Application of Digital Simulation for Training Purposes Through Virtual Reality in The Workplace

Ari Prayogo Pribadi, Vena Jaladara, Chris Dwina Anggiana Br Silalahi, Yusuf Mukasyafah Rizqi Rahman

Department of Health Behaviour Environment and Social Medicine, Faculty of Medicine, Public Health and Nursing, Gadjah Mada University, Yogyakarta, Indonesia
Jl. Farmako Sekip Utara, Yogyakarta 55281 Indonesia

ABSTRACT

Introduction: The International Labor Organization (ILO) considers OSH awareness an essential component of OSH training and education. In addition, virtual reality possesses a unique set of characteristics and components and envisaged that by minimizing the risk of accidents during health and safety training. The aim of the research is to further understand the practicality, user experience and efficacy of virtual reality technology in safety education and training. **Method:** This paper describes and discusses the VR on occupational safety and health. This paper used the Systematic Literature Review to identified 16 articles that are related to VR on occupational safety and health. Articles are written in English and reviews of scientific journals published in the following internet databases; Scopus, SpringerLink, Web of Science, and Wiley Interscience from 2017 to 2023. **Results:** The incorporation of Virtual reality (VR) into numerous settings has been demonstrated by research conducted on literature reviews. This review found that VR applications can be used to investigate human behavior in dangerous situations in many settings, VR can also be used to create an innovative learning environment in the high-risk sectors, simulate a realistic physical environment and provide experience to enhance knowledge of workplace safety. Moreover, it has been demonstrated that VR has positive impact on learning about increasing OSH awareness. **Conclusion:** Several studies have shown that virtual reality is one of the most effective training methods at present. It is believed that the application of VR technology could be used to investigate human behavior in dangerous settings; Additionally, VR can be used to improve HSE employers' understanding of unsafe behavior. The VR improves learning about OSH awareness, risk assessment, and recognizing health concerns.

Keywords: occupational safety and health, safety education, virtual reality, VR training

Corresponding Author:
Ari Prayogo Pribadi
Email: ari.prayogo.p@ugm.ac.id
Telephone: +6281286447994

INTRODUCTION

Every occupation contains hazards that might have adverse consequences on employees and the workplace. According to the 2017 Global Estimate of Occupational Accidents and Work-Related Disease, 5% of all global deaths are work-related. Two-thirds of all work-related deaths worldwide are attributable to the Asian region, followed by Africa (11.8%) and Europe (11.1%) (Hämäläinen, Takala and Kiat, 2017).

The majority of accidents in Indonesia, as reported by the Employment Social Security Administration Agency (BPJS), occur in the workplace. Over the past five years, the number of workplace accidents has risen. In 2017, there were 123,040 cases of workplace accidents. This demonstrates the company's obligation and responsibility to priorities employee safety and health (National Occupational Safety and Health Profile in Indonesia, 2018). occupational safety and health help protect workers and their property to reduce losses. Education and training activities are an engineering solution that can be used to reduce the risk of accidents occurring among workers. Furthermore, Acquisition of training can be utilized in several sectors (Alli, 2008).

Safety education is important to get workers familiar and increase awareness of the potential hazards that may be encountered while doing work as well as fostering an OHS culture and behavior. The training and education approach can be carried out in various ways, the more comprehensive the educational approach, the better the outcome will be (Alli, 2008).

Most of the OSH education and training methods conducted in Indonesia are still quite conventional. This approach has several drawbacks, including boring and low engagement. Whereas training for the workforce is very useful to avoid work accidents and to optimize and increase productivity for the company. Effective training is expected to be able to create appropriate environment and also focusing to safety aspects as well as hazards and risks when conducting the training (Alli, 2008).

Utilizing technological advances is one of the available options. Industrial Revolution 4.0 is a means of communicating with one another in real-time and at any time using the internet and CPS technology to create new values or other optimizations that can be presented in every industrial process (Prasetyo and Sutopo, 2018). Optimizing job and personal performance for fulfilment and success is in the public interest (Nurrohman, 2017). Work can go smoothly if productivity rises and there are no workplace issues.

