Application of Virtual Reality (VR) in Health, Safety and Environment Subject for Fire Exit Training Module

Nabila Farhana Jamaludin[1,2,*], Rashid Shamsuddin[3], Nur Amalina Mohd Nor[4], Siti Farahin Sedek[1], Muhammad Fairis Hadipornama[5]

[1] Department of Chemical Engineering, Universiti Teknologi PETRONAS, Malaysia
[2] Centre of Advanced Process Safety, Institute of Smart and Sustainable Living, Universiti Teknologi PETRONAS, Malaysia
[3] Department of Chemical Engineering, Faculty of Engineering, Islamic University of Madinah, Madinah, Kingdom of Saudi Arabia
[4] Department of Chemical Engineering, Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia
[5] Kinetics Systems Malaysia Sdn Bhd, Malaysia

ABSTRACT

The significance and extraordinary effectiveness of using VR technology into health, safety, and environment (HSE) education are highlighted. It addresses the many benefits that VR has to offer, especially when it comes to fire exit training, by giving students engaging, involving, and profound learning experiences. The research highlights the seamless incorporation of VR into Health, Safety and Environment (HSE) courses, where VR simulations serve as important tools for teaching crucial evacuation tactics and encouraging students' in-depth understanding and preparedness for actual fire emergencies. This study investigates students' responses regarding their understanding in one of the HSE subject following the implementation of VR technology. Valuable student feedback has been gathered through comprehensive surveys, enabling a continuous process of improvement and refinement for the HSE program. Overall, this research stands as a compelling testament to the profound impact of VR in optimizing learning outcomes and fostering a heightened sense of safety awareness in professional environments.

Keywords:
Virtual reality (VR); health, safety and environment (HSE); fire exit training; active learning; VR in teaching and learning; immersive learning

1. Introduction

Public health is severely concerned about workplace mishaps, especially in light of the market's rising demand for new employees. Young or inexperienced workers are more vulnerable to occupational injuries compared to experienced workers. According to statistics, Malaysia suffers from astounding 14,000 illnesses and injuries each year, costing employers RM4 billion in medical expenses [1]. Unsafe behaviors led to economic impacts and safety training should be enhanced to prevent human accidents and property disasters [2].However, traditional methods for safety training such as safety manuals, videos, in person or online lectures, drills and replicating the real occupational safety in real world would be time, cost and safety constraints [3,4].

---

* *Corresponding author.*
E-mail address: nabila.jamaludin@utp.edu.my (Nabila Farhana Jamaludin)

The International Labour Organization (ILO), which promotes the incorporation of OSH information in training and education programs, recognizes the significance of occupational safety and health (OSH). OSH training consists of systematic initiatives designed to enhance the development of OSH-related skills. According to research findings by Blume *et al.,* [5], it can be challenging for employees to integrate the knowledge and the abilities they have learned during their training into their professional environments. This underscores the notion that the mere dissemination of knowledge does not guarantee the transfer of training or the effective application of taught concepts. Consequently, it is important for the construction industry to acknowledge and implement training transfer components.

In order to maximize the learning experience in OSH, virtual reality (VR) method is introduced to implement effective learning strategies. Shamsudin *et al.,* [1] agree that virtual reality training offers a unique learning experience by immersing trainees in simulated scenarios that may pose risks or challenges if replicated in reality. This innovative technology was designed to integrate five short films, engaging multiple senses, including visionary, hearing, olfaction and haptic [6], that brings notable advantages, particularly in hazardous and complex industrial settings, as it creates a safe and controlled training environment. By effectively bridging the gap between theoretical training and practical applications, VR enhances hands-on learning opportunities and engagement. A greater awareness of potential hazards is made possible by the use of mobile VR technology, which enables the production of vivid simulations of building sites. The use of this technology enables learners to actively interact with and experience a variety of hazardous situations [7]. Mobile VR develops a greater awareness of potential dangers by offering an immersive, hands-on learning environment that closely resembles real-life situations.

Moreover, VR training plays a valuable role in fostering the acquisition of essential construction safety skills. In article by Sacks *et al.,* [8], immersing trainees in a controlled virtual environment allows them to actively engage in activities such as identifying hazards, making decisions in high-pressure situations, and applying appropriate safety protocols. This immersive and interactive training experience enables the development and improvement of skills while instilling confidence in effectively addressing safety challenges encountered on actual on sites.

1.1 The Utilization of VR in HSE

The focus of this research is the implementation of Health, Safety, and Environment (HSE) practices in fire exit training. By integrating VR technology, fire escape training programs can be greatly improved, providing an effective and valuable training tool as illustrated in Figure 1. VR enables individuals to engage in realistic simulations of fire emergencies, allowing them to practice essential skills such as identifying fire exit signs, following emergency evacuation procedures, and executing safe evacuation strategies within a virtual environment. This immersive and interactive training method not only enhances participants' under-standing and preparedness for real-life fire emergencies but also increases their engagement. Additionally, VR has been adopted immersive and non-immersive version that can simulate various scenarios in different types of disasters, allowing for the assessment of decision-making abilities and the effectiveness of evacuation strategies [9]. This extensive utilization of VR in fire escape training programs enhances the overall learning experience, delivering a more comprehensive and efficient approach to training.

In the implementation of VR for fire escape training, VR training presents significant benefits in terms of cost and time efficiency. In contrast to traditional training approaches that necessitate physical mock-up sites or equipment, Wang and Lai [10] investigate that mobile VR training offers substantial cost savings. Additionally, it grants trainees the flexibility to access training materials

whenever needed, enabling self-paced learning and convenience. As a result, valuable time is saved, maximizing efficiency in the training process.

Fig. 1. VR utilization for HSE purpose

VR technology offers special benefits for HSE education and training by immersing students in realistic environments without actual risks, allowing them to hone their abilities in a secure environment before adopting these skills to practical scenarios. According to Checa and Bustillo [11], technological developments and easily accessible devices and software are the reason for the growing interest in VR for HSE training. The potential of VR to improve HSE teaching and learning is favored to increase as the technology develops. The advancement of VR technology from desktop to mobile, giving better immersion and interaction capabilities, is also highlighted by studies by Wang *et al.,* [12]. The benefits of this development have been seen in a number of areas, including structural analysis, equipment operation, health and safety in construction, and architecture. Similar to this, Seo *et al.,* [13] illustrate the benefits of VR-based safety education by offering a realistic way to learn through hazards and accident simulations. In comparison to conventional lecture-based methods, VR's interactive nature fosters experiential learning and improves memory retention. All of these results highlight the potential of VR in HSE teaching and training, providing a safe and interesting method to instruct workers in hazardous circumstances and improve safety knowledge and behaviors.

