International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 7 Issue 22 (September 2025) PP. 99-108
DOI 10.35631/IJIREV.722007

INTERNATIONAL JOURNAL OF INNOVATION AND INDUSTRIAL REVOLUTION (IJIREV)
www.ijirev.com

SAFETY PRACTITIONERS' PERCEPTIONS OF VIRTUAL REALITY GAMES AS TRAINING TOOLS IN CONSTRUCTION SAFETY EDUCATION

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Article Info:

Article history:
Received date: 30.06.2025
Revised date: 21.07.2025
Accepted date: 14.08.2025
Published date: 01.09.2025

To cite this document:

Mohd, N. I., Ali, K. N., Ahmad Fauzi, A. F. A., Sunar, M. S., Yusof, Y., & Jamaludin, S. H. (2025). Safety Practitioners' Perceptions of Virtual Reality Games as Training Tools in Construction Safety Education. *International Journal of Innovation and Industrial Revolution, 7* (22), 99-108.

Abstract:

The integration of virtual reality (VR) technology into safety education has emerged as a transformative approach to enhance learning outcomes in high-risk industries such as construction. As traditional training methods often lack engagement and realism, VR games offer immersive, interactive, and risk-free environments for learners to practice hazard recognition and safety protocols. However, understanding the perspectives of safety practitioners is essential to evaluating the practicality and acceptance of such tools in real-world settings. This study examines safety practitioners' perceptions of virtual reality (VR) games as training tools in construction safety education. Using a structured questionnaire, data were collected from a purposively selected group of 88 respondents, comprising Safety and Health Officers (SHO), contractors, Department of Occupational Safety and Health (DOSH) officers, and other stakeholders within the construction industry. The questionnaire focused on five key components: hazard recognition, scenario navigation, precautionary training, environmental familiarity, and hazard pattern identification. Descriptive analysis revealed that respondents strongly agreed on the effectiveness of VR in all areas, with mean scores ranging from 4.09 to 4.22

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on a 5-point Likert scale. The highest agreement was found in VR's ability to familiarise workers with hazardous environments (mean = 4.22), followed closely by navigating hazardous scenarios (mean = 4.21). These findings suggest that safety practitioners view VR games as a valuable supplement to conventional training, capable of enhancing safety awareness, behaviour, and preparedness on construction sites. In conclusion, VR games are perceived as effective, engaging tools that can support the development of a more proactive safety culture in the construction industry. Further development and implementation of VR-based training modules are recommended to strengthen their role in occupational safety education.

Keywords:

Virtual Reality (VR), Construction Safety, Safety Education, Training Tools, Safety Practitioners' Perceptions

Introduction

The integration of virtual reality (VR) games as training tools in safety education represents a significant advancement in educational technology, offering immersive and interactive learning experiences that traditional methods often fail to provide. The application of VR in safety training spans various high-risk industries, including chemical engineering, construction, healthcare, and civil aviation, where it has been shown to enhance engagement, motivation, and knowledge retention among trainees (Bader et al., 2023; Chan et al., 2023; Li & Yu, 2023; Udeozor et al., 2021). This research aims to explore the efficacy of VR games in safety education, highlighting their potential to transform conventional training paradigms and improve safety outcomes.

Recent studies have demonstrated the growing adoption of VR technology in safety training, driven by its ability to simulate realistic and hazardous scenarios without exposing trainees to actual risks. For instance, VR has been effectively utilised in chemical engineering to provide contextual learning experiences that are both engaging and safe (Udeozor et al., 2021). Similarly, in the construction industry, VR-based training has been shown to enhance hazard identification, assessment, and response skills, thereby fostering a preventive safety culture (Bader et al., 2023). The use of VR in healthcare settings, such as fire safety training, has also proven more effective than traditional slide-based lectures, enhancing knowledge acquisition and retention (Rahouti et al., 2021) .