Virtual Reality (VR) provides an opportunity to enhance and learn experiences. VR offers a unified workspace for all functions located in the same physical environment. VR applications in safety training can be designed to provide visual, physical and tactical experiences that indirectly maximize the effect of safety education. Scenarios in VR will be designed in order to workers can feel and solve work safety problems and avoid accidents (Bin *et al.*, 2019).

VR Application

Since its inception more than two decades ago, Virtual Reality (VR) has been utilized and proven effective in numerous sectors and educational fields. Virtual reality (VR) mimics 3D computer models to generate artificial situations in which users are immersed and able to interact with 3D worlds. Yet, 3D-based VR has visual restrictions in the actual world (Radianti *et al.*, 2020).

It has been shown that safety education and training improve safety performance in a variety of industries. Through safety education and training, project personnel can gain a greater understanding of potential hazards on sites and effective mitigation strategies. Effective safety education and training contributes to a reduction in the number of fatal and seriously injured on site accidents. (Podgórski, 2021).

VR training assisted the operators in making quicker, more effective decisions following the accident Through safety toolbox meetings, specific training classes, university safety programs, and on-the-job training, potential hazards are typically identified presently, the majority of safety training courses are conducted on several settings through the use of extensive instructional presentations and films. Workers receive full information regarding site dangers and hazards, as well as safe behaviors and practices, as a result of these training programs, which are provided to them (Xu and Zheng, 2021).

The majority of the current papers focused on how virtual reality is being used in several industries to increase occupational health and safety knowledge and safety training. Although the scientific community appears to be in agreement about the potential VR has to improve workplace safety, few businesses actually using VR for safety training and improve their knowledge.

According to Guo, Yu and Skitmore (2017), virtual reality technology has a legitimate application during the preparation phase, as it improves safety training and makes it simpler to identify and control work hazards. This technology increases the student's interest in safety training, which is a good thing.

Scope and Objectives of this Paper

Health and safety-focused virtual reality training is the primary focus of this study. These tasks carry a high risk of occupational accidents. Therefore, VR training is required to reduce workplace accidents. The aim of this paper is to conduct a comprehensive systematic literature review that examines the application of digital simulation, particularly through virtual reality (VR), for training purposes in the workplace.

The focus of this review is to explore the utilization of digital simulation technologies, with an emphasis on VR, in enhancing training processes

and outcomes across various industries and work settings. We compiled scientific research on the use of virtual reality in training activities. In addition, the results of this publication can be used to conduct additional research on the application of VR as a training tool for Indonesian employees and graduate students.

METHOD

Method of Literature Review

This study has identified articles and reviews of scientific journals published in the following internet databases; Scopus, SpringerLink, Web of Science, and Wiley Interscience from 2017 to 2022. The search profile covered the following topics: Virtual reality, Occupational safety and health, Virtual reality for safety education and training

Research Question

This research question's objective is to assist you to understand what will be performed during the overview of the literature. Research questions also make data collection simpler.

The research question for this study are, how is the experience, application and the impact in using virtual reality, how many participants were involved in this research and how VR can increase knowledge and awareness about occupational safety and health. Table 1 shows the PICOs and the selected criteria to identify the articles.