1.1.1 The Utilization of VR in different applications related to HSE

The substantial opportunity of VR technology to improve HSE training across industries is highlighted by research findings from Patrão and Menezes [14]. The study includes an outstanding VR simulator that imitates real-world situations and functions as an important training tool for HSE programs. Workers can better prepare for dangerous scenarios within a controlled virtual environment by expanding the simulator's depth and enhancing its graphical and sensory realism, learning important skills applicable to real-life conditions. In a related context, Lovreglio *et al.,* [15] compares the efficiency of a YouTube video with a VR simulation for fire extinguisher training. The study shows that VR training improves the video-based method, resulting in better learning acquisition and retention. This benefit becomes more obvious after three to four weeks, demonstrating how the immersive quality of VR simulations helps promotes assurance in using fire extinguisher techniques, thus enhancing work-place safety.

Relatedly, Xue *et al.,* [16] explores the retail industry and looks at how VR technology might improve safety procedures too. The study highlights how important it is to combine the benefits of both online and offline buying through VR shopping experiences, enabling merchants to offer

clients customized precautionary guidance and follow-up assistance. Retailers may efficiently express safety rules and foster a secure shopping environment by prioritising safety in VR shopping environments. This will improve overall safety standards in the retail business. VR has the ability to transform HSE training in other industries, as has been demonstrated both Patrão and Menezes [14] and Lovreglio *et al.,* [15], and its use in retail businesses has the potential to not only promote safety but also boost consumer experiences and satisfaction with products.

VR is a flexible technology with many uses for improving training and safety in a variety of sectors. It provides realistic simulations for HSE teaching and learning, especially for risky circumstances like working at height, and efficiently addresses acrophobia and psycho-physiological symptoms connected to height exposure [17]. Besides, VR has established its utilization towards medical purposes as illustrated in Figure 2. With greater hands-on practice for operations like venepunctures, Agazio *et al.,* [18] mentioned that VR training simulators have transformed medical professional training. An accurate and engaging environment, haptic feedback, repetitive practice, and a secure learning environment are all advantages of VR. It allows for practical and interactive instruction, allowing students to learn from difficult situations that would be impossible to reproduce in the real world due to ethical, financial, and logistical considerations [19]. VR training is useful for emergency evacuation and fire safety in a variety of sectors, despite the initial development expenditures.

In line with Lovreglio *et al.,* [15], a promising tackle is offered by VR technology, which allows for continual training without putting users in danger. Addition of education games in the VR technology makes more interactive contents and promotes more engaging learning [4]. Given its accurate programs, advanced learning outcomes, and optimized security practices, VR has a lot of potential to improve HSE training across industries.

Fig. 2. VR Utilization in medical training

2. Methodology

The educator offers comprehensive training and support in utilizing VR as a digital tool for learning activities. Through these activities, students are able to develop and apply the learning model taught to them. Furthermore, detailed questionnaires were administered to students to gather feedback and evaluation data. The recommended actions for implementing the activities are elaborated in Sub Section 2.1 until 2.5.

2.1 Preparation of VR HSE Module (Fire Exit Training) by the Developer

The developer's task involves preparing the VR HSE module for Fire Exit Training. During this stage, the primary goal is to identify appropriate materials, encompassing various activity aspects,

specific details, and corresponding grading criteria. To facilitate the activities effectively, students were instructed to form groups consisting of 4 to 5 members. The determination of material requirements is a collaborative process, involving input and contributions from the activity proponents.

2.2 Dissemination of Information and Instructions to the Students

The educator in charge provided a video that showcases the steps involved in using VR for HSE purposes. This video serves as a preview for students as shown in Figure 3, offering them an understanding of what to anticipate during the learning activities, particularly when engaging in fire exit training using VR for the first time. Through this immersive experience, students are able to assume the role of a character and explore a realistic environment, simulating a visit to an oil rig and providing them with the opportunity to practice fire escape scenarios within the time given.
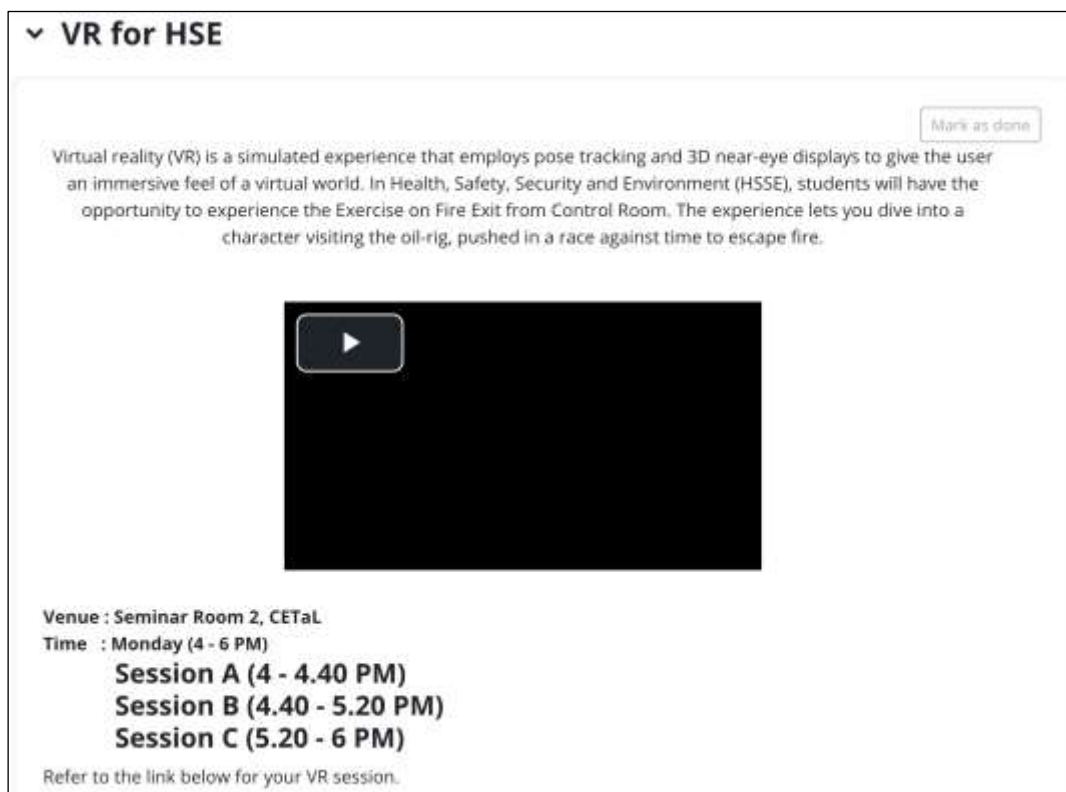
Fig. 3. VR instruction video posted on students' learning portal, ULearn

2.3 Implementation of Activities during Class

Students were provided with the chance to engage in fire exit training as can be seen in Figure 4, where they simultaneously received an immersive and innovative educational experience through the use of VR. By simulating and navigating real-life fire exit situations within a secure and regulated virtual environment, students had the opportunity to refine and practice their evacuation skills.

During the activity, the students enthusiastically participated in the VR simulation, immersing themselves in the challenges and decision-making processes associated with fire evacuation. They gained a comprehensive understanding of the importance of following proper fire safety measures and recognized the critical role that timely and effective evacuation played.

Students' understanding of fire safety protocols was strengthened by incorporating VR into fire exit training, which also created a sense of authenticity and active participation. Students gained a thorough awareness of the possible risks and the urgency involved with fire crises by fully immersing themselves in a virtual world.

