ConSafeVRTrainer: Enhancing Construction Safety Training using Immersive Virtual Reality

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This is to certify that Final Year Project titled

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DECLARATION

It is hereby solemnly and sincerely declared that the work referred to this thesis project has not been used by any other university or institute of learnings part of another qualification or degree. The research carried out and dissertation prepared was consistent with normal supervisory practice and all the external sources of information used have been acknowledged.

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In the name of Almighty Allah, the most Merciful, the Beneficent. We are grateful to Almighty Allah for giving us opportunity to complete this research document by granting us strength, courage, and perseverance.

We are in the red of appreciation to our instructor Dr.-Ing. Abdur Rehman Nasir for his direction, inspiration, and steady consolation all through this research. We value the significant time and individual help provided by him.

We are extraordinarily thankful to every one of the workers and respondents for their significant commitment to this examination study. Furthermore, toward the end, we might want to pay our sincere and fair appreciation to my loved ones particularly our folks, for their unqualified help, support, and persistence.

The subsequent stage of the review was to go through a writing survey. The motivation behind perusing the previous writing was to distinguish the most repeating mishap types during development action and the ongoing preparation procedure. Papers from various creators from one side of the planet to the other were concentrated and afterward the top contributing variables were recorded concerning their number of events and their seriousness and furthermore the ongoing preparation strategy to prepare work, whereupon a writing score was given.

ABSTRACT

With the advancement of technology on a global scale, exploring new and creative approaches to enhance workplace safety has become crucial. Traditional training techniques in construction safety often fall short, resulting in numerous incidents on building sites that lead to severe injuries and operational challenges.

This thesis proposes the development of a Virtual Reality (VR) training module that immerses users in various hazardous scenarios and allows them to interact with virtual objects. The immersive experience provided by VR technology has proven to be highly effective for training purposes, as it enables learners to make decisions in a realistic environment.

The VR training module aims to simulate dangerous situations commonly encountered in construction, such as working at heights, handling equipments and avoiding accidents on site. By experiencing these events within a safe and controlled environment, workers can learn about and practice proper safety precautions. Real-time decision-making within the module will foster critical thinking skills, enabling workers to respond effectively to potentially risky circumstances. Additionally, the module will provide immediate feedback on performance, enabling individuals to identify areas for improvement and reinforce safe practices.

The primary objective of this thesis is to demonstrate how immersive VR technology can significantly enhance construction safety training, resulting in a safer and more productive industry. The development of this VR training module will offer practical and accurate training to workers, minimizing the occurrence of accidents and injuries on construction sites.

To achieve this objective, the research encompasses several key aspects. Firstly, it involves identifying the most frequent types of accidents in construction projects. Subsequently, the immersive VR training module will be created, providing an engaging and immersive experience for teaching construction safety. The module's effectiveness in enhancing safety awareness and danger recognition abilities will be evaluated. Furthermore, the engagement and satisfaction levels of trainees with the immersive VR training module will be measured. Finally, recommendations will be provided for future studies and the further development of immersive VR technologies in the construction sector.

By undertaking this research, the thesis aims to contribute to a safer working environment in the construction industry by harnessing the potential of immersive VR technology. The outcomes will showcase the effectiveness of the VR training module, enabling practical and secure training while reducing the likelihood of accidents and injuries on construction sites.

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List of Acronyms

Acronym	Abbreviation
AR	Augmented Reality
VR	Virtual Reality
XR	Extended Reality
3D	Three Dimensional
BIM	Building Information Modeling
OSHA	The Occupational Safety and Health Administration
NEBOSH	National Examination Board in Occupational Safety and Health
BLS	Bureau of Labor Statistics
HSE	Health and Safety Executive
NSC	National Safety Council
SDGs	Sustainable Development Goals
UNESCO	United Nations Educational, Scientific and Cultural Organization

CHAPTER 1

INTRODUCTION

1.1 Background

Due to hazardous working environments at complex, unstructured, and dynamic construction sites, workers frequently face potential safety and health risks throughout the construction process. In this regard, addressing safety challenges remains one of the top priorities. Construction workers' ability to identify and assess risks is acquired through training, which is one of the primary key factors to determine their safety and wellbeing in hazardous working environments. (Ojha A, Seagers J, Shayesteh S, Habibnezhad M, Jebelli H.,2020)

Workplace safety has risen to the top of the priority list in the modern, technologically advanced society. Because of inadequate training and safety breaches, thousands of fatal accidents and serious injuries take place every year. It has been observed that there is a common absence of formal construction safety training programs for fresh workers that result in work accidents. Instead, employees are expected to learn from their own experiences and mistakes. (Arif M, Nasir AR, Thaheem MJ, Khan KI.,2021).

These vulnerabilities due to lack of adequate training causes human casualities and accidents. In addition to causing human casualties, these disasters can cause organizations to suffer sizable financial losses. As a result, there is an increasing need for efficient training techniques that can replicate actual working situations and get people ready for potential risks. These accidents are unrecognizable due to lack of trainings.

Evidence from the global construction industry suggests that an unacceptable number of safety hazards remain unrecognized in construction workplaces. A recent exploratory effort provided anecdotal evidence that workers often fail to recognize safety hazards that are expected to impose relatively lower levels of safety risk. (Albert A, Pandit B, Patil Y, Louis J., 2020).

When it comes to preparing employees for potential obstacles in the workplace, traditional training techniques like lectures and videos are frequently insufficient because they are inefficient. This study aims to develop a module using technology of Immersive Virtual Reality (VR) to provide the trainees with real-time and interactive trainings. Further this study aims to train the trainees about safety standards by Occupational Safety and Health Organization (OSHA) and National Examinational Board in Occupational Safety and Health (NEBOSH) in multiple languages. Immersive Virtual Reality (VR) module will enables trainees to engage with virtual environments by offering an entirely immersive experience that replaces the user's real-world surroundings with an artificial one.

1.2 Problem Statement

Exploring new and creative approaches to enhance workplace safety is essential as technology advances worldwide. Because traditional techniques for training in construction safety are frequently inefficient, there are many incidents on building sites that result in serious injuries and operational problems.

Because this world is entering into a new age of advancement and technology, it is need of hour to digitalize the safety training methodologies. This research suggests creating a VR training module that immerses users in a virtual construction site vulnerable to certain safety hazards and let them interact with them virtually in order to increase their decision making abilities when exposed to such situations in reality.

Working at heights and avoiding the accidents with the site machinery and vehicles are just a few of the dangerous situations that the module will be created to emulate. Trainees can learn about and put into practice the proper safety precautions by experiencing these events in a safe, controlled environment using VR technology. In addition to this, trainees are provided with multilingual trainings about the different hazards, situations and Personal Protective Equipments (PPEs) according to standards set by Occupational Safety and Health Organization (OSHA) and National Examinational Board in Occupational Safety and Health (NEBOSH) in layman language.

The overall goal of this research is to show how immersive VR technology may considerably enhance the training provided for construction safety, making the sector safer and more productive. By creating this module, it will be possible to give workers practical training in a secure and accurate setting, lowering the possibility of mishaps and injuries on construction sites.

1.3 Research Objective

This research aims:

• To identify the accident types that happen most frequently when working on construction projects and assess how well the current safety education programmers are working.

• To create a VR training module with an immersive experience for training construction safety.

• To assess how well the immersive VR training module works at enhancing safety awareness and danger recognition abilities.

1.4 Overview of Study Approach

A thorough assessment of the most recent research on virtual reality (VR) training for construction safety is what this study intends to do. The research gaps and potential benefits of VR training in the construction sector will be determined by conducting a thorough literature study.

A prototype of an immersive VR training module will be made in order to investigate the efficiency of VR training. This module will simulate common risks and hazards found on construction sites so that participants can experience them and learn how to handle them in a secure virtual environment.

A sample of construction employees will participate in a controlled trial to assess the effectiveness of VR training. VR instruction will be provided to half of the participants. Both before and after the training sessions, quantitative data on decision-making ability, skill acquisition, and information retention will be gathered.

Qualitative interviews with the participants will also be conducted in addition to the quantitative data to get their thoughts on the VR training module and how effective they think it is. These interviews will add to the evaluation of VR training for construction safety by revealing insightful details about the participants' experiences.

On the basis of the data gathered, conclusions will be drawn about the effectiveness of VR training for construction safety. Any possible areas for improvement will be noted, enabling ideas and proposals to be made for further research and the application of VR technology in the teaching of construction safety.

In general, this study intends to fill in the gaps in the literature, evaluate the benefits of VR training for construction safety, and offer insightful information about how successful VR training modules are. The research will support the use of VR technology as an innovative and effective instructional tool in the construction industry. It will also help to continue the development of construction safety training modules.

1.5 Organization of Thesis

The thesis is divided up into several chapters. The research problem, research objectives, and an outline of the study approach are introduced in Chapter 1. An overview of the literature on immersive VR technology, construction safety training techniques, and related topics is provided in Chapter 2. The study's methodology, including the research design, data gathering procedures, and analysis techniques, is described in Chapter 3. The study's findings and outcomes are presented in Chapter 4. The consequences of the study are discussed in Chapter 5 along with suggestions for additional research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The capacity of a safety system to avoid or lessen risks that endanger construction workers can be used to assess its efficacy. The greatest workforce is in the construction industry, which also has the highest rate of occupational injuries and deaths, with 2.8 Million non-fatal injuries out of which 5,333 resulted in fatalities (Bureau of Labor Statistics, 2021).

Even seemingly unimportant accidents can lead to missed work hours, which can have an impact on the project's budget and schedule. Construction workers are frequently exposed to a variety of weather conditions, equipment, and job site variances, increasing their vulnerability to occupational dangers. This makes the construction sector distinctive. This is primarily due to the desire to save time and money on training. Making construction as safe as possible requires concerted effort on the part of all involved: owners, designers, construction companies at all levels of management, construction workers, regulators, and educators. If we look into the numbers and severity of accidents around the globe, it is as, during the last 20 years in the UK, 27% of fatal and 10% of major injuries were construction related (HSE, "Construction Industry." (Online)). Statistics of construction related accidents in US and Singapore show highest fatalities in 24-34 age group, 80% of skilled manpower, and 50% of just before or during the teatime (F. Y. Y. Ling, M. Liu, and Y. C. Woo., 2009). According to the South Australian construction industry, experienced workers have higher potential to cause accidents, while workers employed by small companies are unsecure than larger companies (J. Dumrak, S. Mostafa, I. Kamardeen, and R.Rameezdeen, 2013). Contribution of the key factors to accidents are workers (70%), workplace issues (49%) equipment shortcomings (56%), material conditions (27%) and risk management (84%) (R. a. Haslam. 1998). Education and training, competent personal, Construction management and planning, negligence, personal protection equipment (PPE), availability of regulations and knowledge, enforcement of Safety regulations, unique nature of the industry, Work environment, Machinery/equipment, work method, Supervision and Communication, which are recorded as uncertainties in Kuwait (N. A. Kartam and R. G. Bouz, 1998), USA (T. S. Abdelhamid and J. G. Everett, 2000), and Thailand (T. Pipitsupaphol and T. Watanabe, 2000) that cause accidents.

