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Asian Adult Education Annual Conference

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The purpose of the Asian Adult Education Conference (AAE) is to provide a platform for academic exchange among researchers and scholars in adult and continuing education, as well as higher education, from the East, West, and Rest, especially those who are interested in conducting research related to Asian and Asian Diaspora adult education theory and practice. It seeks to promote mutual learning, enhance shared understanding, and stimulate academic viewpoints and dialogue from various perspectives from global educators. Selected presentation papers are published in peer-reviewed conference proceedings.

Effectiveness of Virtual Reality Technology in Occupational Safety and Health Training

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Abstract

The major reason for incompetent hazard identification by safety personnel is due to ineffective training of hazard identification. Hence, this study aims to examine the effectiveness of Occupational Safety and Health training using Hazard Identification Virtual Reality Simulation.

Keywords: virtual reality, virtual reality simulation, OSH training and training effectiveness

The definition of virtual is electronic simulation using mounted eye –goggles and enable user for 3D interactions or others also defined it as an alternate world computer generated images that give responds towards human movements. Virtual Reality (VR) provides another opportunity in training and education which, it is can be integrated as a system that allow user to communicate with various technology incorporated with scenario that is multisensory manner. Virtual Reality (VR) provides an opportunity to view problems through more than one symbolic representation to achieve greater understanding. The training program incorporating these virtual technologies is defined as a virtual training system. Interestingly, VR systems also acknowledge physical interaction through virtual objects exploiting a haptic device amalgamated with the vision system of computer on the other hand, the VR systems can be used to obtain new abilities (Hürst & Helder, 2011).

There are many training approaches and tools that have been manipulated to increase the effectiveness of Occupational Safety and Health (OSH) training in construction. However, the main concern is on high-engaged training method that could enhance outcome of learning and performance of job. For all these reasons, virtual reality gained its own attention. This technology solves many issues of training especially hazardous training and training involving acquisition of high skills of the task. VR systems also acknowledge physical interaction through virtual objects

exploiting a haptic device amalgamated with the vision system of computer on the other hand, the VR systems can be used to obtain new abilities.

Virtual reality for training will be another effort taken towards providing another dimension of learning experience to the learners. This is especially worth for hazardous job, hazardous learning environment which using the virtual reality may not be frustrating for learners to experience real situations which are impossible to be conducted. Dealing with hazardous work and difficult environment to control, utilizing virtual reality is promising (Jaselskis, & Asce, ,2016).

Statistics reveals high number of injuries, accidents and fatalities in construction industry. When hazards are not accurately identified worker may not be able to adopt effective safety measure to prevent injury and accidents. In Malaysia, the number of occupational accidents were 32,674 cases in 2020, with the number of occupational fatalities being 312 cases (DOSM, 2021). The main sectors that contribute to occupational accidents are Services, followed by Manufacturing and Construction sectors. Although the Construction sector ranks third in terms of numbers of injuries, the industry ranks first in terms of occupational fatalities rate. This sector remains the most dangerous instead of showing a long-term stable trend as it posted the highest rate of occupational fatalities, which is 3.3 times higher than the overall national occupational fatalities in 2020. Higher occupational fatality rates for the Construction sector compared to overall sectors were also recorded in other countries. The US Bureau of Labor Statistics reported 1,008 mortality due to occupational accidents in the US Construction sector in 2021, with a rate of 10.2 death per 100,000 workers, compared to a 3.4 fatalities rate across overall industries.

Current OSH training program is using passive traditional training methods rarely assist in the acquisition of learning and transfer of learning in the work place. Compulsory site-visits for OSH trainees fail to engage and immerse trainees on real hazard and safety scenario due to hazardous work that need to be “stop work”. There is need to replace the existing OSH training methods with a more student-centered training that promote self-learning and training using Virtual Reality technology to improve training effectiveness.

Purpose of the Study and Research Question

The purpose of the study is to examine the effectiveness of OSH training using Hazard Identification Virtual Reality Simulation (HIVRS) among Site Safety Supervisors. Four research questions were developed to achieve the stated research purpose.

1. What the reaction of Site Safety Supervisors regarding the characteristics of Hazard Identification Virtual Reality Simulation in Occupational Safety and Health hazard identification training?
2. Is there a difference in Occupational Safety and Health hazard identification knowledge level between Site Safety Supervisors on site (not using HIVRS) and Site Safety Supervisors using mobile Hazard Identification Virtual Reality Simulation?

3. Is there a difference in the Occupational Safety and Health hazard performance between onsite Site Safety Supervisor (not using HIVRS) and Site Safety Supervisor using mobile Hazard Identification Virtual Reality Simulation?
4. Does mobile Hazard Identification Virtual Reality Simulation has influence on Site Safety Supervisors Occupational Safety and Health hazard identification learning and performance?