Fig. 4. Students' learning activities using VR for Fire Exit Training

2.4 Summative Assessment – Creating Poster Incorporating the VR Elements

Students were required to design a poster that included the VR component utilized in fire exit training as part of the summative assessment. The goal of the poster was to graphically convey the immersive quality of the VR experience while emphasizing the importance and advantages of using VR to improve evacuation skills. Students were urged to create eye-catching posters using interesting graphics, photos, and text.

In order to illustrate the difficulties and decision-making processes associated with fire evacuation, students were encouraged to incorporate relevant and captivating graphics in their posters. Students could display scenes from the VR simulation that showed how they handled realistic fire exit circumstances and honed evacuation procedures. Students were also urged to include supporting figures or facts to highlight the significance of adhering to the right fire safety procedures and the essential relevance of prompt and efficient evacuation. From this activity, students showcased their creativity and communication abilities while demonstrating their understanding of the VR component of fire exit training through this assignment.

2.5 Getting Student's Feedback using a Questionnaire

A questionnaire was effectively used to obtain input from the students and to compile their ideas and viewpoints. This questionnaire was designed to gather information about respondents' opinions and experiences with the VR fire escape training exercise. The questionnaire was composed up of several comprehensive inquiries intended to elicit detailed input. The degree to which they felt the VR experience to be immersive and engaging was one of the general impressions that students were asked to provide. Additionally, they were urged to discuss any difficulties they had with the simulation and their opinions of the decision-making procedures involved in a fire evacuation.

Students were prompted to assess the efficiency of VR technology in improvement of their educational experience and its contribution to a greater grasp of fire safety procedures through the

use of a questionnaire. This made it possible to gather insightful input and facilitate a thorough assessment of the VR fire exit training session. As a result of the insights gained from the students' comments, the training program was refined and improved, guaranteeing that future students would gain from the learning experience.

3. Finding and Discussion

In class activities, groups of students have actively engaged in forming teams of 4 to 5 members with the objective of selecting a case study related to accidents reported in various industries in Malaysia. The purpose of this activity is to analyze the chosen case study and propose potential implementations of VR technology to mitigate or prevent similar accidents, ultimately minimizing their consequences.

Feedback regarding the utilization of VR in learning and teaching, particularly in the context of HSE was gathered through questionnaires completed by students from various courses as listed in Figure 5. The questionnaires included 14 specific questions related to the use of VR in HSE. The educator in charge provided a video that showcases the steps involved in using VR for HSE purposes.
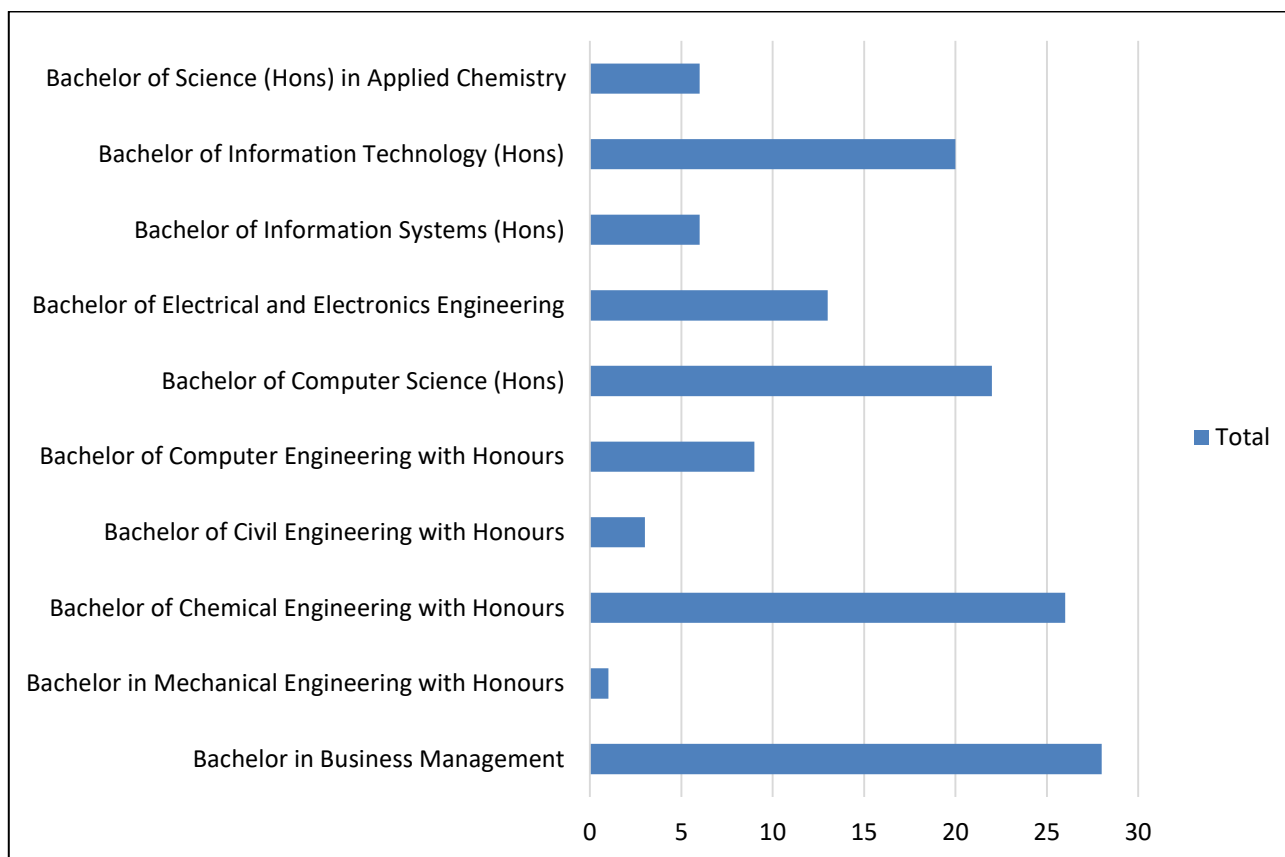
Fig. 5. Number of students from different courses