2.2 Most Occurring Accident in Construction Industry

With a high rate of accidents and injuries, the construction sector is one of the most dangerous. One in five worker deaths in the private sector in the United States, according to the Occupational Safety and Health Administration (OSHA), occurs in the construction industry (OSHA, 2021). This demonstrates how crucial it is to comprehend the many kinds of accidents that frequently happen in the construction sector to establish efficient safety measures.

The most common accident categories in the construction sector are falls, electrocutions, collisions with objects, and being caught in or between events. According to OSHA's estimates for 2020, falls were the main factor in roughly 39% of fatalities in the construction sector. Roofs, ladders, scaffolds, and other elevated surfaces can all cause falls. Nearly 9% of fatalities in the construction sector are due to electrocutions, which are brought on by contact with electrical sources (OSHA, 2021). These accidents frequently happen when workers meet power lines or electrical apparatus.

Approximately 8% of fatalities in the construction business are caused by struck-by accidents (OSHA, 2021). These events happen when equipment or building materials fall and strike the workers. Incidents involving workers being caught in or between objects, such as being wedged in between two moving cars or entangled in machinery, occur frequently. According to OSHA (2021), these occurrences are responsible for about 5% of fatalities in the construction business.

The likelihood of accidents and injuries in the construction business makes it one of the most dangerous professions. The "Fatal Four," also known as falls, struck-by-object accidents, electrocutions, and caught-in-between mishaps, are the leading causes of fatalities in the construction business, according to the National Safety Council (NSC). In the United States, 63.7% of construction worker fatalities in 2019 might be attributed to these four groups.

In the year 2013-2017, FFH accounted for 49% of fatal accidents in Great Britain (HSE, 2018). Workers risk serious injury or even death when they fall from ladders, scaffolds, roofs, and other elevated surfaces. The second most common cause of fatalities was being struck by an object, which accounted for 22% of all fatalities (Hinze J, Huang X, Terry L,2005). On the job site, large machines, vehicles, or falling things like materials, tools, or equipment can all strike workers. In 2019, electrocutions accounted for 8.2% of all fatalities, ranking third among all causes of death. Contact with live wires or electrical equipment can electrocute workers. 9.4% of all fatalities were caused by caught-in-the-middle accidents (Haslam *et al.*, 2005), the fourth most common cause of death. Workers risk significant injury or even death when they become trapped in or between pieces of machinery, equipment, or buildings.

Long-term exposure to high temperatures and humidity can cause heat stress in employees, which can result in dehydration, heat exhaustion, and heat stroke. Heat stress was discovered to represent a substantial risk. Work should be arranged at cooler times of the day, and workers should be given access to cool drinks, rest breaks, and shaded spaces to reduce heat stress (Karin Lundgren,2013).

The NSC and the Bureau of Labor Statistics (BLS), among other sources, provide support for these statistics. According to the National Safety Council (NSC), 63.7% of construction worker fatalities in the US occurred in 2019 because of falls, struck-by-object occurrences, electrocutions, and caught-in-between mishaps (National Safety Council, 2021). According to the Bureau of Labor Statistics (BLS), the three biggest causes of fatalities in the construction sector in 2019 were falls, occurrences involving being struck by an object, and caught-in-between mishaps (Bureau of Labor Statistics, 2020).

Burns, chemical exposures, and heat exhaustion are additional hazard types that frequently happen in the construction sector. Contact with hot surfaces, chemicals, or fires can result in burns. Skin irritations, breathing troubles, and other health problems can result from chemical exposure. When workers are exposed to high temperatures and humidity levels for an extended amount of time, heat exhaustion can happen, which can result in dehydration and heat stroke (Harris D, 2021).

Employers and employees must follow safety standards and recommendations to reduce these types of mishaps. Employers can make sure that employees are aware of the risks they can face while carrying out their jobs by offering training programs, personal protective equipment, and job hazard analyses. Employers can also put engineering controls in place to safeguard staff from hazards like falls and other dangers, such as guardrails and fall protection systems (Sawacha E,1999).

More dangers could endanger construction workers in addition to the top accident categories. These risks include those related to noise, vibration, and ergonomics. High levels of noise and vibration are regularly experienced by construction workers, which can cause hearing loss, musculoskeletal diseases, and other health problems.

In conclusion, the leading causes of fatalities in the construction business include falls from the height, being hit by moving vehicles, contact with the electricity, machine mishandling Exposure to Bio-Hazardous Chemicals and Gases. Employers and employees must be aware of these risks and take the necessary precautions to prevent accidents and injuries on the job site.

The following data is based on the literature study by respectable authors and frequency is defined as the occurrence of the accident type in the studied literature.

Table 1 Types of accidents through literature

Types of accidents	**Frequency**	**References**
Falls from Height	1	(Haslam *et al.*, 2005; N.Aniekwu, 2007; Alinaitwe, Mwakali and Hansson, 2007; Dėjus, 2007; Ale *et al.*, 2008; López *et al.*, 2008; Rahim *et al.*, 2008; Gürcanli, Müngen and Akad, 2008; Im *et al.*, 2009Ling, Liu and Woo, 2009; Pérez-Alonso *et al.*, 2012; Halvani *et al.*, 2012; Mohammed and Ishak, 2013; Solís-Carcaño and Arcudia- Abad, 2013; Dumrak *et al.*, 2013; Chong and Low, 2014; Yilmaz, 2015; Winge and Albrechtsen, 2018; GÜRCANLI and MÜNGEN, 2013; Ali, Khahro and Memon, 2014; Williams, Adul Hamid and Misnan, 2018)
Contact with electricity	0.6	(Haslam *et al.*, 2005; Alinaitwe,Mwakali and Hansson, 2007; T. Dėjus, 2007; N.Aniekwu, 2007; Ale *et al.*, 2008; Gürcanli, Müngen and Akad, 2008; Im*et al.*, 2009; J Dumrak *et al.*, 2013; Solís-Carcaño and Arcudia-Abad, 2013; Chong and Low, 2014; Yilmaz, 2015; Williams, Adul Hamid and Misnan, 2018)
Machine Mishandling	1	(Haslam *et al.*, 2005; N.Aniekwu, 2007; T Dėjus, 2007; Alinaitwe, Mwakali and Hansson, 2007;Ale *et al.*, 2008; López *et al.*, 2008; Rahim *et al.*, 2008; Im *etal.*, 2009; Ling, Liu and Woo, 2009; Mohammed and Ishak, 2013; Solís-Carcaño and Arcudia-Abad, 2013; Gürcanli and Müngen, 2013; J. Dumrak *et al.*, 2013; Ali, Khahro andMemon, 2014; Yilmaz, 2015; Williams, Adul Hamid and Misnan, 2018b; Winge and Albrechtsen, 2018)

Types of accidents	Frequency	References
Exposure to Bio-Hazardous Chemicals and Gases	0.7	(Haslam *et al.*, 2005; Ale *et al.*, 2008; Camino López *et al.*, 2008; Rahim *et al.*, 2008; Pérez-Alonso *et al.*, 2012; Solís- Carcaño and Arcudia-Abad, 2013; Dumrak *et al.*, 2013; Gürcanli and Müngen, 2013; Mohammed and Ishak, 2013; Chong and Low, 2014; Yilmaz, 2015; Winge and Albrechtsen, 2018)
Accidents caused by being hit by moving vehicles	0.28	(Alinaitwe, Mwakali and Hansson, 2007; Dėjus, 2007; Camino López *et al.*, 2008; Gürcanli, Müngen and Akad, 2008; Im *et al.*, 2009;Pérez-Alonso *et al.*, 2012; Solís-Carcaño and Arcudia-Abad,2013; Chong and Low, 2014)

2.3 Current Safety Training Methodologies

To make sure that employees are informed of potential hazards and are trained to carry out their job obligations safely, the construction industry uses several safety training approaches.

One popular approach is classroom instruction, which frequently includes lectures, films, and interactive exercises to inform employees about safety rules, practices, and procedures. Hands-on training is frequently used to supplement classroom instruction, giving employees real-world experience, and allowing them to demonstrate their understanding of safety procedures in a controlled setting.

On-the-job training, which involves learning safety practices while working on a building site, is another approach to safety training. An experienced worker who serves as a mentor and walks the student through the safety procedures and practices typically conducts this type of training (Teck AG,2015).

2.3.1 The Utilization of Classroom to Support Training

The typical location for supporting training and education has long been the classroom. To inform employees of safety policies, procedures, and practices, lectures, films, and interactive exercises are conducted. The goal of classroom training is to provide employees with a fundamental awareness of the risks they can face on the job site and the steps they should take to prevent accidents. It offers an organized setting where students can communicate with teachers and peers, access learning resources, and take part in debates and practical exercises. When paired with additional approaches like e-learning or on-the-job training, using the classroom setting can be an efficient way to give training.

The capacity to give prompt feedback and clarification is one advantage of classroom instruction. Trainees can obtain immediate feedback on their performance as well as observations from instructors and answers to their inquiries. This can aid students in fixing errors and enhancing their comprehension of the material. Classroom instruction also allows for group debates and collaborative learning, which can improve students' capacity for critical thought and problem-solving.

The flexibility of classroom instruction to meet the requirements of students is another advantage. Depending on the comprehension level and development of their students, teachers might alter their strategy and approach. Additionally, classroom instruction can be modified to match the requirements of a particular audience, such as new hires or workers looking to advance their careers(Stephen OO,2022).