Perspective and Relevant Literature

Previous studies showed that virtual reality is already widely used and applied in various training such as automotive, medical, transportation and welding training system (Irizarry & Abraham 2005, Li, Chan & Skitmore, (2012). However, there are still a few studies that devoted this technology for OSH training, to be specific as training tools that could perform high engagement and confirm high measurement of OSH performance. Studies by Perlman, Sacks and Barak (2013), confirm that usage of virtual reality promise increase learning acquisition and high transfer of training through various type of OSH training. However, there are still many studies investigated on the design and development of virtual reality simulation but lacking in evaluating the effectiveness of OSH training using virtual reality simulation on both OSH learning and OSH performance (Huang, Rauch, & Liaw (2010).

A recent literature review that investigated the effectiveness of VR for health professionals' education has found that when compared with traditional education or other types of digital education, VR may improve post-intervention knowledge and skills. Virtual environments could, in fact, deliver cost-efficient, safe and potentially effective training (Kyaw et al, 2019).

In another study by Souza et al (2020) found that virtual reality effect knowledge transfers and retention in collaborative group-based learning for Neuroanatomy students. The study conducted an experiment to investigate knowledge transfer in a group-based learning game. The study introduces a VR serious game to support teaching and learning processes in neuroanatomy health education. A between-subjects experiment was conducted with 23 students to jointly assess learning, knowledge retention, and sense of presence.

As a control condition, grouped students assembled a physical model of the human brain, while in the experimental condition, a virtual brain was assembled. In each group, one participant assembled the brain, while the others observed and verbally collaborated in a group-based learning strategy. Findings of the study shown high mean scores in the virtual condition. When comparing the knowledge test performance before and immediately after the experiment, the study found significant difference only for the virtual condition. The same can be observed for retention.

Samadbeik et al., (2018) found that the use of virtual reality can improve learning effect. Subjects who accepted virtual reality training have higher performance level in medical practice, and the application of such ability plays an important role in improving the performance of different medical groups. Chae et al., (2018) found that, through evaluation and questionnaire survey,

participants using virtual reality can better understand and learn the required training content than those in the control group. In addition, learners prefer to train them with VR.

Kim et al., (2020) conducted an experimental study on apprentices of gardeners to investigate the proportion, composition, and creativity of IVR interface and paper sketching as well as the behavior of learners compared with design results. The effectiveness of design quality improved when students performed IVR after their completed drawings, and the sequence had more effective results in terms of proportion and composition. Yang and Liu (2022) researched on the influence of immersive virtual reality (IVR) on skill transfer of learners found that that training methods have significant differences in post-test scores. Immersive virtual experimental teaching plays a significant role in the skills transfer of learners.

Overall, the related studies showed that virtual reality based training are a promising tool for education in various industrial sectors. When compared to the traditional learning methods, virtual reality technology is preferred by learners and promote equal or better learning and performance, never worse.

This study was conducted to bridge the research gap. Firstly, in particular the application of virtual reality technology in OSH training in construction sector in Malaysia is still lacking. Secondly, studies to examine the effect of VR based training in particular to OSH learning and OSH performance is also still limited. Hence to understand the using of virtual reality technology in OSH training and education, this research is underpinned by the constructivism theory

The constructivist philosophy holds that knowledge is constructed through an individual's interaction with the environment. Constructivism is not a new theory. The core ideas of this theory have existed for over a century, with Jean Piaget (1950) and John Dewey (1958) as among the first few to develop a clear idea of it. As opposed to behaviorism that holds to knowledge reproduction, constructivism as a learning theory emphasizes the combination of inputs from the senses, existing knowledge, and new information to develop new meaning and understanding through active, authentic, cooperative and reflective learning activities. Jonassen, Hernandez-Serrano, and Choi (2000) and Greening (1998) list virtual reality as one of the technologies that can support constructive learning. Virtual reality provides a controlled environment in which learners can navigate, and manipulate the virtual objects found within, and more important, the effects of such interaction can be observed in real time. Virtual reality is therefore very well suited for providing exploratory learning environments which enable learners to learn through experimentation. Generally, constructivists believe that learners can learn better when they are actively involved in constructing knowledge in a learning-by-doing situation. Winn (1993) highlights that the characteristics of virtual reality and the axioms of constructivist learning theory are entirely compatible, and asserted that constructivist theory provides a valid and reliable basis for a theory of virtual reality learning. Bricken (1990), Chen and Teh (2000) and Winn (1993) are among others who further point out how the various capabilities of this technology can support constructivism.