Figure 6 demonstrates that 116 students have engaged in the walkthrough session, which familiarizes them with the key locations on the oil rig before undertaking the fire evacuation activity, while 18 students have not participated. These findings suggest a noteworthy level of interest and preparedness among the majority of students, indicating their commitment to understanding the topic and acquiring the essential materials before commencing the activity.
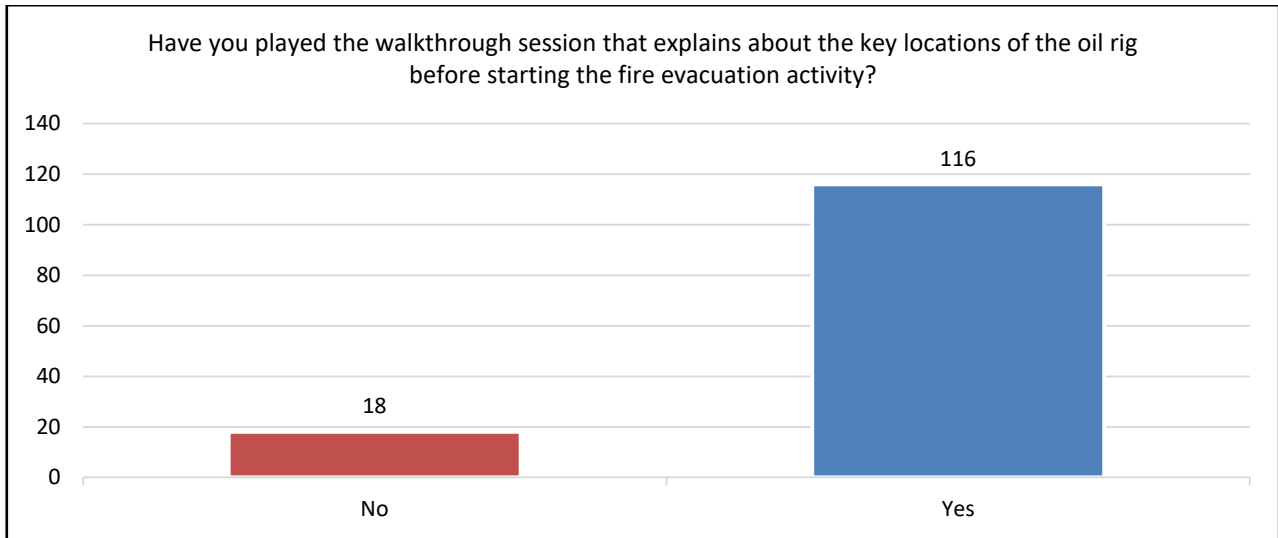
Fig. 6. Students played walkthrough session that explaining the key locations of the oil rig before starting the fire evacuation activity

During the lesson, it was observed that a significant proportion of students found the game to be easy as illustrated in Figure 8, and this can be attributed to the clarity of the instructions. This finding is supported by Figure 7, which indicates that 105 students considered the directions to be extremely clear.

Virtual reality (VR) technology provides numerous benefits, especially in hazardous and complex industrial environments, as it offers a secure and controlled training environment. By effectively bridging the gap between theoretical instruction and real-world applications, VR enhances opportunities for hands-on learning and promotes higher levels of engagement.
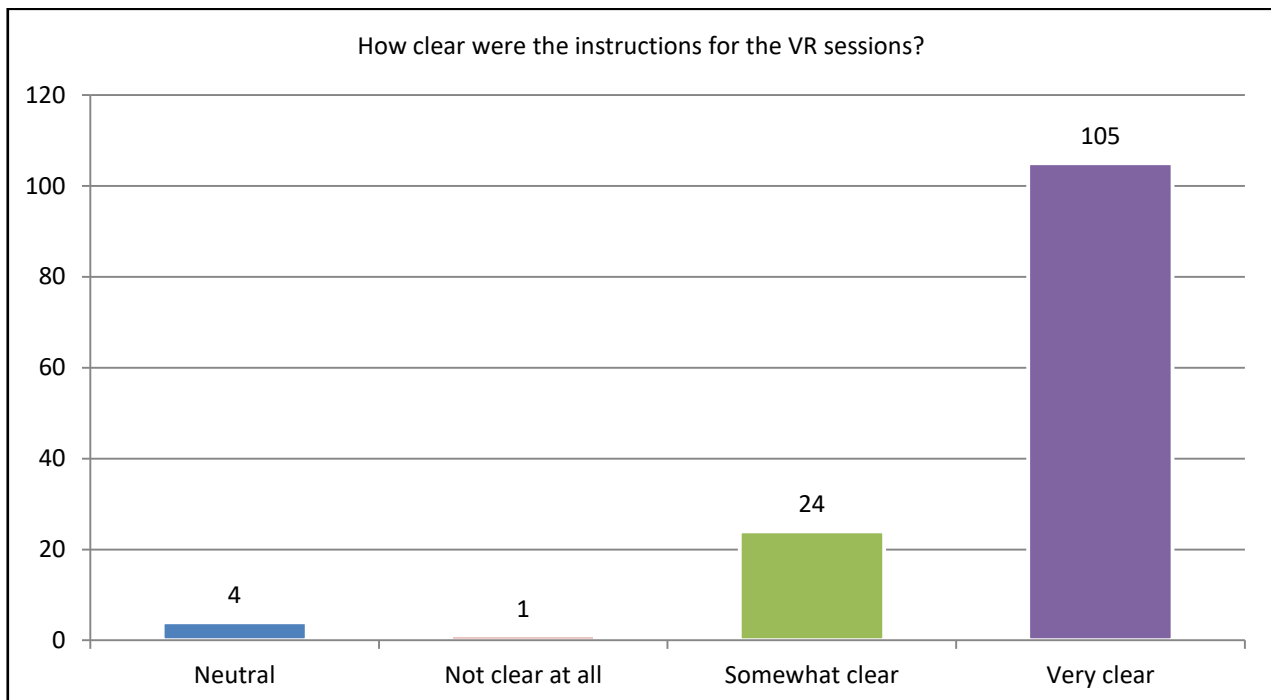
Fig. 7. The comprehensibility of the instructions provided for the virtual reality (VR) sessions
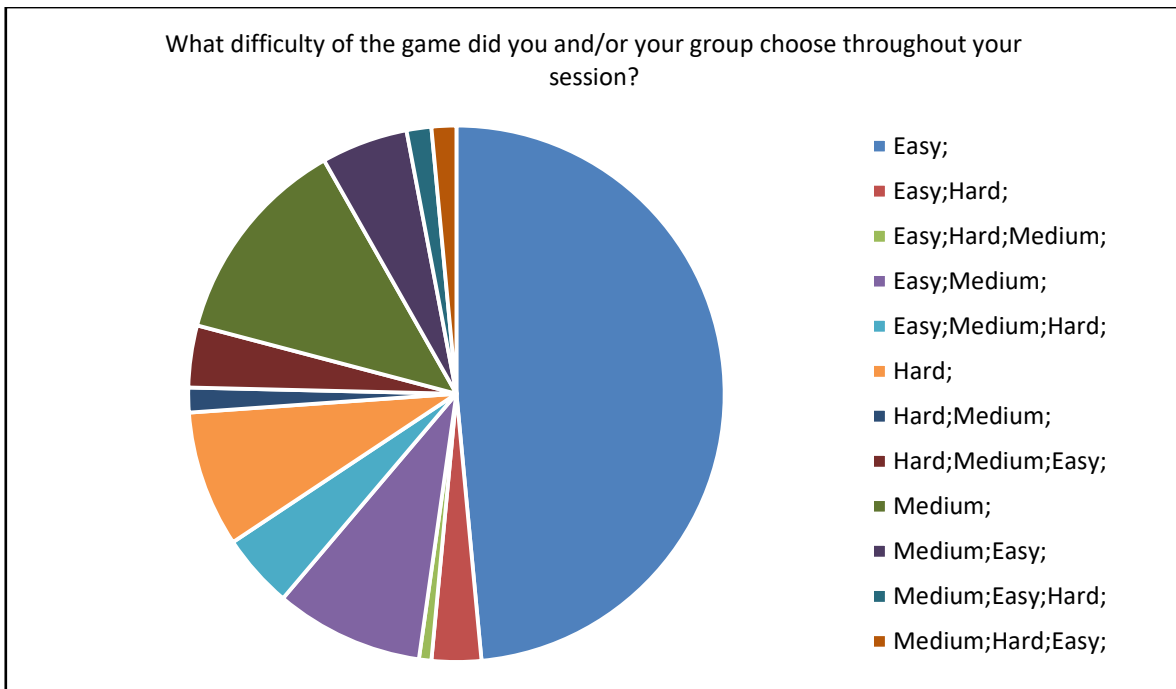
Fig. 8. The difficulty of the game throughout the sessions