Moreover, the application of VR in safety training is not limited to professional environments. Studies have shown that VR can be used to teach children about fire hazards and escape techniques, making the learning process more engaging and effective (Smith & Ericson, 2009). The versatility of VR technology extends to various domains, including food safety, road safety, and occupational safety and health (OSH) training, where it has been shown to improve safety awareness and behaviour (Lee et al., 2022; Muhammad Amirul Fawwaz Nik Abdullah et al., 2022; Pribadi et al., 2023a) .

Virtual Reality for Safety Education

Virtual reality (VR) has emerged as a powerful tool for safety education, providing immersive and realistic environments where trainees can practice recognising and responding to hazards without exposure to real risks (Chiu & Tsuei, 2022; Isleyen & Duzgun, 2019; Yoo et al.,

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2017). This technology is particularly beneficial in high-risk industries such as mining, construction, and manufacturing, where traditional training methods may not adequately prepare workers for real-world dangers (Isleyen & Duzgun, 2019; John et al., 2020; Patil et al., 2023) . VR simulations allow for the creation of various hazardous scenarios, enabling trainees to develop critical decision-making skills in a controlled, risk-free setting (Isleyen & Duzgun, 2019; John et al., 2020) .

Effectiveness of VR in Enhancing Safety Knowledge

Studies have shown that VR significantly improves safety knowledge and awareness compared to traditional training methods. A meta-analysis revealed that VR has a significant effect on motivation, a medium effect on presence and safety knowledge, and a negligible effect on safety behaviour (Chiu & Tsuei, 2022). Additionally, VR-based training has been found to enhance the understanding of occupational safety and health (OSH) concepts, leading to better hazard recognition and risk assessment (Pribadi et al., 2023a, 2024) . For instance, VR training in the electrical sector has demonstrated significant improvements in OSH understanding among workers.

Practical Applications and Benefits

The field of VR-based safety training has seen several recent developments aimed at enhancing the effectiveness and accessibility of these tools. One notable trend is the incorporation of game-based learning elements, which have been shown to increase motivation and engagement among trainees (Chan et al., 2023; Hasan, 2023). For example, the VR LaboSafe Game used in chemical industry training significantly boosted intrinsic motivation and engagement, suggesting that gamified VR experiences can make safety training more appealing and effective (Chan et al., 2023) . Additionally, the concept of 'virtual training pills'—short, focused educational games—has emerged as a promising approach to delivering safety training content in a more digestible and impactful manner (Longo et al., 2021) .

VR's practical applications in safety education are vast. In the construction industry, VR has been utilised to simulate hazard recognition tasks, leading to improved safety scores and increased trainee engagement (Wu et al., 2020). Similarly, VR-based training in manufacturing settings has demonstrated effectiveness in identifying safety violations and reducing workload (Gramopadhye et al., 2014). The immersive nature of VR also enables the simulation of complex scenarios, such as underground mining hazards, where trainees can practice installing safety measures like rock bolts (Isleyen & Duzgun, 2019).

Challenges and Moderating Factors

Despite its benefits, implementing VR in safety education faces challenges such as high costs, infrastructure requirements, and the need for instructor training (Leong, 2024). Additionally, factors like locomotion and the quality of VR training can moderate its effectiveness. For example, the better technical quality of VR training has been linked to improved performance in skill application (Oppermann et al., 2024). Moreover, the training context and the experience level of trainees significantly impact the outcomes of VR-based safety education (Man et al., 2024).

Future research should focus on exploring more independent and moderating variables to optimise VR's effectiveness in safety education (Chiu & Tsuei, 2022) . There is also a need to develop standardised design principles for VR safety training to ensure consistency and

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reliability across different industries (Haj-Bolouri & Rossi, 2021) . As VR technology continues to evolve, its potential to transform safety education and training will likely expand, offering innovative solutions to enhance workplace safety and reduce accident rates (Pribadi et al., 2024; Retnanto et al., 2019).

Significance of the Research

The significance of using VR games as training tools in safety education lies in their potential to revolutionise traditional training methods. VR technology offers a unique combination of immersion, interactivity, and realism, which can lead to better learning outcomes and safer work environments. By providing trainees with hands-on experience in a controlled virtual setting, VR can help bridge the gap between theoretical knowledge and practical application, ultimately reducing the incidence of work-related accidents and injuries (Wu et al., 2020; Yoo et al., 2017).