Table 1. PICOs and Selected Criteria

| PICOs	Inclusion Criteria	Exclusion Criteria
Population	University Student and Workers who are trained through virtual reality on occupational safety and health	Individuals who are not utilizing virtual reality for their training in occupational safety and health, including both students and workers.
Intervention	Training and Education through VR on occupational health and safety.	Conventional occupational safety and health training and education
Comparison	not applicable	not applicable
Outcome	Effective training method through VR to improve occupational health and safety knowledge among workers and student	Studies not reporting any outcome.
Study Design	Full articles, experiments, quantitative and qualitative design, combined method.	Abstracts, conference papers, and articles that are not full-length research articles.
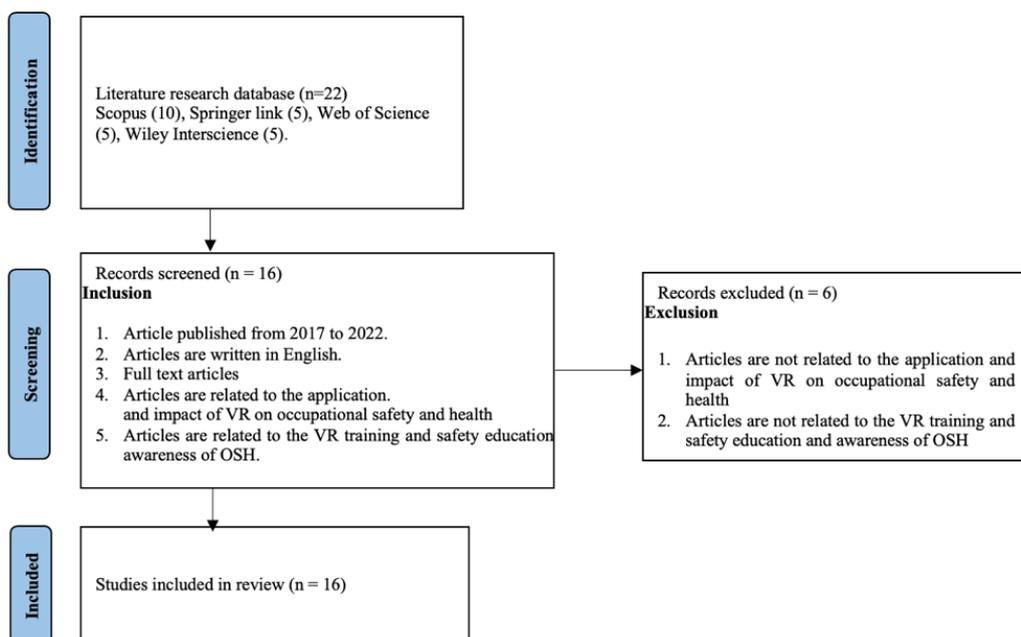
Figure 1. Flow Diagram For Systematic Review

Table 2. Brief Summary

Authors	Methods	Size of Study Group	Results
(Grega, Nečas and Lancik, 2021)	Experimental design	4 groups respondents	VR is "pushed" into each segment and its presentation undoubtedly leaves a significant impression on every individual who has the opportunity to try its application
(Joshi *et al.*, 2021)	Experimental design	32 Students	Understanding safety protocols more precisely and avoiding accidents more effectively than with traditional training methods.
(Shi *et al.*, 2019)	Experimental design	126 Participants	Virtual reality in safety studies and recommendations for improved safety training programs.
(Ji *et al.*, 2023)	Experimental design	48 participants	The result implies that diminished quality of life virtual reality (DQL-VR) has made significant progress in teaching hazard awareness and risk perception, particularly for long-term health difficulties. Diminished quality of life virtual reality (DQL-VR) also improves learners' knowledge retention. Diminished quality of life virtual reality (DQL-VR) also lets learners anticipate and experience hazards in a safe environment.
(Bernal *et al.*, 2022)	Experimental design	16 Participant	This system demonstrates marginally acceptable usability, with potential for improvement and widespread acceptance (among utility technicians) for operation training focused on safety for such hazardous tasks.
(Chander *et al.*, 2021)	Experimental design	19 Participants	VR might possibly be utilized as a training tool for fall prevention training by exposing new employees to high-altitude hazardous workplace conditions in a safe and convenient method with additional VR familiarization, repeated exposure, and training with varied virtual heights.
(Davila Delgado *et al.*, 2020)	Combined Method (Quantitative and Qualitative Method)	54 Participants	The study shows that AR and VR could be applied in a variety of ways throughout a constructed asset's life cycle, which have been classified into six use-cases: stakeholder engagement, design support, design review construction support, operations and maintenance support, and training.
(Domingo and Bradley, 2018)	Qualitative Design with grounded theory approach	21 Students	Overall, students reported positive experiences and value in virtual reality, however their technical issues emphasized the need for proper technology and institutional technological support for successful virtual environment implementation in online education.
(Rokooei *et al.*, 2023)	Experimental Design	46 Participants	The findings revealed that the VR module had a good influence on roofing experts.
(Wu *et al.*, 2020)	Pre- and post-comparison study	109 Participants	Trainees who had prior experience with deep NSI/SI performed better on the accuracy rate and time required to make 20 decisions than those who had no prior experience with VR training.
(Retnanto *et al.*, 2019)	Experimental Design	34 Participants	It provides an excellent method of emphasizing the learning process in petroleum engineering education and encourages active learning for future generations.
(Clifford *et al.*, 2019)	Experimental Design	23 Participants	That there were no significant discrepancies in stress levels between the VR training activity and the real-world exercise, as evaluated by HRV, and no significant differences between VR and radio-only workouts, as measured by the Short Stress State Questionnaire (SSSQ)
(Deb *et al.*, 2017)	Experimental Design	26 Participants	Overall, the study findings indicate the new virtual reality technology's effectiveness for research on full motion activities.
(Meyer, Omdahl and Makransky, 2019)	Pre and post study design	118 Participants	The findings revealed a media-method interaction, with pre-training having a positive effect on knowledge ($d = 0.81$), transfer ($d = 0.62$), and self-efficacy ($d = 0.64$) shortly after the intervention, and on self-efficacy ($d = 0.84$) in a one-week delayed post-test in the immersive VR condition.

