www.cpwr.com • www.elcosh.org

THE CENTER FOR CONSTRUCTION
RESEARCH AND TRAINING

PARS: Using Augmented Panoramas of Reality for Construction Safety Training

Masoud Gheisari
Behzad Esmaeili

University of Florida
George Mason University

January 2019

8484 Georgia Avenue
Suite 1000
Silver Spring, MD 20910

PHONE: 301.578.8500
FAX: 301.578.8572

 CPWR is the research and training arm of NABTU. Production of this document was supported by cooperative agreement OH 009762 from the National Institute for Occupational Safety and Health (NIOSH). The contents are solely the responsibility of the authors and do not necessarily represent the official views of NIOSH.

CPWR Small Study Program

PARS: Using Augmented Panoramas of Reality for Construction Safety Training

Study Number: 17-7-PS

Final Report

Prepared by:

Masoud Gheisari, Ph.D. (PI)
Assistant Professor, Rinker School of Construction Management
College of Design, Construction, and Planning
University of Florida
322 Rinker Hall
Gainesville, FL 32611
Phone: 352-273-1166
Email: masoud@ufl.edu

Behzad Esmaeili, Ph.D. (Co-PI)
Assistant Professor, Sid and Reva Dewberry Department of Civil,
Environmental and Infrastructure Engineering
Volgenau School of Engineering
George Mason University
Nguyen Engineering Building, Suite 1405
4400 University Drive, MS 6C1
Fairfax, Virginia 22030
Phone: 703-993-3688
Email: besmaeil@gmu.edu

November 30, 2018

Abstract: Virtual reality (VR)-based approaches have been used to facilitate safety knowledge transfer and increase hazard awareness by providing safe and controlled experiences of unsafe scenarios for construction safety training applications. However, high computational costs, long development times, and the limited sense of presence and realism associated with existing VR methods have posed significant challenges to using such VR-based safety training platforms. Unlike the VR environments that provide unrealistic computer-generated simulations of the environment, 360-degree panoramas can create highly realistic and detailed simulations of environments while giving users a high sense of presence. In this project we developed and validated *PARS* (*PAnoramas of Reality for Safety*), as a hazard-identification training tool based on panoramas of reality, which enables learners to navigate, observe, and identify hazards in the complex context of real construction sites. A comparative experiment between VR and PARS was also conducted to assess their capabilities for hazard identification purposes.

Key Research Factors and Finding.

1. *PARS* (*PAnoramas of Reality for Safety*), provide a low-cost, simple-to-capture representation of real settings and create unbroken views of a whole region surrounding an observer, thereby allowing for an interactive look-around experience of a real jobsite with a strong sense of presence.
2. Virtual reality (VR) is more computationally intensive and requires more time to create a representation of a real construction jobsite than *PARS.*
3. VR provides a clear and simple representation of reality which makes hazard identification simpler comparing to *PARS*
4. *PARS* provides a true-to-life representation of reality which makes hazard identification harder comparing to VR
5. VR is "cleaner" than *PARS*, which makes VR easier to identify hazards but does not provide a realistic or relatable environment as *PARS* does.

Introduction.

The backbone of any occupational health and safety discussion is hazard identification; however, current methods of teaching hazard identification are losing their relevance, as they are lecture based and passive. The emergence of the Net Generation—those who have grown up with information technology—will oblige instructors to relinquish passive means of teaching and instead place more emphasis on creating active learning experiences that embrace virtual technologies and digital sites [1]. Although there has been a significant amount of research on safety education using virtual sites, there are opportunities to further understand the effectiveness of using digital construction sites for educational purposes. In particular, investigating the use of real construction projects and not a computer-generated virtual representation of the environments will create a true-to-life experience of visiting a real construction project. Currently, virtual modeling methods such as Building Information Modeling (BIM) provide media to visualize components and manage and coordinate associated construction management activities. These virtual models mediate to simulate and address the replacement of the full real world conditions – time, physical space, and material properties. However, these models hinder and diminish the full perception of the real-world environment, providing users with an unreal computer-generated simulation of a construction environment. One of the emerging technologies that can address this limitation is using augmented panoramas of reality.

In addition to creating interactive training experiences for tech-savvy trainees, augmented panoramas of reality have a high potential to enhance training of hard-to-reach or illiterate workers. The number of immigrant workers in the U.S. construction labor force is increasing. According to the U.S. Census Bureau [2], foreign-born workers composed almost 22.4 percent of all construction workers in the country. One of the factors that contribute to a higher number of injuries among immigrant workers is literacy level; a significant portion of these workers are illiterate even in their native language—rendering written manuals less successful. Therefore, there is increasing attention to developing training materials based on visual cues. Safety training programs based on augmented panoramas of reality can play a significant role in addressing this immediate need.