(Burke et al., 2006) labeled lectures as least engaging form of training method, claims that they are commonly used in health and safety related information exchanges. However according to their research, it is as not effective as other forms of training. It could also be accompanied by additional methods, like discussions, question answers, visual presentations etc. Figure 1 shows the lecture on safety from (Enerpac, 2017)

Figure 1 Classroom training.(Enerpac, 2017)

In conclusion, using a classroom environment to help training and education can be quite successful. It offers an organized setting where students can engage with teachers and peers, access learning resources, and take part in practical exercises and debates. Although classroom instruction may have some disadvantages, it can nevertheless be an important part of a comprehensive training programmer.

2.3.2 The Utilization of On-the-Job Coaching to Support Training

A learner and an experienced coach or mentor interact directly during hands-on coaching, a type of instruction. It entails giving employees hands-on training and the chance to demonstrate their understanding of safety procedures in a controlled setting. Because it enables employees to put the knowledge they have gained in the classroom into practice, it is frequently offered in conjunction with classroom training. In fields like manufacturing, healthcare, and construction where practical knowledge and skills are crucial, this kind of training is frequently used. Since it enables students to receive individualized feedback and direction, hands-on coaching can be a successful technique to support training and education (Council BB,2010).

The capacity to tailor instruction to the individual needs of the learner is one advantage of hands-on coaching. Coaches can modify their methods to fit the learner's speed, learning style, and level of competence. Additionally, instructors can give learners quick feedback on how they performed, which can aid in error correction and skill improvement (Dashti Q,2019).

The chance for learners to see and learn from seasoned experts is another advantage of hands-on tutoring. Coaches can offer their knowledge and expertise while demonstrating best practices, which can aid learners in developing their skills more quickly and efficiently. Hands-on coaching can also help students gain confidence and lower their risk of working mistakes or accidents.

However, there may be disadvantages to hands-on coaching as well. For instance, scheduling and coordinating coaching sessions could be challenging, especially if the coach is a busy professional. Furthermore, some students can find it difficult to learn in a one-on-one environment or might feel intimidated by the coach's degree (Teodoriu C,2019). Figure 2 shows the ho on-the-job coaching is provided to the professionals.

Figure 2 On-the-Job coaching (Source: OSHA Mid Atlantic)

In conclusion, on-the-job coaching can enhance training and education effectively, especially in fields where real-world experience is crucial. It enables students to put their academic knowledge to use in practical contexts, get rapid feedback, and pick the brains of more seasoned peers. On-the-job coaching may have some disadvantages, but it can still be an important part of a thorough training programmer.

On-the-job training is an efficient technique to teach employees about safety practices, since it gives employees real-world experience and enables them to see how skilled personnel carry out their job obligations safely.

2.3.3 The Utilization of Technology to Support Training

Virtual reality (VR) and augmented reality (AR), two technology-based safety teaching techniques, have grown in popularity recently. These techniques give employees a more participatory and immersive training experience, enabling them to participate in simulated dangerous scenarios in a safe setting (Placencio-Hidalgo D,2022).

In fields where learners may be geographically separated or have limited access to mentors or subject matter experts, this kind of mentoring can be especially helpful. Email, instant messaging, video conferencing, and online learning tools are just a few examples of the many ways that technology-based mentoring can be implemented.

Giving students individualized and adaptable training is one benefit of technology-based mentorship. Mentors can offer one-on-one support and direction to learners at their speed and according to their schedule. This can ensure that students are getting the assistance they require to complete their training objectives (Gentry LB, 2008).

Technology-based mentoring may also be less expensive and time-consuming than conventional mentoring programmers. It can lessen the need for costly and time-consuming in-person meetings and travel. Additionally, because they are not constrained by a learner's geography, it can help mentors connect with more students (Ahmed S,2018).

Technology-based mentorship can have some pitfalls, though. For instance, if they do not have enough one-on-one engagement, trainees could feel cut off from their mentor or the training process. Technical problems or communication impediments, such as language difficulties, or disparities in technological platforms, may also exist. Figure 3 from Lack J. (2020) shows the use of digital technologies in trainings.

Figure 3 Use of Simulations for Trainings (Lacko J. 2020)

Technology-based mentoring can still be an important part of a thorough training program despite these possible downsides. It can give students individualized and adaptable instruction, ease financial and time pressures, and help close the knowledge gap between students and subject matter specialists (Zhao D, 2015).

According to a study by Teizer and Lee (2013), VR-based safety training can be a useful tool for instructing employees on how to carry out their job obligations safely. According to the study, employees who underwent VR-based safety training were better able to recognize threats and were more willing to follow safety procedures as directed.

2.3.4 The utilization of Mobile Applications to Support Training

A worker's mobile device now has access to safety training resources, danger identification, and other safety-related information thanks to the development of mobile applications. These programmers enable workers to receive safety training whenever it is convenient for them, making it simpler for them to learn and comprehend safety protocols (Virnes M, 2017).

In several industries, including construction, they are rising in popularity as a tool to help train and learn. Additionally, they can provide real-time feedback on performance and development, as well as enhance communication between students and instructors (Barbarosoglu BV, 2016.).

According to a study by Arif M, Nasir AR, Thaheem MJ, Khan KI (2021), provision of safety training modules for workers through mobile application can overcome the language barriers and enhance their hazard recognition ability.

Delivering training material in a way that is user-friendly and interesting to learners is one of the main advantages of mobile training applications. Videos, animations, and interactive quizzes are examples of multimedia components that can increase learners' engagement with the training materials and enhance memory recall (Alrumayh AS, 2021).

However, using mobile applications for training might also provide some potential difficulties. The requirement for trainees to have access to dependable and continuous internet connectivity, which may not be available everywhere, is one recurring problem. Additionally, there can be worries about data security and privacy, especially if the programmer is used to gathering sensitive or private data (Azhar S, 2015)

Mobile applications are nevertheless a useful tool for assisting training and learning in the construction sector and other industries, despite these difficulties. They give students a flexible and accessible way to interact with the training material and get assistance and criticism from peers and instructors (Chen Y,2011).

Mobile applications can be a useful tool for providing safety training to employees in the construction sector. According to the study, employees who utilized the mobile application were better able to recognize threats and were more inclined to follow safety procedures as directed.

Figure 4 shows the use of mobile applications for the training purposes.

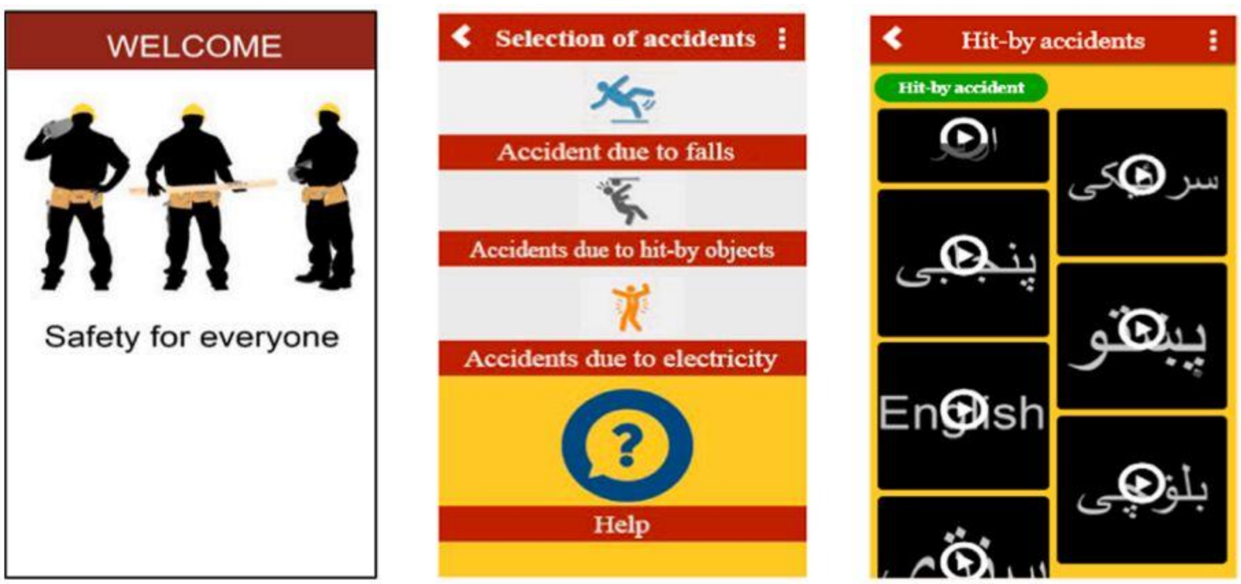


Figure 4 Mobile Applications for training (Arif M, Nasir AR, Thaheem MJ, Khan KI.,2021)

2.4 Use of VR Simulation for Training

A growing number of businesses are using virtual reality (VR) technology to boost training, productivity, and safety. Virtual reality simulation has been applied in the construction sector to educate workers on safety procedures, spot potential dangers, and enhance all-around site safety. The usage of VR simulators for construction safety will be the main topic of this section of your literature review.

VR simulation can significantly improve workers' safety awareness and assist them in spotting potential hazards on construction sites. It was discovered that workers who received VR training had superior safety knowledge and could detect possible hazards more precisely than those who received traditional training methods. The study involves using a VR simulator to instruct construction workers on safety measures.

Workers can be trained on how to operate equipment, like cranes, via VR simulation. In a study published in 2021, Liu et al. investigated the use of virtual reality simulation to instruct crane operators on safe operating practices. The study discovered that virtual reality training helped operators recognize possible hazards and increased their knowledge and comprehension of safe crane operations. According to the study's findings, virtual reality simulation can be a useful tool for teaching crane operators and enhancing site security.

To assess safety design and pinpoint potential safety concerns in construction projects, virtual reality simulation has also been used. To analyze the safety of construction design, created a VR-based safety evaluation system. It was discovered that the system was successful in locating safety risks and making suggestions for safety enhancements.

Overall, virtual reality simulation has shown the potential in enhancing site safety. The technology can be used to identify possible safety concerns, enhance worker safety knowledge, and instruct them on safety procedures. To fully comprehend the value of VR simulators for construction safety and to determine the optimal methods for their application, more research is necessary.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

The research approach used for this study is covered in this chapter. The research methodology used in this study reveals the deliberate method used to achieve the study's goals and respond to its research questions.

This project strives to contribute to the development and progress of training methodologies for construction safety by identifying common accident types and assessing the effectiveness of current safety education programmers. Utilizing immersive VR technology offers a special chance to give students a realistic and interesting learning experience, potentially revolutionizing safety teaching methods in the construction industry. Figure provides a schematic representation of the research approach followed in this study.