Advanced Table 2. Brief Summary

Authors	Methods	Size of Study Group	Results
(Ooi, Tanimoto and Sano, 2019)	Experimental Design	20 Participants	The Instructional Materials Motivation Survey (IMMS) assessment results revealed that the suggested approach outperformed the current instructional resources. Furthermore, the group trained with the suggested methodology was able to start fire extinguishing more quickly than those trained using conventional methods, and the average evacuation risk was reduced.
(Roldán *et al.*, 2019)	Experimental Design	20 Participants	The results of this study showed the proposed training method, which is based on process mining and virtual reality, is competitive with conventional approaches. Furthermore, user evaluations are more acceptable in terms of mental tension, perception, learning, outcomes, and performance.

RESULTS

This study will search for previous research articles featuring the term; "The Application and Impact of Digital Simulation for Training Purposes Through Virtual reality in The Workplace" to address current research topics. The findings of the study are shown in Table 2. These journals were chosen based on inclusion and exclusion criteria, and 16 journals meeting these requirements. The inclusion of this research are; Full article published from 2017 to 2022, written in English, and related to the application on training and impact of VR on occupational safety and health. Whereas, the exclusion criteria are the articles are not related to the application on training and impact of VR on occupational safety and health using the following keywords: occupational safety and health, safety education, virtual reality, VR Training, The flow diagram for the systematic review is shown in Figure 1.

DISCUSSION

This article reports 16 articles that met the inclusion and exclusion criteria (Table 2) provides a summary of their findings). This research identified articles and reviews of scientific journals published from several countries as seen in Figure 2. The majority of countries addressing virtual reality, particularly in terms of training and education, are the United States, followed by China, Korea, and the United Kingdom, and the rest of them distributed across Asian countries.

As seen from Table 2, VR is one of the methods utilized in numerous published research articles. VR applications can be used to investigate human behavior in dangerous situations. In addition, VR can also be used to increase HSE managers' knowledge

of risky behavior in construction work, such as falling from a height, which is one of the main focuses in providing workers with the appropriate precautions (Shi *et al.*, 2019). VR's sophisticated visualization technology can simulate a realistic physical environment and provide experience to enhance knowledge of workplace safety. VR can also be used to create an innovative learning environment. In addition, VR can enhance the ability to identify potential dangers, allowing users to comprehend the direct repercussions of their actions without suffering any actual harm (Shi *et al.*, 2019).