Furthermore, the scalability and adaptability of VR technology make it an ideal solution for a wide range of training scenarios. Whether it is training construction workers on hazard identification, educating healthcare staff on fire safety procedures, or teaching children about fire escape techniques, VR games can be tailored to meet the specific needs of different audiences (Le et al., 2015; Smith & Ericson, 2009). As research in this field continues to evolve, the integration of VR into safety education is expected to become more widespread, offering new opportunities for enhancing safety training across various industries.

Methodology

This study employed a structured questionnaire to capture practitioners' perceptions regarding the development of a game-based learning storyline in the field of occupational safety and health. The main objective was to gather informed feedback from relevant stakeholders to guide content design and ensure contextual relevance. Participants were selected using purposive sampling to ensure that only individuals with direct experience and domain knowledge were included. The selected respondents included Safety and Health Officers (SHOs), contractors, Department of Occupational Safety and Health (DOSH) officers, and other relevant stakeholders. This sampling strategy is suitable for targeting specific professional groups who possess the insights required for content validation (Restrepo-Tamayo & Gasca-Hurtado, 2023).

The questionnaire was developed based on the key areas discussed during a focus group session, with items designed to assess the practicality, relevance, and educational value of the proposed game elements. To ensure clarity and relevance, the questionnaire items were structured to be concise and easily understood by practitioners from diverse technical backgrounds (Joungtrakul et al., 2025). The instrument was administered directly after the brainstorming session, allowing participants to reflect on the ideas discussed and provide immediate feedback. This timing also helped improve response accuracy and engagement, consistent with best practices in structured data collection during collaborative sessions (Turauskas & Vaitkuniene, 2004).

Upon collection, responses were reviewed for completeness and analysed to identify patterns in perception and areas of consensus or concern. The results provided valuable input for aligning the game plot with real-world expectations, particularly regarding the effectiveness of safety training and stakeholder engagement. By using a well-targeted questionnaire supported

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by expert sampling, this method ensured that the development process was guided by practical insights grounded in the professional experiences of the intended audience (Understanding Communication Research Methods, 2024).

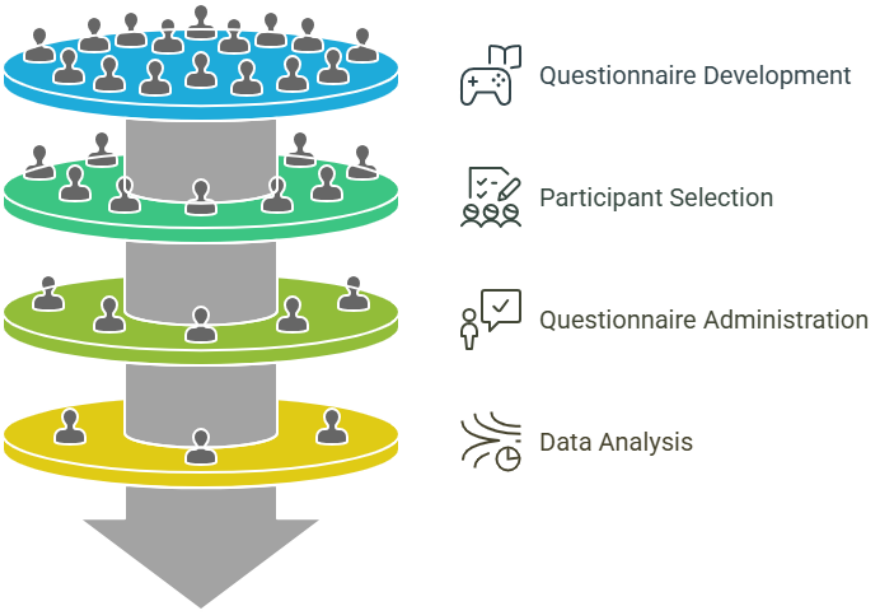

Figure 1: Data Collection Process

Results and Findings

Respondents' Background

The distribution of respondents' years of experience, as illustrated in Figure 2, provides insight into the professional backgrounds of the participants involved in the study. All respondents are safety practitioners actively engaged in the construction industry, representing a diverse range of experience levels. The most significant proportion of participants, accounting for 34.15% (n = 28), reported having between 5 and 10 years of industry experience. This indicates that a significant portion of the group comprises mid-career professionals who possess both practical exposure and a developing depth of expertise in managing safety on construction sites.