Research techniques Figure 5 illustrates the methodology the researcher will use to complete his investigation and address the research questions. The following is a description of the methods used for this study:

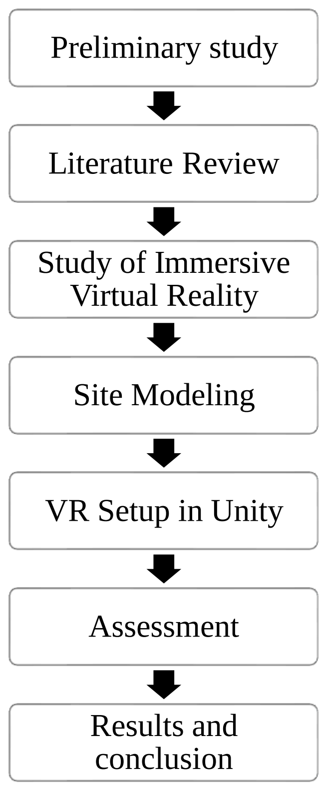


Figure 5 Research methodology

3.2 Preliminary Study

The preliminary study offered a theoretical foundation and revealed areas that needed further investigation regarding virtual reality training and construction safety. To get opinions from construction workers and safety experts, questionnaires and interviews were undertaken. The main study's research topics, design, and methods were all influenced by the preliminary study's findings, resulting in a thorough assessment of the many types of accidents and safety education initiatives in the construction sector.

3.3 Literature Review

The study's second phase was reading through the literature. Reading the earlier literature served the objective of identifying the present training methods and the accident kinds that occur most frequently during construction activity. After studying papers by authors from throughout the world, the main contributory factors were highlighted in terms of how frequently they occurred, how serious they were, and how they were being trained laborer at the time.

3.4 Study of Immersive Virtual Reality

3.4.1 Utilization of Unity 3D for Game Development

The concerted knowledge of Unity 3D, C#, and Oculus Tackle can be abused for construction safety training using immersive virtual reality (VR) to produce realistic and interactive training modules. Unity 3D is a popular game development machine that provides a comprehensive set of tools for creating virtual environment and interactive simulations. C# is a programming language generally used with Unity 3D to develop the sense and functionality of the VR operation. Oculus Tackle, including the Oculus Rift or Oculus Quest headsets, offers immersive VR interaction with high-quality illustrations and precise shadowing. By integrating these technologies, construction safety training programs can pretend dangerous scripts, exigency response situations, and outfit operations, enabling trainees to develop critical skills in safe and controlled environment.

3.4.1.1 Unity 3D

Unity 3D serves as the foundation for creating virtual surroundings and scripts in construction safety training. Its important plate capabilities and drugs machine enable the development of largely realistic simulations (Unity Technologies.)

3.4.1.2 C#

C# is an extensively used programming language within the Unity development terrain. It enables the creation of interactive and dynamic rudiments in virtual surroundings, allowing for the perpetration of safety protocols, stoner relations, and feedback mechanisms (Microsoft.).

3.4.1.3 Oculus Hardware

Oculus hardware such as the Oculus Rift S or Oculus Quest headsets, provides the immersive VR experience necessary for effective construction safety training. This hardware offers high-resolution displays, precise movements, and ergonomic design, creating a sense of presence and realism for trainees (Oculus.).

By combining the capabilities of Unity 3D, C#, and Oculus tackle, construction safety training programs can produce realistic and interactive virtual simulations. These operations give trainees with hands-on experience in relating hazards, responding to extremities, operating ministry, and managing pitfalls, eventually perfecting safety mindfulness and reducing plant incidents.

3.5 Site Modeling

3.5.1 Context Development

Before the actual modeling of construction site, planning was done to determine the type of environment that demanded to be generated for the virtual reality (VR) construction safety training module. In addition to the environment, considerations are taken to plan the site topography of the module. Also, the target areas to be focused on are defined here. The following framework defines the context development phase.

Figure 6 shows the framework for the Context Development.

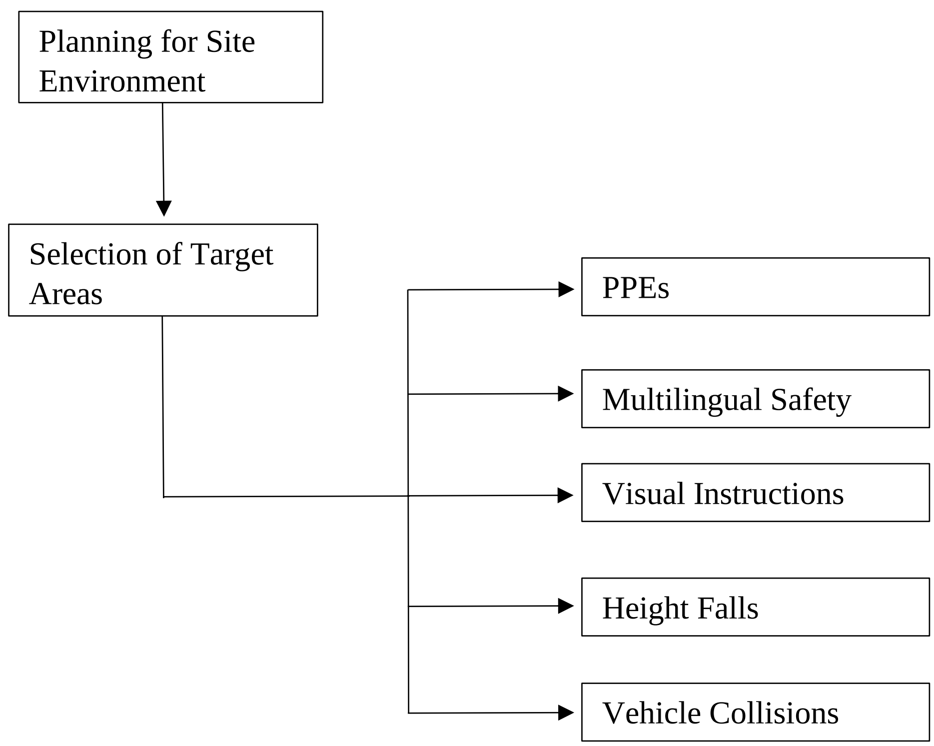


Figure 6 Framework for the Context Development

3.5.2 Scripting

The first step in the module is language selection, when the trainee is given the option of English, Urdu, or Punjabi. The module immerses the student in an immersive site environment after language selection.

The chosen language is used to deliver audio instructions at certain locations that explain the any potential risks, and the necessary safety measures for on-site operations. The trainee then uses personal protective equipment, which may include a safety helmet, boots, fire extinguisher, jacket, and goggles. The learner is given audio instructions on how to use PPE properly before this engagement.

The trainee then has the option to attend a meeting room where visual lessons in the form of videos highlight the dangers of height falls and the effects of ignoring safety precautions after listening to the audio instructions.

After that, the trainee is instructed to perform brick masonry work on a scaffolding system that is three floors above the ground. To avoid mishaps, the trainee must navigate and avoid several dangerous spots on the scaffolding where there is a chance of falling. The student will resurrect in the simulated world if they fall from the height.

The facility is continuously being used by different vehicles; therefore, the trainee must maneuver carefully to avoid crashes. The trainee will resurrect in the virtual environment in the event of a collision.

Figure 7 shows the framework for the scripting.

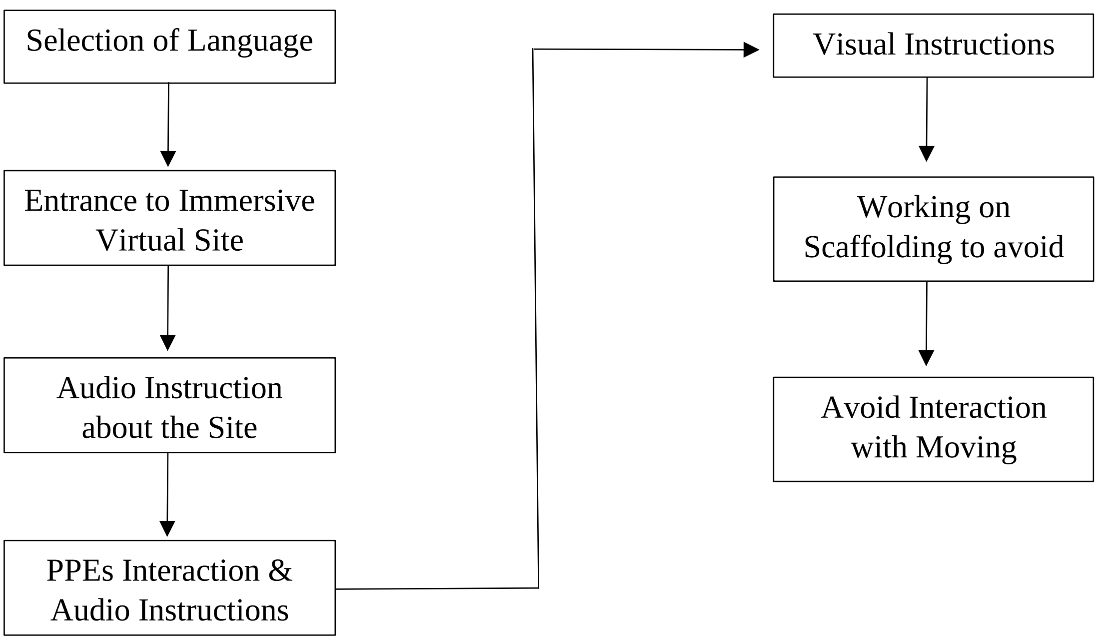


Figure 7 Framework for the Scripting

3.5.3 Construction Site Modeling

3.5.3.1 Site Topography Modelling

The landscape of the construction site was thoroughly modelled using Trimble SketchUp while taking construction safety precautions. The goal of the virtual terrain was to give trainees a realistic depiction of the various site conditions typically seen in construction projects by simulating both flat and hilly terrains.

3.5.3.2 Non-Interactive Site Components

To develop an immersive virtual world that faithfully depicts a construction site, a variety of non-interactive site components were modelled. Trainees can visually traverse and become familiar with the various features and structures normally found on construction sites by including these elements when they go into the VR training session. Some of the non-interactive objects added are:

- Tower Cranes
- LGS Structures
- RCC Structures
- Material Site
- Concrete Mixing Plant
- Dozers
- Excavator
- Concrete Mixer

Figure 8 to Figure 15 shows the 3D Models of some of the non-interactive site objects.