Research conducted by Shi *et al.* (2019) demonstrates that the construction industry is integrating VR. This is evident from the safety training programs implemented in each study, as well as an increase in construction workers' safety knowledge, identification of potential occupational hazards, and risk awareness.

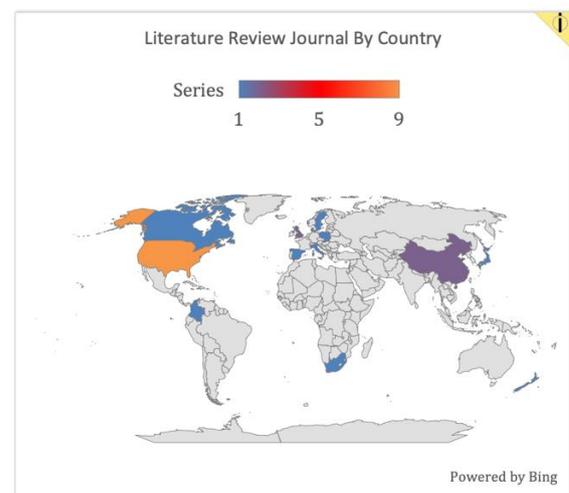The impact of virtual reality is not limited to one sector. According to Joshi *et al.* (2021), VR

Figure 2. Systematic Review Journal by Country

enhances the experience of safety procedures in the concrete manufacturing sector. VR improves comprehension of safety protocols and real-world experiences from precast/prestressed concrete processing plants. VR provides low-cost, low-risk scenario training. Simulation results showed that over 50% of participants had no symptoms of the simulated condition.

In addition, the mining industry requires new solutions to promote professional adjustment and health and safety, particularly among new employees. According to Patle *et al*. (2019) performed an exhaustive analysis of the literature on digital environments for industry-specific safety training They examined simulated emergency safety measures in advanced manufacturing settings (e.g., chemical processes and oil and gas rigs). The research indicated that adopting safety procedure simulation training in VR involves a large financial commitment when compared to traditional simulators: the initial cost is higher since professional training is necessary to provide a decent virtual reality experience (Patle *et al*., 2019). The investment yields a significant rate of return and provides value. This is a result of the plan's capacity to systematize knowledge while preserving knowledge, competency, and abilities. Large industries/processes with greater risk considerations stand to gain the most from an investment in VR-based simulation training.

Training by VR showed 81% of participants in the VR group rated VR as "Easy to Understand," and 94% preferred VR as a learning method over other methods (including video) that had been exposed. Then, in the electricity industry, it has proven to be beneficial for operation training that emphasizes safety in hazardous tasks such as electrical substations (Bernal *et al*., 2022).

According to Ji *et al*. (2023), VR has a positive effect on learning about OSH awareness, OSH risk assessment, and identifying health hazards. Technical constraints necessitate VR operational skills; the production process is time-consuming; instructors with specialized skills are required; and VR users must exert additional effort to acquire new skills.

Literature articles also illustrated the challenges this technology is currently facing. According to a number of studies (Guo, Yu and Skitmore, 2017), the current technological state restricts the use of virtual reality for safety applications, and additional research is required on both the technological and adoption aspects.

Skilled professionals favor conventional training over VR. It is conceivable that distinct employer groups will favor distinct types of training. However, the use of virtual reality enables businesses to conduct in-depth analyses and optimize work safety solutions without having to physically construct the required workplace situation.

VR is used to train workers in several fields, including safety. VR technology in workplace safety training assumes that it can increase students' and employees' safety processes, knowledge, and ability to avoid working hazards. Virtual reality lets learners explore, progress, and follow instructions at their own pace. Virtual reality training does not depend on weather or student location.