Based on the above studies and underpinning theory, three hypotheses are formulated as below:

Hypothesis 1:

There is difference of OSH hazard identification knowledge level between onsite Site Safety Supervisor and Site Safety Supervisor using mobile Hazard Identification-Virtual Reality Simulation.

Hypothesis 2:

There is difference of OSH hazard performance between onsite Site Safety Supervisors and Site Safety Supervisor using mobile Hazard Identification-Virtual Reality Simulation.

Hypothesis 3:

The Hazard Identification-Virtual Reality Simulation has influence on Site Safety Supervisors OSH hazard identification learning and performance.

Figure 1 shows the research framework of this study. In this study HIVRS characteristics namely immersion, features and interaction are hypothesized to influence OSH training effectiveness in particular OSH learning and OSH performance. The study also hypothesized that the usage of HIVRS during OSH training would improve OSH learning and skills and OSH performance of the Site Safety Supervisor.

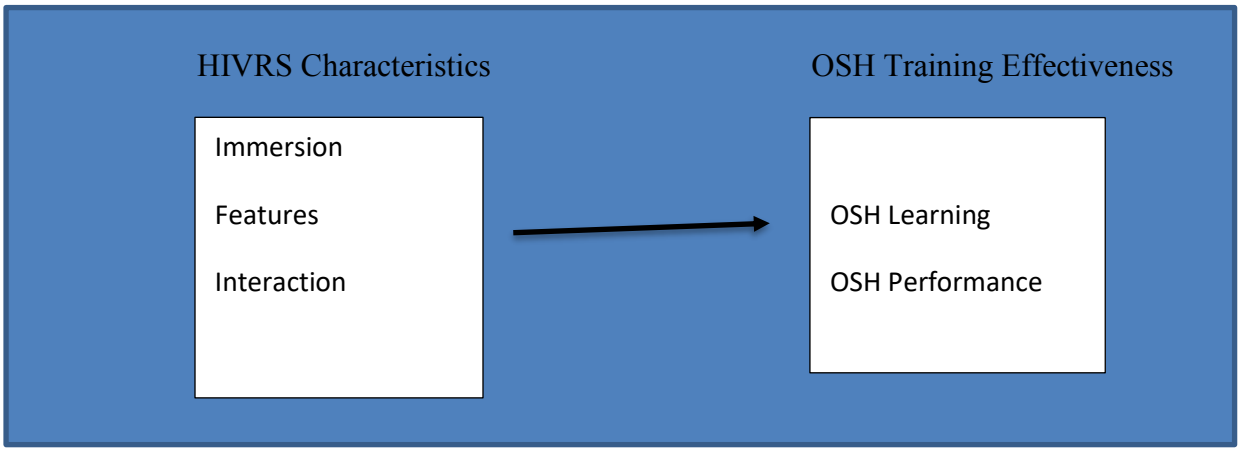

Figure 1: Research Framework

Research Design

A Hazard Identification Virtual Reality Simulation (HIVRS) was invented to assist Site Safety Supervisor to identify and recognize hazards accurately. The content of HIVRS is based on the 21 safety modules in construction site for examples modules related to excavation safety, working from heights safety, welding and cutting safety and etc. incorporating related hazards and unsafe act for each safety module. HIVRS content was validated by OSH experts and institutions. Base on the purpose of the study that is to examine the effectiveness of virtual reality simulation in OSH hazard identification training, thus quantitative method was employed using survey. A number of 208 trainees attending OSH Hazard identification training using Hazard Identification Virtual Reality Simulation participated in the research. The samples were selected using purposive sampling technique. The sample were divided into two groups that is onsite Site Safety Supervisor (not using HIVRS) and Site Safety Supervisor using HIVRS. Data were collected through the distribution of questionnaire and from Hazard Identification Risk Assessment and Risk Control (HIRARC) form as well from record of Job Safety Assessment, Toolbox Talk and Walkabout Inspection. The questionnaire was distributed through face to face to the selected trainees who are the Site Safety Supervisors. HIRAC form filled up by the Site Safety Supervisor was used to measure the level of OSH hazard identification learning (knowledge). Trainees' increase in learning was observed based on the total number of hazard identified and accurately identified in real construction site. Job Safety Assessment (JSA), Toolbox Talk and Walkabout Inspection records that were recorded 3-6 months after OSH VR training were used to measure Site Safety Supervisor OSH hazard identification performance. Mean score was used to analyze Site Safety Supervisor reaction on HIVRS OSH training whereas t-test statistics was used to determine OSH hazard identification learning and OSH hazard identification performance between onsite Site Safety Supervisor and Site Safety Supervisor using HIVRS. Regression statistics using Partial Least Square –Structural Equation Model (PLS-SEM) was used to predict the influence of HIVRS OSH training on OSH hazard identification learning and OSH hazard identification performance.