Figure 8 3D Model for the Dozer

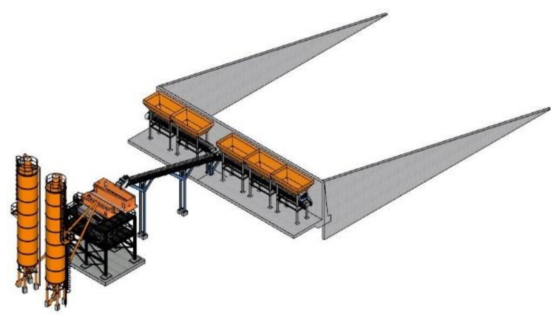


Figure 9 3D Model for the Concrete Mixing Plant

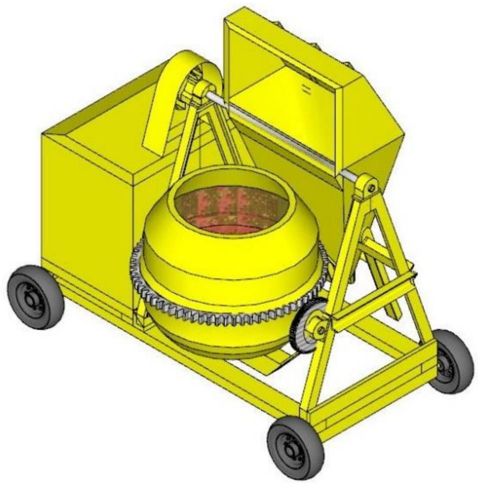


Figure 11 3D Model for Concrete Mixer

Figure 10 3D Model for Excavators

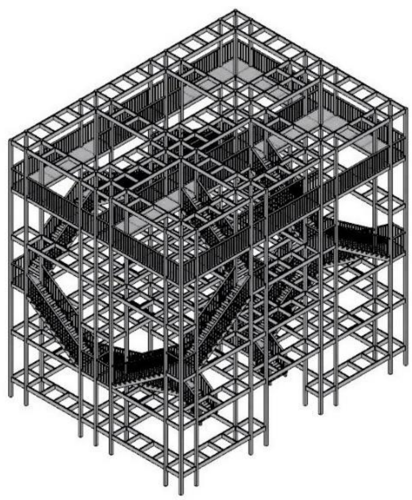


Figure 12 3D Model for the LGS Structure

Figure 13 3D Model for the Material Query

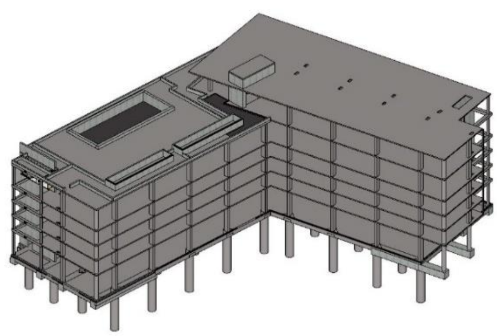


Figure 14 3D Model for the RCC Structure

Figure 15 3D Model for the Tower Crane

3.5.3.3 Interactive Site Objects

To enhance hands-on learning opportunities, interactive site objects were included to the VR training module in addition to non-interactive elements. The purpose of these interactive elements is to replicate safety-related tasks and risks associated with height falls and vehicle crashes. Trainees can interact with these things and experience a variety of scenarios, like working with masonry on a three-story building or maneuvering around construction site equipment including front-end loaders, transit mixers, and dumpers. Trainees can gain a better awareness of safety procedures and potential risks related to their workplaces through these interactive activities.

Following is the list of the objects for the Interactive activities:

- PPEs
- Meeting Room/Container
- Vehicles
- Scaffolding Setup

Figure 16 shows 3D Model for the Site Container, Figure 17 shows 3D Model for the PPEs, Figure 18 shows 3D Models for the Scaffolding Setup,19 shows 3D Models for the Vehicles with the Interaction and Figure 20 shows 3D Model for Site inside Trimble SketchUp.

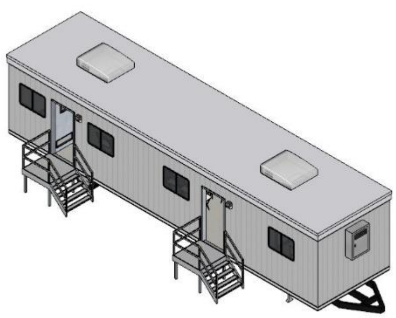


Figure 16 3D Model for Site Container

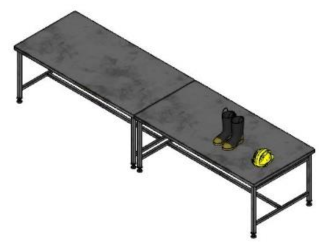


Figure 17 3D Model for the PPEs

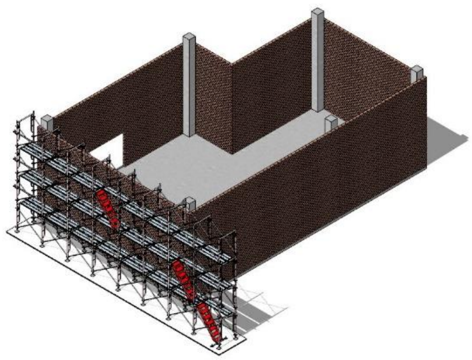


Figure 18 3D Model for the Scaffolding Setup

Figure 19 3D Model for the Interactable vehicles

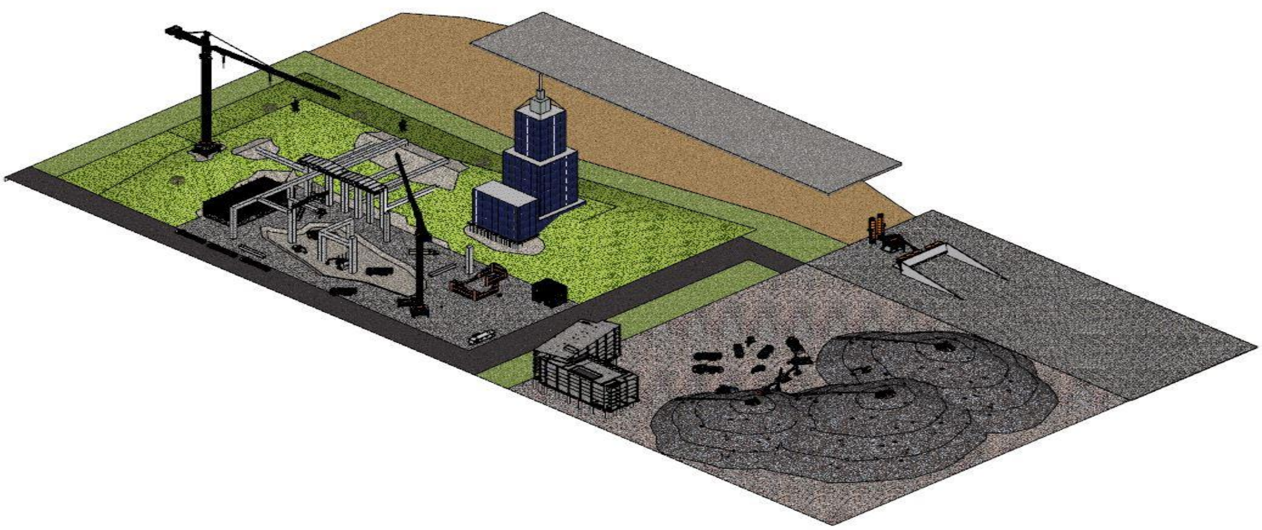


Figure 20 3D Model for the Site inside Trimble SketchUp

3.6 VR Setup in Unity

3.6.1 Immersive VR Environment

After the modeling is complete, models are imported into Unity 3D for further VR Setup.

First of all, Unity's controller is setup to give the trainee's first-person view in Oculus's Headsets. Unity's XR Interaction Toolkit is installed that is further used to develop XR Rig. XR rig is the trainee's first-person view in Module's Immersive Environment. Unity's "Track Pose Driver" Component is added to give the head rotation to the Trainee in the VR Environment. Trainee's hand meshes are added as the child of main camera in XR Rig. In this way, hands will move with the camera.

Unity's "Continuous Move Provider (Action-Based)" component is added to the XR Rig to give continuous motion to the trainee.

Unity's "Continuous Turn Provider (Action-Based)" component is added to XR Rig to give continuous rotation to the trainee.

In this way Controller is setup for the Immersive VR experience and trainee can move around the site on real time scales.

All site the objects are provided with Unity's Colliders either from Box, Sphere or Mesh Collider according to their geometry.

Following figure depicts the Unity's Interface for Immersive VR Environment that is being experienced by the Trainee in Oculus Rift S.

Followings are the salient features of Immersive VR Environment:

- Immersive
- Real time site visualizations
- Realistic Experience
- Real life experience
- Realistic Textures and Detail

Figure 21 gives the overview for the Immersive VR Environment inside Unity 3D.

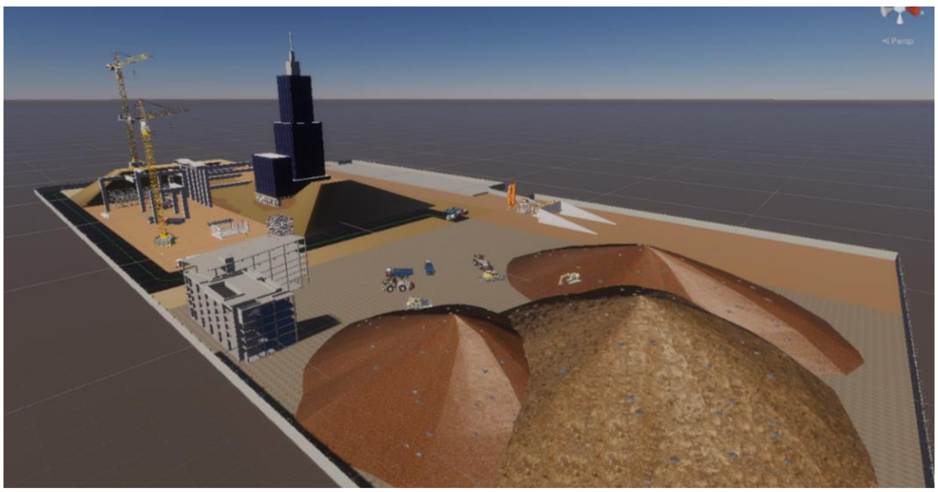


Figure 21 Overview of the Immersive VR Site inside Unity 3D

3.7 Scenes Development in Unity

3.7.1 Language Integration

Three different languages are Integrated into the module. Trainee is given audio instruction in either of the selected language. There are 7 different points in the module where trainee is given the Instructions according to the standards set by OSHA and NEBOSH in layman format.