Previous research address the impact of virtual reality on work related to construction. In the construction industry, integrating occupational safety and health training with VR technology is highly recommended. VR is considered to be more effective at sustaining concentration as well as increasing focus in employees, allowing it to be used for high-risk jobs. Work at height is one example; this may be performed for fall prevention training and communicating dangerous work environments to new employees in a way that is more efficient and safer (Davila Delgado *et al*., 2020; Chander *et al*., 2021; Rokooei *et al*., 2023) .

Apart from construction sector, VR could also be used in the mining, medical, and manufacturing industries. Due to the improved perception, learning, and performance of employees, VR training systems in the mining industry may compete with conventional methods (Roldán *et al*., 2019). Another study (Wu *et al*., 2020), demonstrates that the use of VR may have a significant effect on participants, particularly in terms of anxiety management.

The effectiveness of implementing VR is also experienced in pedestrian safety trials and evacuation systems. Effectiveness is considered when VR is able to show an accurate, realistic, and visually designed (Deb *et al*., 2017).

VR is also used for media training, including decision-making training in firefighters training (Clifford *et al*., 2019) and catastrophe training to raise awareness of disasters (Ooi, Tanimoto and Sano, 2019). Furthermore, the VR-trained group may perform more accurate, quick, and effective activities.

Apart from training, VR has the potential to become an instructional media. This has the potential to generate an incredible experience when combined with direct situations that can be observed digitally. According to Retnanto *et al*. (2019), students are engaged in the VR experience, and this is an excellent technique to emphasize the learning process in education. Domingo and Bradley (2018) , as well as Meyer, Omdahl and Makransky (2019), reveal that students believe that utilizing VR has a positive impact on knowledge transfer, effectiveness, and self-efficacy.

CONCLUSION

It has been demonstrated that VR has a positive impact on learning about increasing OSH awareness, OSH risk assessment, and identification of health hazards. In Indonesia, it is necessary to advance the use of VR for HSE training and education in high-risk industries. The massive use of virtual reality (VR) training for work safety in a variety of industries may be related to the hazardous working environment. A high-risk industry justifies the increased cost of developing a virtual reality scene. According to the reviewed articles, virtual reality training can help companies prepare for actual emergency situations. Moreover, it has been demonstrated that the implementation of VR in the workplace improves worker behavior and heightens their risk awareness during their activities. Additionally, VR training could enhance the safety culture of employees and student.

ACKNOWLEDGMENTS

REFERENCES

Alli, B. (2008) Fundamental Principles Of Occupational Health And Safety. 2nd edn. Geneva: International Labour Office.

Bernal, I. F. M. *et al*. (2022) 'An Immersive Virtual Reality Training Game for Power Substations Evaluated in Terms of Usability and Engagement', *Applied Sciences*, 12(2), pp. 1-21.

Bin, F. *et al*. (2019) 'Construction safety education system based on virtual reality', IOP Conference Series: Materials Science and Engineering, 563(4), pp. 1-7.

Chander, H. *et al*. (2021) 'Impact of Virtual Reality–Generated Construction Environments at Different Heights on Postural Stability and Fall Risk', *Workplace Health and Safety*, 69(1), pp. 32–40.

Clifford, R. M. S. *et al*. (2019) 'Creating a Stressful Decision Making Environment for Aerial Firefighter Training in Virtual Reality', *IEEE Conference on Virtual Reality and 3D User Interfaces*, pp. 181-189.

Davila Delgado, J. M. *et al*. (2020) 'A Research Agenda for Augmented and Virtual Reality in Architecture, Engineering and Construction', *Advanced Engineering Informatics*, 45(December 2019), p. 101122.

Deb, S. *et al*. (2017) 'Efficacy of Virtual Reality in Pedestrian Safety Research', *Applied Ergonomics*, 65, pp. 449–460.

Domingo, J. R. and Bradley, E. G. (2018) 'Education Student Perceptions of Virtual Reality as a Learning Tool', *Journal of Educational Technology Systems*, 46(3), pp. 329–342.

Grega, M., Nečas, P. and Lancik, B. (2021) 'Virtual Reality Safety Limitations', *INCAS Bulletin*, 13(4), pp. 75–86.