Results

The findings are as follows:

1. The mean score for Site Safety Supervisor's reaction on Hazard Identification Virtual Reality Simulation are 3.18 (Virtual Reality Training Features), 3.60 (Virtual Reality Immersion) and 3.82 (Virtual Reality Interaction). The findings show that Site Safety Supervisor are satisfied with HIVRS features, immersion, and interaction.
2. The t-test score shows a significance difference of OSH learning between onsite Site Safety Supervisor and Site Safety Supervisor using HIVRS. The Site Safety Supervisor using HIVRS in identifying hazard learned more about hazard identification in construction. The t-test of OSH learning that is Occupational Safety Hazard Recognition Index (t=47.0) and Occupational Safety and Health Hazard Identification Accuracy Index (t=38.5) respectively showed a significant difference between these two Site Safety Supervisors.

The Site Safety Supervisor using HIVRS were able to identify 81% hazards as compared to onsite Site Safety Supervisor 46 %. Hypothesis 1 is accepted.

3. The t-test score also shows a significance difference of Occupational Safety Health Performance between onsite Site Safety Supervisor and Site Safety Supervisor using HIVRS (t=47.57). The Site Safety Supervisor using HIVRS revealed a more improved OSH performance as compared to Site Safety Supervisor not using HIVRS. Hypothesis 2 is accepted.
4. R square values from PLS-SEM analysis reveals that virtual reality immersion, feature and interaction in combination explained 50.7% of OSH learning variance and 55.5% of OSH performance with moderate effect size f2 =0.18 (OSH performance) and f2=0.15 (OSH learning) respectively Cohen, (1988). The Stone-Geisser test Q2=0.303 confirms the model has predictive relevance due to Q2 score exceeds 0 (Henseler et. al 2009). Hypothesis 3 is accepted.

Discussion

The results of this study provide empirical evidence for the successful transfer of OSH knowledge and skills learned in OSH virtual reality training to an analogous real-word task. Participants or adult learners using HIVRS during OSH training to identify hazard at the construction site achieved higher hazard identification recognition and accuracy rates and an improved OSH performance at the real construction site than participants who are not using HIVRS. Further, they were significantly more knowledgeable about the hazard identification immediately after training. This finding is expected given the hypothetical dependence of learning and training transfer on the similarity between the trained task and the actual task, and the properties of the VR that is immersive, features and interactive used during training**.**

The results of this study supported by the findings from other studies (Sacks, Perlman and Barak 2013, Kyaw et al., 2019, Souza et al., 2020). The general results are in accordance with the literature, which indicates that the use of VR can play an important role in the learning of different industrial professionals since the experience is engaging, immersive, interactive, enjoyable, useful and have a positive effect on learning and performance.

The findings also in parallel with what is stated in the constructivism when the findings revealed that the adult learners were able to perform their task better in the real situation after went through the virtual reality based training. According to constructivists learning is a combination of inputs from the senses, existing knowledge, and new information to develop new meaning and understanding through active, authentic, cooperative and reflective learning activities. Virtual reality was found as one of the technologies that can support constructive learning. According to constructivist theory, ‘learning’ is the result of a process of construction and not a mechanism of representation. It has to be ‘considered as a process which is the circle of reality’ (D’Agnese, 2003), and that comes about through action and thought. Virtual realities take on the same characteristics of learning environments since they reproduce the complexity of the reality, presenting complete tasks, which are mainly based on the interaction rather than on pre-determined instructional sequences, and they allow a construction of knowledge strongly determined by the context.

The effective use of VR for OSH education may improve knowledge, performance and training transfer and deliver cost-efficient, safe and effective training. The current findings and previous studies show that virtual reality technology are promising, including in OSH education, when compared to the traditional learning methods, are preferred by learners, and improve learners learning and performance.

Implication for Adult Education

Training with VR was more effective over time, especially in the context of cast-in-situ concrete works. Given the need for improved training and the advantages of training using VR, incorporation of VR in construction safety training is strongly recommended**.** The findings implied that VR facilitate and maximize adult learning and VR support OSH training. Another implication of the study is that VR enhance adult learners transfer of learning in real situation. The VR technology is also applicable for adult learners in skill based training, thus can be useful for vocational and technical education adult learners. The current research findings showed that VR technology is promising not only in reducing training cost but also able to promote effective training effort as well as achieving training goal and training objectives.

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