In Figure 9, it can be observed that students made fewer game attempts during the session, indicating their successful completion of the game in fewer attempts. This suggests that the students likely had a clear understanding of how the game functioned, attributed to clear instructions and the user-friendly nature of the tool.
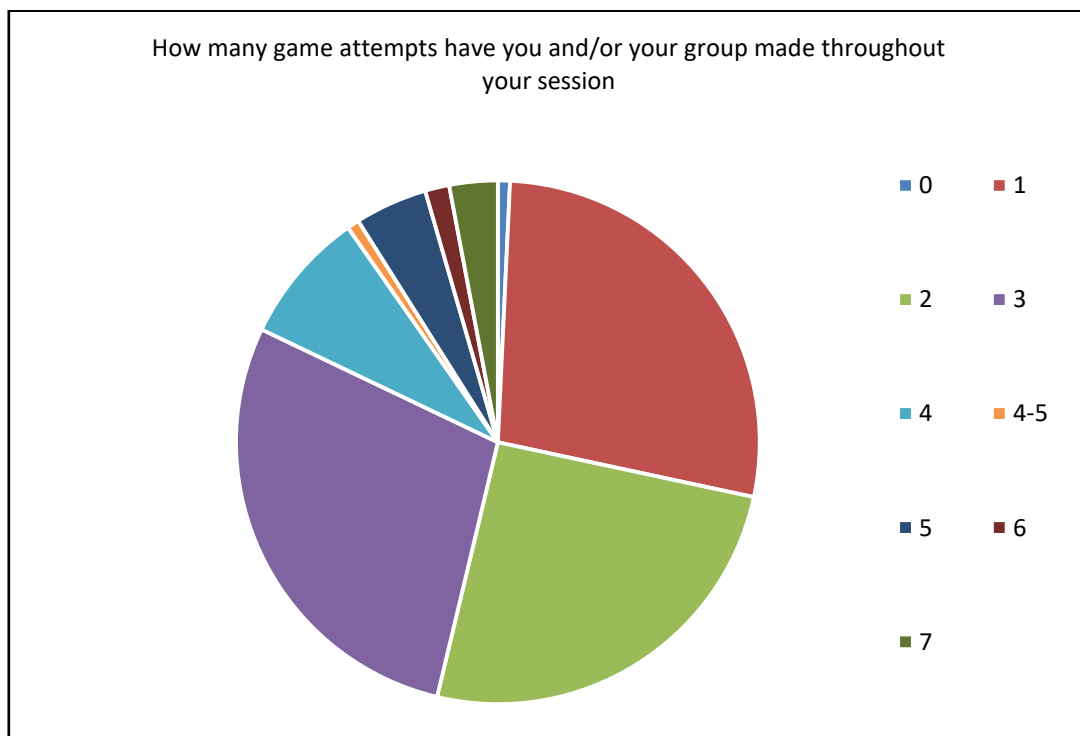

Fig. 9. Number of attempt each group made throughout the sessions

This assertion is supported by Figure 10, where the majority of groups completed the VR session within the estimated time.
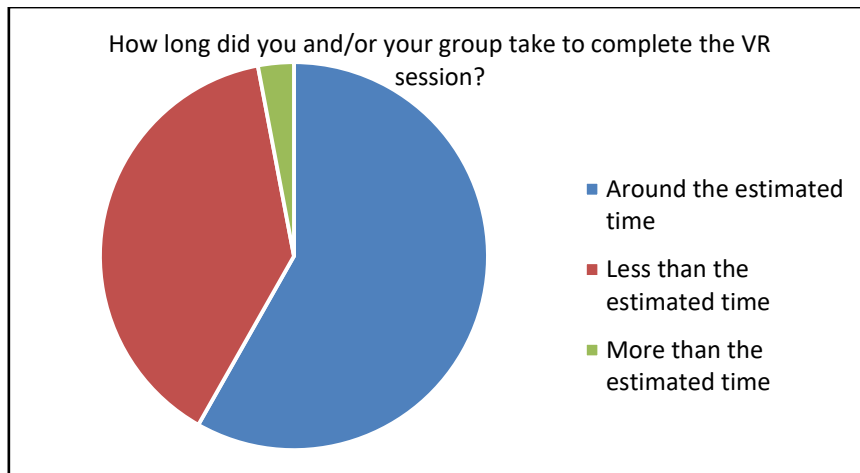
Fig. 10. The duration for groups to complete the VR session

From Figure 11 to 13 clearly demonstrated the success of the VR session in enhancing their understanding of the HSE subject. By simulating a fire hazard scenario, students were agreed that they were able to gain a clear comprehension of the necessary steps to take during a fire emergency on an oil rig.
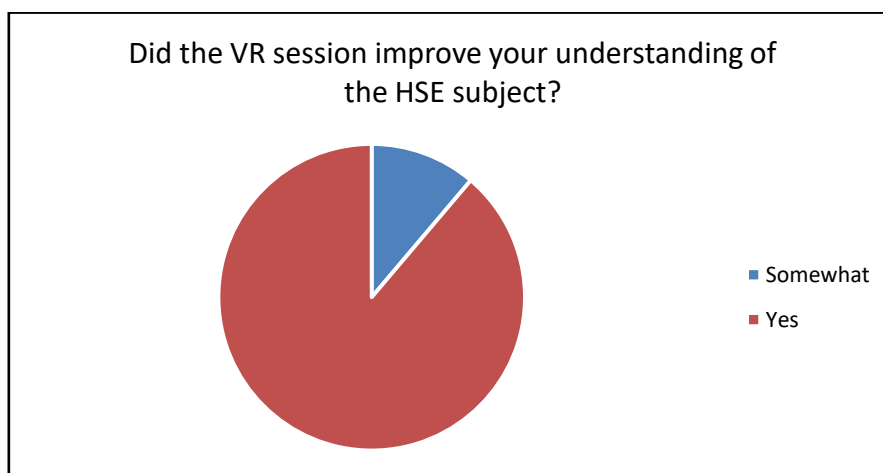