Guo, H., Yu, Y. and Skitmore, M. (2017) 'Visualization Technology-based Construction Safety Management: A Review', *Automation in Construction*, 73, pp. 135–144.

Hämäläinen, P., Takala, J. and Kiat, T. B. (2017) 'Global Estimates Of Occupational Accidents And Work-Related Illnesses 2017', *IECON Proceedings (Industrial Electronics Conference)*, p. 25.

Ji, Z. *et al*. (2023) 'Integrating diminished quality of life with virtual reality for occupational health and safety training', *Safety Science*, 158 (February), pp. 1-12.

Joshi, S. *et al*. (2021) 'Implementing Virtual Reality Technology for Safety Training in the Precast/ Prestressed Concrete Industry', *Applied Ergonomics*, 90(January), pp. 1-11.

Meyer, O. A., Omdahl, M. K. and Makransky, G. (2019) 'Investigating the Effect of Pre-training when Learning through Immersive Virtual Reality and Video: A Media and Methods Experiment', *Computers and Education*, 140(June), pp. 1-17.

National Occupational Safety and Health Profile in Indonesia (2018) 'National Occupational Safety And Health (OSH) Profile In Indonesia 2018', (1), pp. 1–58.

Nurrohman, B. (2017) 'Optimalisasi Pelayanan E-KTP Guna Meningkatkan Validitas Data Kependudukan di Kecamatan Majasari Kabupaten Pandeglang', *Jurnal Kajian Administrasi dan Pemerintahan Daerah*, 10(6), pp. 98–107.

Ooi, S., Tanimoto, T. and Sano, M. (2019) 'Virtual Reality Fire Disaster Training System for Improving Disaster Awareness', *ACM International Conference Proceeding Series*, Part F1481, pp. 301–307.

Patle, D. S. *et al*. (2019) 'Operator Training Simulators in Virtual Reality Environment for Process Operators: A Review', *Virtual Reality*, 23(3), pp. 293–311.

Podgórski, D. (2021) ILO Guidelines on Occupational Safety and Health Management Systems, Handbook on Standards and Guidelines in Ergonomics and Human Factors.

Prasetyo, H. and Sutopo, W. (2018) 'Industri 4.0: Telaah Klasifikasi Aspek Dan Arah Perkembangan Riset', *J@ti Undip : Jurnal Teknik Industri*, 13(1), pp. 17-26.

Radianti, J. *et al*. (2020) 'A Systematic Review of Immersive Virtual Reality Applications for Higher Education: Design Elements, Lessons Learned, and Research Agenda', *Computers and Education*, 147, pp. 1-29.

Retnanto, A. *et al*. (2019) 'Active Student Engagement in Learning - Using Virtual Reality Technology to Develop Professional Skills for Petroleum Engineering Education', *Proceedings - SPE Annual Technical Conference and Exhibition*, pp. 1-9.

Rokooei, S. *et al*. (2023) 'Virtual Reality Application for Construction Safety Training', *Safety Science*, 157, pp. 1-9.

Roldán, J. J. *et al*. (2019) 'A Training System for Industry 4.0 Operators in Complex Assemblies based on Virtual Reality and Process Mining', *Robotics and Computer-Integrated Manufacturing*, 59, pp. 305–316.

Shi, Y. *et al*. (2019) 'Impact Assessment of Reinforced Learning Methods on Construction Workers' Fall Risk Behavior using Virtual Reality', *Automation in Construction*, 104, pp. 197–214.

Wu, S. H. *et al*. (2020) 'Effects of Virtual Reality Training on Decreasing the Rates of Needlestick or Sharp Injury in New-Coming Medical and Nursing Interns in Taiwan', *Journal of Educational Evaluation for Health Professions*, 17, pp. 1–9.

Xu, Z. and Zheng, N. (2021) 'Incorporating Virtual Reality Technology in Safety Training Solution for Construction Site of Urban Cities', *Sustainability*, 13(1), pp. 1–19.