS SD*, *2*(1), 37-44. https://doi.org/10.30742/tpd.v2i01.885

Ridha, M., Arifitama, B., & Syahputra, A. (2022). Penerapan Augmented Reality Pada Sekolah Menengah Kejuruan Atlantis Depok Menggunakan Marker Based Tracking. *JURNAL INDUSTRI KREATIF DAN INFORMATIKA SERIES (JIKIS)*, *2*(1), 11-19.

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0

Riyadi, A., Suandi, F., Riwinoto, R., Kurniawan, D. E., Hafiedz, R., Sakti, W., ... & Khairunnas, B. (2023). Pengembangan Virtual Tour 360 Interaktif untuk Meningkatkan Pengunjung Wisata di Pulau Mubut. *ASPIRASI: Publikasi Hasil Pengabdian Dan Kegiatan Masyarakat*, *1*(4), 29-39. https://doi.org/10.61132/aspirasi.v1i4.111

Saruni, C. V., Dapas, S. O., & Manalip, H. (2017). Evaluasi dan analisis perkuatan bangunan yang bertambah jumlah tingkatnya. *Jurnal Sipil Statik*, *5*(9).

Sukirman, S., Reza, W. A., & Sujalwo, S. (2019). Media Interaktif Berbasis Virtual Reality untuk Simulasi Bencana Alam Gempa Bumi dalam Lingkungan Maya. *Khazanah Informatika: Jurnal Ilmu Komputer dan Informatika*, *5*(1), 99-107. https://doi.org/10.23917/khif.v5i1.8054

Tampubolon, S. P., Sarassantika, I. P. E., & Suarjana, I. W. G. (2022). Analisis Kerusakan Struktur Bangunan dan Manajemen Bencana Akibat Gempa Bumi, Tsunami, dan Likuifaksi di Palu. *Bentang: Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil*, *10*(2), 169-186. https://doi.org/10.33558/bentang.v10i2.3263

Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). The risk perception paradox—implications for governance and communication of natural hazards. *Risk analysis*, *33*(6), 1049-1065. https://doi.org/10.1111/j.1539-6924.2012.01942.x

Wiguna, W. P., & Sudiarno, A. (2019). Design and Construction of Edugame as an Effort to Increase Passenger Safety Awareness of On Board Behavior and Carried Things. *ITS Engineering Journal*, *7*(1), 151–155. https://doi.org/10.12962/j23373539.v7i1.28683

ISSN: 2716-3865 (Print), 2721-1290 (Online)
Copyright © 2024, Journal La Multiapp, Under the license CC BY-SA 4.0