Instructions are given in the following languages:

- English
- Urdu
- Punjabi

The scripts prepared according to OSHA and NEBOSH standards were recorded by the speakers volunteering for the module. The volunteers participating were fluent in languages that the project pursued to incorporate in safety modules.

Enum data type was used to create 3 different options in the form of 3 different languages in Unity’s Audio Manager. Audio Manager plays the source/language that is selected from the available options.

3.7.2 PPEs Interaction

Trainee is given interaction with Personal Protective Equipments (PPEs). Before interaction trainee is given audio instruction in either of the selected language for each PPE. During instruction, trainee is guided about the standards set by OSHA and NEBOSH for usage, precautions, do’s and do not ‘s about PPEs.

For the interaction of two objects in Unity, an Interactor and an Interactive is required. In this case, XR Origin is always selected as Interactor. “XR Direct Interactor” component is added on hands meshes to make them Interactor. Furthermore, “Box Collider” component is added on hands to detect collision with the interactable.

PPEs are Interactable in this case. “XR Grab Interactable” component is added on each PPE to make them interactable. “Box Collider” component is added on each PPE to detect any collision with the Interactor/Hands Meshes. “Rigid Body” component is added to provide physics properties to the PPEs.

Figure 22 shows the Personal Protective Equipment setup inside Unity.

Figure 22 PPEs setup inside Unity

3.7.3 Visual Instructions

Trainee is further provided with the visual instruction. For the visual instructions, videos are displayed inside the meeting room/site container for the height falls. In this way the trainee is encouraged to go through the causes and the remedies to be taken before they encounter any potential hazard. These videos are displayed on a monitor lcd inside the meeting room/site container.

A "Canvas" game object is added to the lcd and target videos are added as the media for the canvas. These videos are being played on repeat.

Figure 23 represents Site Container Inside Unity 3D and Figure 24 represents Site Container Interior inside Unity 3D.

Figure 23 Site Container Interior Inside Unity

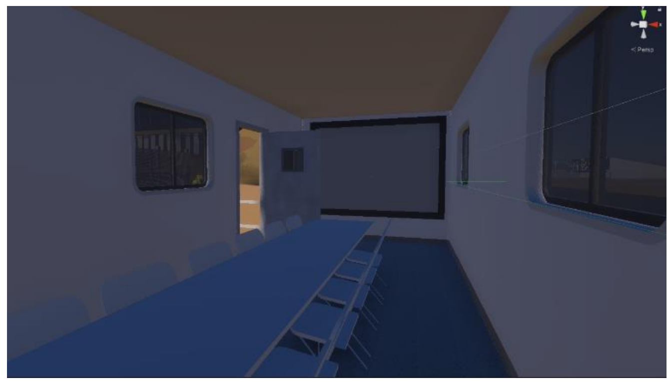


Figure 24 Site Container Interior Inside Unity

3.7.4 Vehicle Collision

Animation/Motion is provided to 3 different types of vehicles including Dumper, Front End Loader, and Transit Mixer. These vehicles are provided the motion throughout the site at different paths and locations. Trainee must avoid the collision with the vehicles while working and moving on the site. Trainee is respawned incase accident happens with the vehicle while moving on site.

Unity's package was used for the movement of vehicles. This package updates each the position of the vehicle on each point which looks like a continuous smooth motion for the vehicles.

A layer of dangerous objects was created that included the vehicles. "Box Collider" component was added to each moving vehicle which detects the Trainee/XR Origin's collision and respawns the trainee/XR Origin once the collision happens.

Figure 25 shows Transit Mixer Moving on Site and Figure 26 shows Front End Loader Moving on Site.

Figure 25 Transit Mixer moving on site

Figure 26 Front End Loader moving on site

3.7.5 Height Falls

A scaffolding setup is installed on the site where trainee must do the brick masonry work at third floor level height. Safety obstacles are provided throughout the scaffoldings. But there are certain points on the scaffolding where obstacles are not provided and there is potential of height fall while working on height. Trainee must work while avoiding the potential hazards of falling.

Interactor is already provided to the hand meshes. Bricks are made the interactable as done previously during PPEs Interaction. Trainee must use the controllers to grab the bricks and place them on the wall.

A box game object is added next to the hazardous points with "mesh renderer" component turned off so that it is invisible. This box game object is added to the "Dangerous Objects Layer" as done previously during vehicle collision. It is done so that Trainee respawn at the original position once falls from the height.

Figure 27 shows Scaffolding Setup for Height Falls and Figure 28 shows Hazardous Areas on Scaffolding Top.

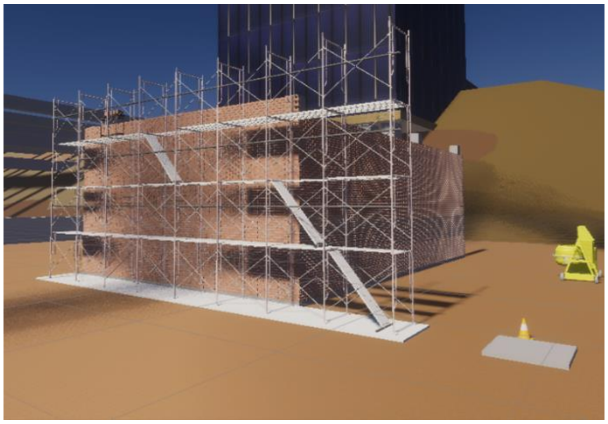


Figure 27 Scaffolding Setup for Height Falls

Figure 28 Hazardous Areas on the Scaffolding Top

3.8 Assessment

The objective of the evaluation phase is to assess the VR safety module. A framework for information design was put forth by Carliner (2000), and it consists of three key evaluation categories: physical, cognitive, and affective design. The investigations from (Kay, 2014; Shirley et al, 2014; Van Der Meij & Van Der Meij, 2014) were used to choose the components for these categories.

Four factors—sound, pace, viewability, and duration—focus on the physical or tangible design of the safety module during physical design review. The narration's volume and clarity are measured by sound. The narration's and the animated scene's pace are gauged. Viewability evaluates the module's key elements and highlights. If the module's duration is appropriate for the respondent, then the duration is complying.

With the assistance of six variables—similarity, understanding of the module and narration, completeness, information processing, explain ability, and improvement in knowledge—cognitive design evaluation focuses primarily on the success of VR safety modules. Similarity indicates whether the audience has previously viewed a comparable module on the same or a different topic in any format.

Understanding assesses the narration's relevancy (language correction) and the end-users understanding of the module's goal. Completeness is a measure of how accurately the safety modules reflect the real world, including if there are enough specifics and whether there are any common issues that need to be fixed. Information processing guarantees the module's clarity and understandability. The explain-ability assessment determines if the respondent could clearly explain the module's objectives. If the safety module helped them learn more about safety, their level of knowledge has increased.

With the use of two variables—level of interest and future preference—affective design evaluation measures audience interest and engagement as well as whether they think the VR module is worthwhile for future recommendation. The viewer's level of interest indicates whether they become disinterested or bored while us the VR module. Each respondent is asked about future recommendations whether they would want to observe further interactive activities on various safety training modules using the same methodology for validating the efficacy of the safety training modules.

Figure 29 shows Carliner's Three-Part framework for Information Design.

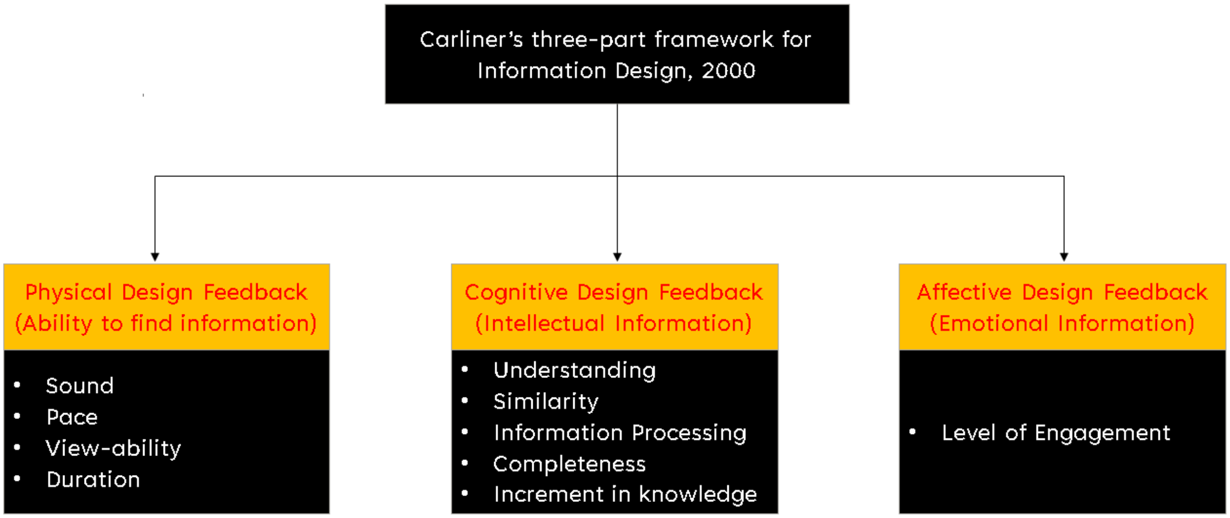


Figure 29 Carliner's Three-Part framework for Information Design

3.9 Results, conclusions & recommendations

Results from the interview would be compiled afterward. Conclusions will be drawn from the findings, and suggestions for additional research will be put forth.

Figure 30 shows the model architecture for the module.