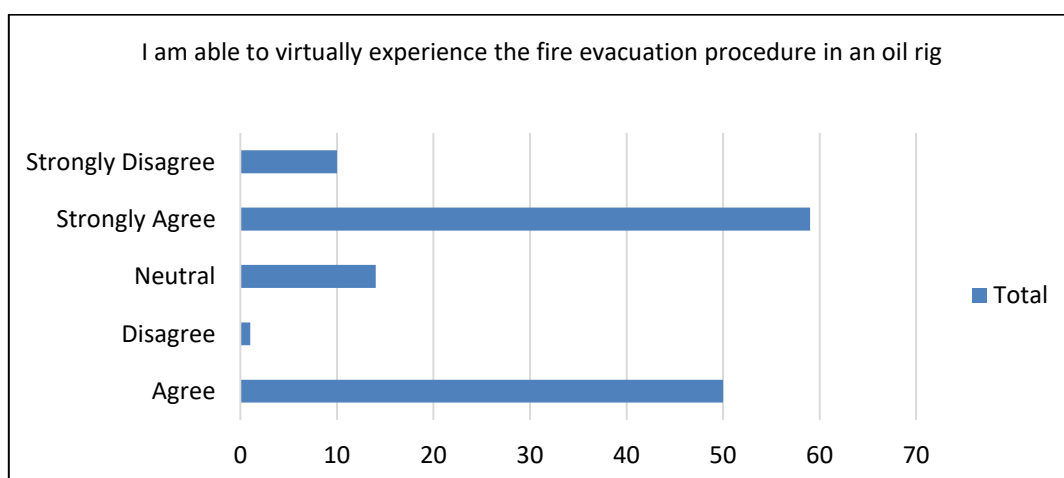**Fig. 11.** The level of understanding of HSE subject after VR session

Fig. 12. Students experience the fire evacuation procedure in an oil rig using VR
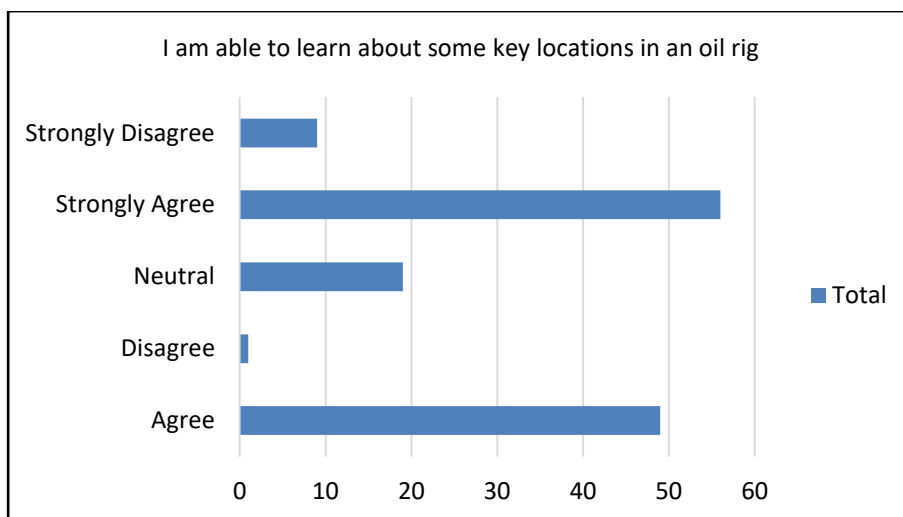
Fig. 13. The ability for students to identify key location in an oil rig using VR

By incorporating VR technology, Figure 14 proofs that students have been able to actively participate in navigating evacuation routes during fire hazards on an oil rig, providing an immersive and interactive training experience that enhances their understanding and awareness of real-life incidents in such environments. This experience contributes to the development and improvement of their skills, instilling confidence in effectively addressing safety challenges that may arise during on-site situations.
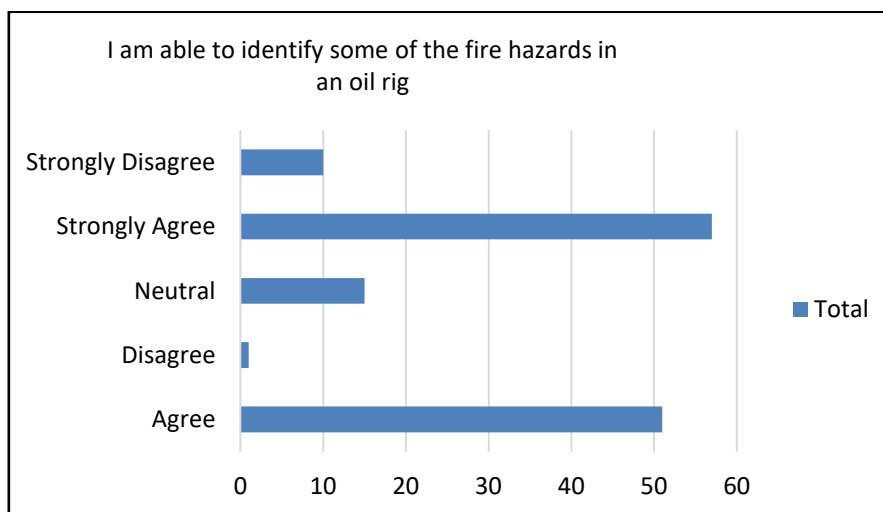