The second-largest group consisted of individuals with less than five years of experience, representing 27.00% (n = 22) of the sample. These early-career safety practitioners bring fresh perspectives and current knowledge of contemporary site practices and safety standards. Meanwhile, 21.95% (n = 18) of respondents reported having 10 to 15 years of experience, indicating a considerable presence of experienced professionals with comprehensive knowledge of safety protocols and risk management in construction environments.

Participants with over 15 years of experience constituted a smaller segment of the sample. Specifically, 10.98% (n=9) had 15 to 20 years of experience, and 6.10% (n=5) had more than 20 years. While these groups were smaller in number, their extensive field exposure offered valuable insights grounded in long-term engagement with evolving construction safety practices. Overall, the wide distribution of experience levels among construction safety practitioners in this study contributes to a rich dataset, enabling a well-rounded understanding of industry needs and challenges.

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DOI 10.35631/IJIREV.722007

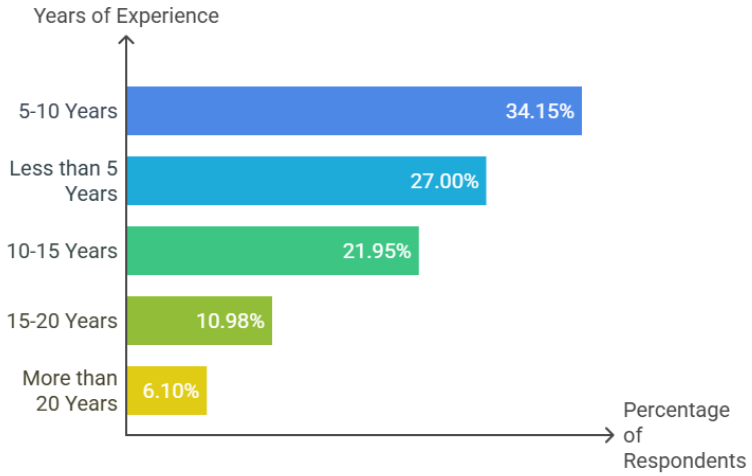

Figure 2: Years of Industry Experience of Respondents

Safety Practitioner Perception of the Use of VR Technology in Safety Education

The perception of safety practitioners towards the application of virtual reality (VR) in safety education is generally positive, as reflected in the high mean scores across all measured components. Table 1 demonstrates that practitioners recognise the practical advantages of VR in replicating real-world hazards in a controlled and immersive training environment. This aligns with existing literature that supports the efficacy of VR in enhancing training quality, engagement, and safety awareness (Bader et al., 2023; Udeozor et al., 2021).

Table 1: Safety Practitioner Perception Towards Safety Education Using Virtual Reality

No.	Safety Education Components	Mean
1	VR can enhance hazard recognition skills	4.15
2	VR can help navigate workers in hazardous scenarios	4.21
3	VR can train workers to be more precautious	4.15
4	VR can be familiar with hazardous environment	4.22
5	VR can help workers identify patterns of hazard	4.09

Enhancing Hazard Recognition and Environmental Familiarity

The highest mean score (4.22) was recorded for the component stating that "*VR can be familiar with hazardous environment*," followed closely by "*VR can help navigate workers in hazardous scenarios*" (mean = 4.21). These findings suggest that safety practitioners value VR's capability to simulate realistic, high-risk environments. Such simulations enable workers to gain exposure to hazardous conditions without putting them in actual danger. This perception is supported by Isleyen & Duzgun, (2019), who emphasised the benefit of immersive training for preparing workers in high-risk fields such as mining and construction. Similarly, John et al., (2020) noted that realistic simulations help trainees internalise hazard dynamics more effectively than conventional methods.