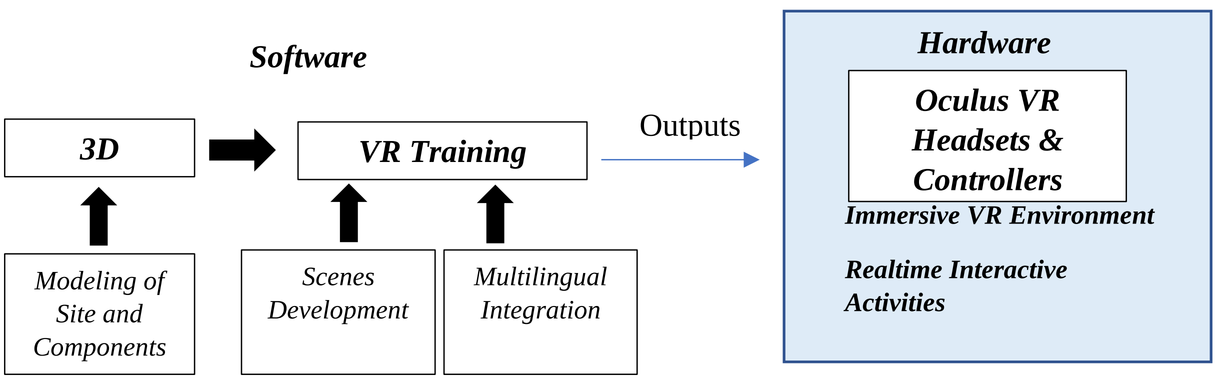
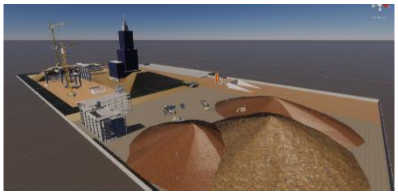
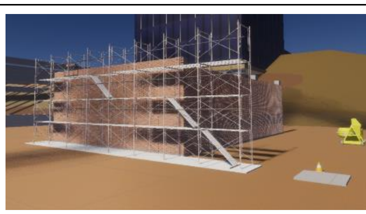


Figure 30 : The Module Architecture

Table 2 shows the description of ConSafeVRTrainer.

Table 2 The description of ConSafeVRTrainer Module

Outputs	Context	Achievement
 *Immersive VR Environment*	Immersive VR training environments reduce accidents by providing realistic simulations and allowing workers to experience danger without risking it.	An Immersive VR Based environment is developed using real-life scenarios and references for a hypothetical construction site where trainees can perform interactive and non-interactive activities.
 *Multilingual Training*	Multilingual VR-based construction safety training greatly benefits trainees by providing language-specific, immersive, and interactive learning experiences regardless of language ability to gain a deeper understanding of safety protocols.	Trainees can select either language from English, Urdu, and Punjabi. Trainees are provided with the safety protocols and standards set by OSHA & NEBOSH in their selected languages.
 *PPEs Trainings*	PPEs training helps trainees understand the importance of using protective gear such as safety helmets, safety boots, fire extinguishers, safety jackets, and safety glasses.	Trainees are provided with audio instructions about the PPE usage in front of them in their selected language according to standards set by OSHA & NEBOSH.
 *Visual Instructions*	Visual Trainings help by providing visual representations of potential construction hazards and safety protocols, improving workers' understanding of safety guidelines, ultimately reducing accidents and promoting a safer work environment.	For the visual instructions, videos are displayed inside the meeting room/site container for the height falls. In this way the trainee is encouraged to go through the causes and the remedies to be taken before they encounter any potential hazard.
 *Vehicle Collisions*	Vehicle collisions on construction sites are dangerous as they can seriously injure or kill workers and pedestrians. It can also damage equipment, structures and materials, leading to delays and increased costs.	Motion is provided Dumpers, Front End Loader, and Transit Mixer. Trainee must avoid the collision with the vehicles while working and moving on the site. Trainee is respawned incase accident happens with the vehicle while moving on site.
 *Height Falls*	Falling from height on a construction site is dangerous as it can seriously injure or kill workers. It can also lead to long-term disability, increased medical costs, and project delays.	A scaffolding setup is installed on the site where trainee must do the brick masonry work at third floor level height. There are certain points on the scaffolding where there is potential of falling from height. Trainee must work while avoiding the potential hazards of falling

CHAPTER 4

DATA COLLECTION & RESULTS

4.1 Introduction

The data gathered through one-on-one interviews is recited in this chapter. These interviews were done to determine whether computer-generated safety modules are useful for learners and whether they may serve as a viable substitute for traditional safety training methods.

4.2 Field Interview Questions

With the assistance of interviews, real-world data and experiences are acquired (Yin, 2003). Out of the 42 open-ended questions given to the workers, 17 focused on their demographics, work history, preferred method of communication, and whether they had ever had or witnessed an accident while working in the construction industry. The Annexure I attachment contains the whole questionnaire. The questionnaire was written in both English and Urdu. For employees who did not speak Urdu, a translator was available on-site to translate both the questions and the answers. Through questionnaire surveys, a wide range of people can be accessed in order to acquire a more comprehensive understanding, allowing for the collection of versatile data.

4.3 Characteristics of the Respondents

A total of 22 respondents from the two different sites were evaluated. Firstly, they were asked some demographic questions, followed by exhibition of the safety modules. The researcher proceeded with younger respondents with lesser work experience and little to no educational background to achieve maximum positive output. All the respondents were male, between the ages of 18-33+.

4.4 Field Interviews

Two sites in NUST Islamabad were selected to carry out the field interviews. These three sites have workers who speak Punjabi, Pashto, Saraiki and Urdu in majority along with a few other languages as well. The interviews were set up in casual manner. There are three main elements in the VR safety modules; accidents due to heights, hit-by moving objects and the instructions about the Personal Protection Equipment (PPEs). Therefore, majority of 22 workers prone to such accidents were selected by default.

Figure 31 to 35 are the responses from the participants during evaluation of module.

In Figure 31, the respondents' age range is depicted. Among the participants, 7 (41%) were between the ages of 18 and 22; 9, or 32%, were between the ages of 23 and 27; 4, or 18%, were between the ages of 28 and 33; and just 2, or 2%, were over the age of 33. Furthermore, as shown in Figure 32, 14 (67%) of the workers had no experience at all. Only 1 (5%) respondent had experience of more than 11 years, whereas 4 (19%) workers had experience of 4 to 7 years, 2 (9%) of 8 to 11 years, and 4 (19%) of 4 to 7 years.

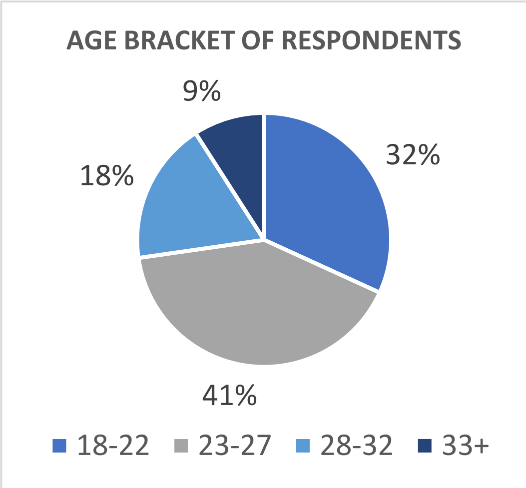


Figure 31 age of respondents

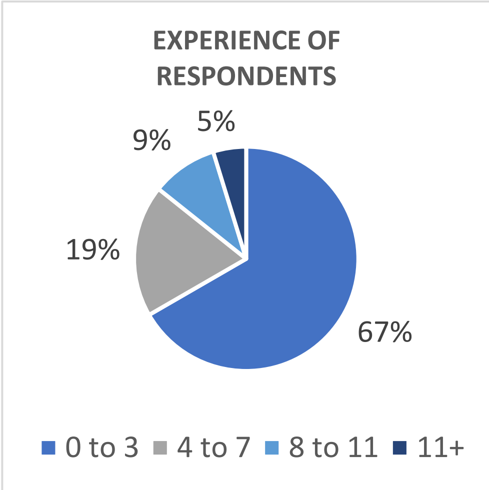


Figure 32 experience of respondents

Figure 33, which depicts the participants' educational backgrounds, reveals that 15 (68%) of the workers had no formal schooling. 04 (18%) individuals completed high school or later, while 02 (09%) participants attended primary school, 01 (05%) participants attended secondary school, and so on (Site Supervisors). The responders were questioned about a number of prior accidents

It is shown in Figure 34, out of the total 22 respondents, 14 (63.64%) of them had witnessed major to minor accidents in their workplace. The figure 35 displays the designation of the respondents, it depicts that 12 (55%) were unskilled laborers, 06 (27%) were skilled laborers and 04 (18%) were supervisors.