Fig. 14. The ability of students to identify fire hazards in an oil rig using VR

According to the findings in Figure 15, it is obvious that students find the use of VR as a teaching tool to be innovative and engaging. VR's ability to simulate various scenarios allows for the evaluation of decision-making skills and the effectiveness of evacuation plans. The extensive integration of VR into fire escape training programs enhances the overall learning experience, providing a comprehensive and effective instructional approach. Additionally, the adoption of VR technology facilitates students' understanding of the learning process. In line with the user-friendly controls and accessibility of the VR game further enhance students' learning experiences which an intuitive and responsive tool is essential for optimal engagement and comprehension as specified in Figure 16.
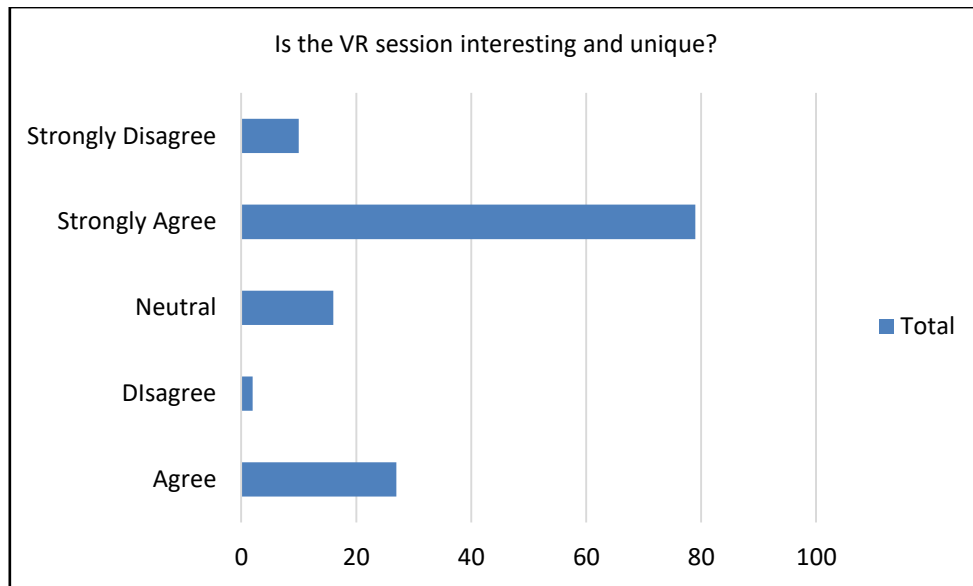
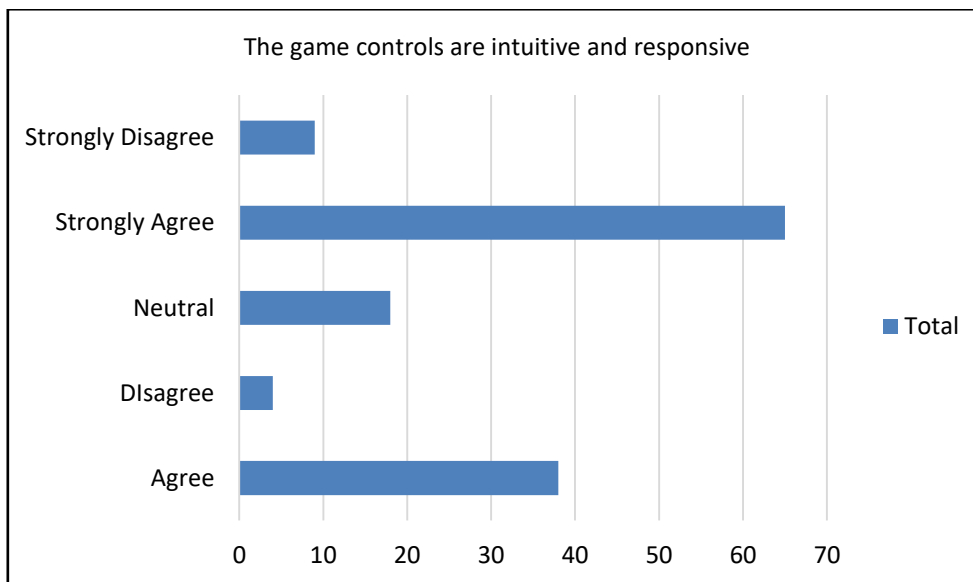**Fig. 15.** The student's opinion of VR session

Fig. 16. The intuitively and responsively of the game

The VR session was characterized by fewer technical difficulties, enhancing the ease and fluidity of learning for participants. With no interruptions or technical issues, students could fully engage with the VR content and focus on the learning objectives. This positive experience with minimal technological challenges increases the likelihood of students choosing VR gain for educational purposes in the future, as proven in Figure 17.

Due to its captivating and immersive qualities, as well as its capability to replicate real-life situations, VR possesses significant potential as an educational tool. As a result of their positive encounters, Figure 19 shows that most of the students are inclined to share their experiences with others, thereby acknowledging the value and effectiveness of VR for learning purposes. Figure 18 reveals that majority of the students would recommend VR to others as a tool for learning due for learning purposes.
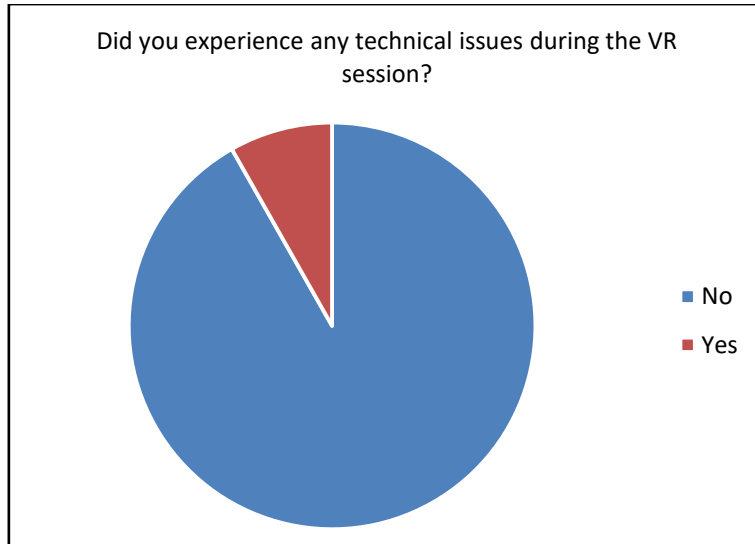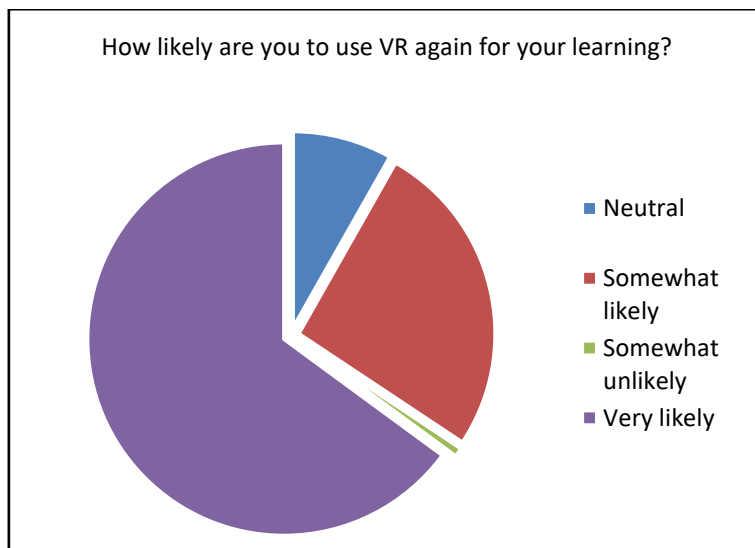
Fig. 17. Technical issue during VR session

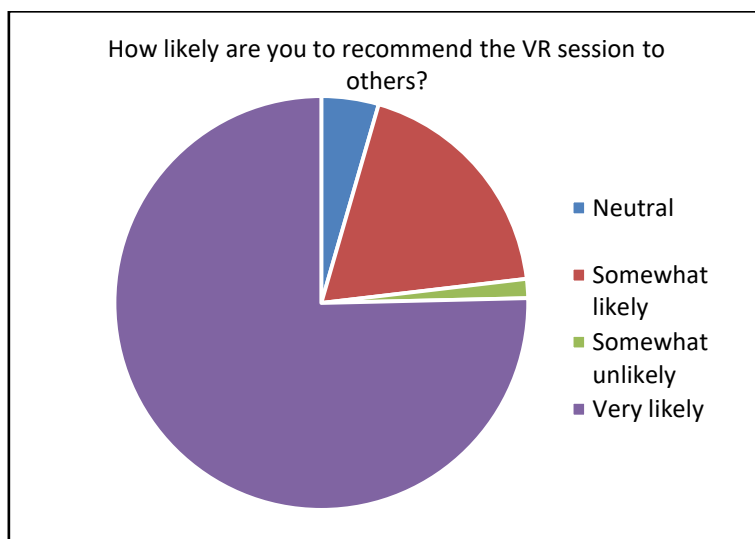**Fig. 18.** The likeliness to use VR again for learning

Fig. 19. The likeliness to recommend the VR session to others

4. Conclusions

In conclusion, research has shown that the use of virtual reality (VR) technology in learning and teaching, particularly in the field of health, safety, and the environment (HSE), has been successful and promising. Virtual reality (VR) has actively engaged students while also boosting their understanding of real-life situations and safety standards in a variety of classroom activities, such as case study analysis and walkthrough sessions. The VR application's importance in fostering successful learning experiences is shown by the good response from students, who emphasized the clarity of the instructions and the user-friendliness of the VR program.