Skill Development and Pattern Recognition

VR was also positively perceived as a tool for developing hazard recognition skills (mean = 4.15) and instilling precautionary behaviour (mean = 4.15). These components reflect the belief that VR can significantly contribute to the behavioural aspect of safety training by reinforcing

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EISSN: 2637-0972
Volume 7 Issue 22 (September 2025) PP. 99-108
DOI 10.35631/IJIREV.722007
safe practices and encouraging critical thinking in complex situations. Previous studies have affirmed that VR facilitates a better understanding of occupational safety and health (OSH) concepts by allowing repetitive and varied exposure to hazardous scenarios (Chiu & Tsuei, 2022; Pribadi et al., 2023b). The ability to practice and learn from errors in a no-risk environment enhances both confidence and competence.

Furthermore, the perception that *"VR can help workers identify patterns of hazard"* (mean = 4.09) reflects recognition of the cognitive benefits of VR. Through repetitive simulations, workers are exposed to recurring themes and indicators of danger, thereby improving their pattern recognition over time. This aspect of training is essential in preventing accidents and was highlighted in studies, such as Wu et al. (2020), which found that VR-supported safety training improved hazard detection and responsiveness in construction settings.

Implications for Safety Education and Future Directions

These perceptions underscore a shift in the mindset of safety practitioners towards more technologically driven training methods. The strong support for VR-based safety education suggests that its integration into training programs is not only feasible but also encouraged by those directly involved in site safety. However, while positive perceptions are a critical first step, effective implementation requires addressing barriers such as equipment cost, training for instructors, and standardisation of content (Leong, 2024; Oppermann et al., 2024)

The findings align with calls from researchers for broader adoption of immersive tools in safety education. As emphasised by Chiu & Tsue (2022), future studies should investigate moderating variables, such as trainee experience, industry type, and technical quality, to further optimise training outcomes. Developing clear instructional design principles, as suggested by Haj-Bolouriand Rossi (2021), will also be essential in scaling VR training across various sectors.

Conclusion

The findings of this study reveal a strong and consistent positive perception among safety practitioners regarding the use of virtual reality (VR) technology in safety education. The high mean scores across various components, including enhanced hazard recognition, navigation through hazardous scenarios, improved precautionary behaviour, and familiarity with dangerous environments, these insights are consistent with previous literature, which highlights the ability of VR to replicate real-world risks in a safe, controlled, and immersive setting, thereby enhancing knowledge retention, motivation, and decision-making skills.

The application of VR was particularly valued for its capacity to simulate realistic scenarios that allow trainees to engage with and learn from high-risk situations without actual exposure. Practitioners recognised VR's potential not only to reinforce safety procedures but also to develop pattern recognition skills crucial for anticipating and mitigating hazards. These results suggest that VR can play a crucial role in advancing traditional training methods, bridging the gap between theoretical instruction and practical experience in industries where safety is paramount.

In conclusion, the use of VR games in safety education represents a significant advancement in training methodologies. By leveraging the immersive and interactive capabilities of VR technology, educators and trainers can create more engaging and effective learning experiences that improve safety outcomes and foster a culture of prevention. As the field continues to

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develop, further research and innovation will be essential in maximising the potential of VR-based safety training tools. In summary, VR is a transformative tool in safety education, offering immersive, risk-free training environments that significantly enhance safety knowledge and awareness. While challenges remain, the benefits of VR in preparing workers for hazardous situations are clear, making it a valuable addition to traditional training methods. Continued research and development will further solidify VR's role in creating safer workplaces across various industries.

Acknowledgements

This article is part of research titled *"Gamification Content Design of Mixed-Reality Environment for Construction Project's Hazard Identification, Risk Assessment and Risk Control (HIRARC) Training Module"*, funded under the R.J130000.7352.4B894 by the National Institute of Occupational Safety and Health (NIOSH).

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