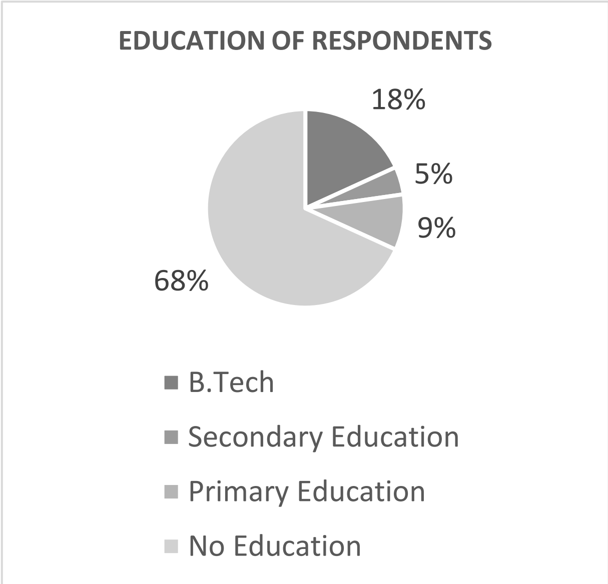


Figure 33 Education of Respondents

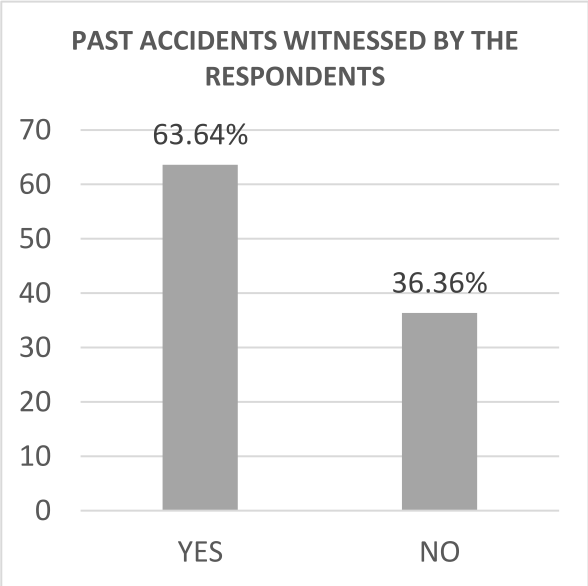


Figure 34 Past accidents witnessed by the respondents

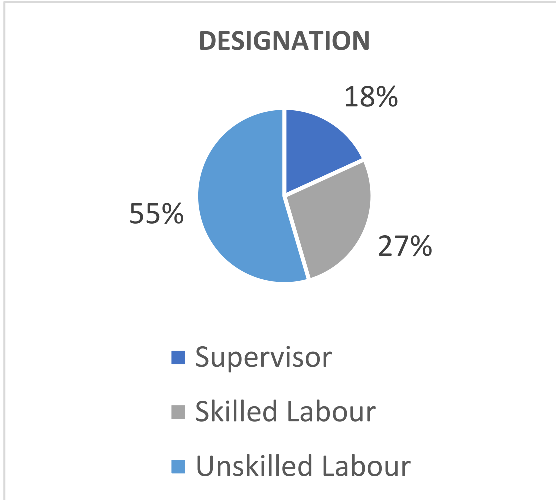


Figure 35 Designation of Respondents

4.5 Discussion

According to the feedback, the majority of comments regarding the physical, cognitive, and emotive evaluation of the safety modules that had been produced were favorable. The participants expressed satisfaction with the narration's volume quality and clarity, which increases the likelihood that they will understand it in the cognitive domain, as also predicted (Ashaver, 2013). Moreover, the added audio narrations have been reported as the major factor to understand the shown modules. The comments about the pace of narration also demonstrate that audio narrations were timed to match the on-screen movements, minimizing the likelihood of deviating from the topic matter.

According to (Clark and Mayer, 2012), most participants gave positive reviews regarding the viewability and pace of the animation, which indicates that the participants had no trouble differentiating the items on the screen due to their rapid movement. However, it was noted that as the player was moving at a moderate to slow speed, the animation's tempo could have been accelerated. Because the participants expressed a wish for the duration of the module to be extended to cover more accidents and their appropriate cures, neutral and negative answers were obtained on its length. Even though they had never previously seen similar content, the participants in the cognitive assessment were largely happy with the related understanding, information processing, and explanation elements.

This meets the criterion put forth by (Bishop and Cates, 2001) that a viewer should not only be able to see the visual content but also be able to quickly understand and clarify the content. Most participants offered their desire to utilize and further promote comparable VR safety modules for other accident kinds within the affective domain, demonstrating their positive motivation and a higher degree of interest. The staff also thought that the created modules might raise safety knowledge among newly hired personnel on-site. In addition to the good comments, there have been certain instances where numerous adjustments have been proposed by the participants. These ideas largely related to the physical layout, demanding changes to the aesthetic scenery of specific modules.

Table 3 shows the results for the assessment of ConSafeVRTrainer.

Table 3: Assessment of ConSafeVRTrainer

Physical	**Description**	**NORMAL**		**LOW**		**HIGH**	
		No.	**%**	**No.**	**%**	**No.**	**%**
	SOUND	16	73	4	18	2	9
	PACE OF NARRATION	15	68	4	18	3	14
	PACE OF ANIMATION	16	73	6	27	0	0
	VIEWABILTY	18	82	0	0	4	18
	DURATION	17	77	3	14	2	9
Cognitive	**Description**	**POSITIVE**		**NEUTRAL**		**NEGATIVE**	
		No.	**%**	**No.**	**%**	**No.**	**%**
	UNDERSTANDING	13	59	7	32	2	9
	INFORMATION PROCESSING	12	55	8	36	2	9
	COMPLETENESS	14	64	5	23	3	14
	SIMILARITY	16	73	5	23	1	5
	EXPLANATION	17	77	3	14	2	9
	INNCREMENT IN KNOWLEDGE	15		6		1	
Affective	**Description**	**POSITIVE**		**NEUTRAL**		**NEGATIVE**	
		No.	**%**	**No.**	**%**	**No.**	**%**
	LEVEL OF ENGAGEMENT	18	81	3	14	1	5
	RECOMMENDATION	21	95	1	5	0	0

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Introduction

The research and conclusions are presented in this section. The data gathering from earlier chapters is summarized. Future research is also recommended, along with recommendations based on the study's findings.

5.2 Conclusion

ConSafeVRTrainer, concentrated on creating an immersive VR training module that would improve safety instruction in high-risk settings. The goal of the module was to provide an interactive VR module with an open-world setting that would offer people working in dangerous industries a thorough and interesting learning experience. The module included numerous languages, including English, Urdu, and Punjabi, to enable accessibility and to effectively communicate safety recommendations. To bridge the gap between complicated rules and practical understanding, these instructions were carefully translated into layman's language from industry standards like Occupational Safety and Health Administration (OSHA) and National Examination Board in Occupational Safety and Health (NEBOSH). The most frequent on-site mishaps, according to the module, were height falls and occurrences involving objects or vehicles. In order to accurately recreate these risky situations in the VR world, interactive scenarios were created. The goal was to immerse trainees in realistic situations while raising their knowledge of the hazards involved and encouraging the adoption of required safety measures. Interactable Personal Protective Equipment (PPE) with voice instructions was a key feature of the VR module that allowed trainees to interact with virtual PPEs while learning how to use and maintain them properly.

According to the input given by the construction employees during the assessment phase, the framework can be used to design training materials that will raise awareness among newly hired construction workers who have little to no prior work experience.

For the initial model generation stage of the development process, Sketchup was used. The models were then imported into Unity 3D where they underwent further reworking and implementation. These widely used software programs offered the adaptability and functionality required to develop an engaging and immersive VR training curriculum. The project's successful completion illustrated the potential of immersive VR technology to improve safety training. The package provided a thorough and successful training experience by combining realistic simulations, bilingual instructions, and interactive features, supporting continuous efforts to increase workplace safety and decrease accidents. While the VR module showed potential, it's crucial to recognize that more study and improvement are still required to maximize its utility. Future versions could investigate more risk scenarios, including a wider variety of languages, and take advantage of advances in VR technology to improve the training experience's realism and effectiveness. In addition to the two accident types that were taken into consideration for the study, there are numerous other accident types that occur relatively regularly during building projects and result in severe loss of human life or permanent injury. Future research is also advised to examine how the framework's application throughout the execution phase affects the project's safety record

5.3 Contribution for Academia

The study offers a thorough assessment of the most recent safety training approaches. With the aid of prior research, it was determined that teaching through intractable approaches is the most effective strategy when other pedagogical techniques don't produce the desired results in a certain situation. The study also emphasizes the need of using local languages in the training curricula, demonstrating the urgent need for safety instruction in situations where most of the audience cannot read or write in a widely spoken language (English). The researcher also offers a framework for academic experts to create and duplicate the safety training modules, which is essential for the deployment of occupational safety training across industries and in addition to other nations. This achieves the Sustainable Development Goals (SDGs) of UNESCO as: Goal 03 Good Health and Well-being, Goal 04 Quality Education, and Goal 09 Industry, Innovation, and Infrastructure.

5.4 Contribution for Industry

Out of the 22 participants who used ConSafeVRTrainer, it was discovered during the assessment process that 14 of them witnessed workplace accidents at some point in their lives. These statistics revealed the horrifying state of the construction industry and the absence of safety implementation measures, were dangerously high. This argument shows that all the significant players were negligent and that there were insufficient safety enforcement processes, which led to many workplace accidents, particularly in developing nations. This study also highlighted potential workplace risks that could occur during a building activity, as well as their solutions by giving a computer-generated VR module. By highlighting the necessity of adhering to workplace safety procedures that reduce injuries, this raises awareness of safety habits among the audience and illustrates the negative effects of accidents and dangerous work practices. These safety components are also transportable, accessible, and widely available. They are adaptable (different languages, different visual settings), making them appropriate for other sectors. The VR modules offer a safer and more effective alternative to traditional training methods that are not audience-centric and are therefore more susceptible to being out of date.

5.5 Recommendations

In the future, more accidents may be covered. Most of these were unable to be included in the module due to time restrictions. There is a recommendation is to Personalize the training, as different workers have different needs and skill levels, we develop interactable module for different skill level and specify them for each operation i.e., Development of VR Based Simulators for Machine Operators. Another recommendation is Development of an Immersive VR Module to provide Equipment usage and Handling Training. Integrate the usage of Mixed Reality (AR & VR) Environments and Modules for Construction Project Management & Planning.

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Annexure I – Questions for assessment

Background information/General Questions
➢ Name ➢ Education ➢ Where do you belong from? (City/Village name) ➢ Experience ➢ Field of work ➢ Any disability? ➢ Mother tongue ➢ Any other languages? ➢ Mode of communication between other workers? ➢ Mode of communication with supervisor? ➢ Are you able to read? ➢ Have you ever met an accident in your work life? ➢ If yes, what was the type of accident? ➢ Have you ever witnessed any accident in your work life? ➢ If yes, what was the type of accident? ➢ Are you given any safety education before starting on a new work? ➢ If yes, in what form?
Physical Design of the Module
➢ Please give your feedback about the volume/sound of modules? ➢ What are your reviews about the narration? Were they effective and ➢ appropriate for instructional purposes? (Used correct terminologies, language) ➢ Describe the pace of the narration. ➢ Share your views about the speed of the Voiceover? ➢ Did you notice any highlighted regions? What were they indicating? ➢ Comment about the animations/graphics (Whether were they easy to ➢ understand) ➢ Can you distinguish important objects in the module?What should be the ideal duration of the module? ➢ Was the presentation adequate? Was it missing anything?
Cognitive Design of the Module
➢ What was the purpose of this module? ➢ Have you seen any similar thing before?

- Discuss any mistakes or errors in the module shown if you have noticed. Highlight any ambiguities in the module that you did not understand?
- How much time did it take you to process or understand the message in the module?
- Elaborate the hazards of accidents that you just saw.
- What are your views about the remedies shown for the hazards? Do you have any better idea?
- Did the module in any way, help increase your knowledge that youdid not have before?
- Anything specific that caught your attention? Why?
- What are the things that you would like me to add?
- If asked, would you be able to remember and explain the contents shown after a few days?
- Would you recommend this module to your colleagues? Why?

Affective Design if the Module

- Share your experience while experiencing the module?
- How much mental effort did you need to understand?
- Discuss anything that you found boring or of lesser interest in the module.
- If given, would you prefer to experience more similar scenario on different
- topics?