VR technology offers a secure and controlled training environment that has proven beneficial in hazardous and complex industrial settings. By simulating various scenarios, VR enhances fire escape training programs by evaluating decision-making abilities and assessing evacuation strategies. The positive experiences and improved understanding of HSE subjects reported by students demonstrate the effectiveness of VR in enhancing knowledge and skill development. In conclusion, effective VR classroom integration improves student engagement, comprehension, and readiness in HSE. In a secure and regulated setting, VR provides students with a thorough and effective method of learning while preparing them for obstacles in the real world.

References

[1] Shamsudin, Nurshamshida Md, Nik Hasnaa Nik Mahmood, Abdul Rahman Abdul Rahim, Syazli Fathi Mohamad, and Maslim Masrom. "Virtual reality training approach for occupational safety and health: a pilot study." *Advanced Science Letters* 24, no. 4 (2018): 2447-2450. https://doi.org/10.1166/asl.2018.10977

[2] Durmuş, Umut, and Murat Günaydın. "Virtual Reality Based Decision Support Model for Production Process of Museum Exhibition Projects." *International Journal of Human–Computer Interaction* 40, no. 11 (2024): 2887-2904. https://doi.org/10.1080/10447318.2023.2175161

[3] Scorgie, D., Z. Feng, D. Paes, F. Parisi, T. W. Yiu, and R. Lovreglio. "Virtual reality for safety training: A systematic literature review and meta-analysis." *Safety science* 171 (2024): 106372. https://doi.org/10.1016/j.ssci.2023.106372

[4] Feng, Zhenan, Vicente A. González, Robert Amor, Ruggiero Lovreglio, and Guillermo Cabrera-Guerrero. "Immersive virtual reality serious games for evacuation training and research: A systematic literature review." *Computers & Education* 127 (2018): 252-266. https://doi.org/10.1016/j.compedu.2018.09.002

[5] Blume, Brian D., J. Kevin Ford, Timothy T. Baldwin, and Jason L. Huang. "Transfer of training: A meta-analytic review." *Journal of management* 36, no. 4 (2010): 1065-1105. https://doi.org/10.1177/0149206309352880

[6] Rendevski, Nikola, Diana Trajcevska, Mario Dimovski, Konstantin Veljanovski, Aleksandar Popov, Naile Emini, and Dimitar Veljanovski. "Pc vr vs standalone vr fully-immersive applications: History, technical aspects and performance." In *2022 57th International Scientific Conference on Information, Communication and Energy Systems and Technologies (ICEST)*, pp. 1-4. IEEE, 2022. https://doi.org/10.1109/ICEST55168.2022.9828656

[7] Johnson, S., Attfield, S. and Wiseman, R., "The benefits and challenges of immersive virtual reality training in construction." International Journal of Construction Education and Research, (2018).

[8] Sacks, Rafael, Amotz Perlman, and Ronen Barak. "Construction safety training using immersive virtual reality." *Construction Management and Economics* 31, no. 9 (2013): 1005-1017. https://doi.org/10.1080/01446193.2013.828844

[9] Kanade, Sameeran G., and Vincent G. Duffy. "Use of virtual reality for safety training: a systematic review." In *International Conference on Human-Computer Interaction*, pp. 364-375. Cham: Springer International Publishing, 2022. https://doi.org/10.1007/978-3-031-06018-2_25

[10] Wang, X. and Lai, J., "Exploring the effectiveness of virtual reality-based training for construction safety," Automation in Construction, vol. 101 (2019): 272–283.

[11] Checa, David, and Andres Bustillo. "A review of immersive virtual reality serious games to enhance learning and training." *Multimedia Tools and Applications* 79, no. 9 (2020): 5501-5527. https://doi.org/10.1007/s11042-019-08348-9

[12] Wang, Peng, Peng Wu, Jun Wang, Hung-Lin Chi, and Xiangyu Wang. "A critical review of the use of virtual reality in construction engineering education and training." *International journal of environmental research and public health* 15, no. 6 (2018): 1204. https://doi.org/10.3390/ijerph15061204

[13] Seo, Hyun Jeong, Gyu Mi Park, Minjie Son, and Ah-Jeong Hong. "Establishment of virtual-reality-based safety education and training system for safety engagement." *Education Sciences* 11, no. 12 (2021): 786. https://doi.org/10.3390/educsci11120786

[14] Patrão, Bruno, and Paulo Menezes. "A virtual reality system for training operators." *International Journal of Online Engineering* 9, no. S8 (2013): 53. https://doi.org/10.3991/ijoe.v9iS8.3383

[15] Lovreglio, Ruggiero, Xinyue Duan, Anass Rahouti, Robyn Phipps, and Daniel Nilsson. "Comparing the effectiveness of fire extinguisher virtual reality and video training." *Virtual Reality* 25, no. 1 (2021): 133-145. https://doi.org/10.1007/s10055-020-00447-5

[16] Xue, Liangchao, Christopher J. Parker, and Helen McCormick. "A virtual reality and retailing literature review: Current focus, underlying themes and future directions." *Augmented reality and virtual reality: The power of AR and VR for business* (2019): 27-41. https://doi.org/10.1007/978-3-030-06246-0_3

[17] Chardonnet, Jean-Rerny, Cédric Di Loreto, Julien Ryard, and Alain Housseau. "A virtual reality simulator to detect acrophobia in work-at-height situations." In *2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, pp. 747-748. IEEE, 2018. https://doi.org/10.1109/VR.2018.8446395

[18] Agazio, Janice B., Constance C. Pavlides, Caterina EM Lasome, Norma J. Flaherty, and Rebecca J. Torrance. "Evaluation of a virtual reality simulator in sustainment training." *Military Medicine* 167, no. 11 (2002): 893-897. https://doi.org/10.1093/milmed/167.11.893

[19] Shiradkar, Sayli, Luis Rabelo, Fahad Alasim, and Khalid Nagadi. "Virtual world as an interactive safety training platform." *Information* 12, no. 6 (2021): 219. https://doi.org/10.3390/info12060219

[20] Schwebel, David C., Joan Severson, Yefei He, and Leslie A. McClure. "Virtual reality by mobile smartphone: improving child pedestrian safety." *Injury prevention* 23, no. 5 (2017): 357-357. https://doi.org/10.1136/injuryprev-2016-042168