In this project, we use augmented panoramas of reality as a ubiquitous technique for visualizing complex occasions on construction sites that can be augmented with different layers of safety-related information (PARS: PAnoramas of Reality for Safety). Unlike the traditional virtual environments that provide an unrealistic computer-generated simulation of the environment, PARS can create highly realistic and detailed representations of the real construction sites while giving users a sense of immersion. These features enable PARS to become a robust tool for developing training materials specifically for construction safety. In such an environment, construction workers and professionals are capable of navigating within the data-rich environment of a real construction project to observe and identify the safety challenges in various spots. PARS would provide an opportunity for trainees to not only experience the real construction site but to learn more about safety challenges on such a unique and complex construction project. Developing training platform found in panoramic environments will provide a fruitful place to investigate new ways of hazard identification training by bringing real physical hazardous situations closer to users in a completely safe controllable way.

Research Background.

Construction Safety Training and Hazard Identification

Considering that potential hazards on construction jobsites increase the chances of an incident [3,4], the ability to identify hazardous conditions before initiating a working task is an indispensable tool to achieve proactive safety management and risk mitigation. However, since it is almost impossible to eliminate all hazards from a working environment, construction workers themselves must be able to identify hazards and make proper decisions to avoid accidents. As a result, awareness and identification of hazards is the basis of any robust construction safety program [5,6].

Training programs are often used by employers to improve the hazard-recognition skills of their personnel [7]. Insufficient safety training has been consistently identified as a leading attribute in accident occurrence [7–9]. In particular, hazard-recognition training is of critical importance because it raises workers' awareness of common risks on the construction jobsite by transferring safety-related knowledge to the workforce. Ultimately, this training encourages workers and professionals to make safety-conscious decisions, minimize risk, and avoid potential injuries. Consequently, scholars and industry professionals agree that safety training is paramount to enhancing hazard recognition on complex and dynamic jobsites [7,9].

While important research efforts have been undertaken in the past to advance this type of intervention [e.g. 10,11], studies demonstrate that deficiencies remain within the commonly applied training methods. First, some of the issues attributed to inefficiencies of safety training have been linked to the inherent characteristics of construction as an industry: The short-term nature of construction employment, companies' variable safety cultures and training budgets, and the difficulties involved in demonstrating the benefits of safety all have significant impacts on the effectiveness of training programs [12–16]. Second, deficiencies specific to the design of traditional safety training methods have been identified in previous studies. Low levels of engagement in safety training (lectures, videos, or demonstrations) have been proven to provide minimal efficiency in conveying safety-related knowledge, including hazard-identification skills [11,17,18]. Third, current safety-assessment techniques can contribute to poor safety performance in construction projects, a reality resulting from the challenge of translating an assessment's static in-text descriptions of complex safety problems (i.e., construction process, location and site environment) to knowledge about dynamic real-life situations [19]. Combined, these factors indicate that a large percentage of hazards remain unrecognized in the workplace [20,21].

Additionally, a recent study showed that traditional training programs — even those generally accepted within the industry — still suffer limitations in helping workers acquire hazard-recognition skills. Hasanzadeh et al. [22] used eye-tracking technology to measure the impact of safety knowledge (in terms of training, work experience, and injury exposure) on construction workers' attentional allocation toward jobsite hazards. Their study found that although work experience and injury exposure significantly impact visual search strategies and attentional allocation toward hazards, the difference between workers with and without the OSHA 10-h certificate was not significant. While the results did not state that the

OSHA 10-h certificate is ineffective, the study revealed the need for developing more innovative training techniques, such as the high-engagement methods for safety training (e.g., trainee-centric, highly interactive) that have been proposed in recent years [9,23]. Hasanzadeh et al.'s [22] results underscore the potential benefit of integrating both tacit knowledge (work experience and injury exposure) and explicit knowledge (e.g., interactive training) to enhance worker safety.

Application of Virtual Reality in Construction Safety Research

In response to the shortcomings of traditional safety training, academia has explored the use of virtual reality (VR) to create active learning experiences that engage the learner. VR has been used to provide training opportunities for dangerous tasks in the jobsite, allowing users to avoiding exposure to potential harm. Researchers in the domain of safety have designed VR systems as serious games to achieve effective learning within digital environments, promoting user motivation and active engagement in their instructional practices as summarized in Table 1.

Table 1: VR Applications for Safety Training

Authors	Purpose
Li et al. [19]	Used a game engine combined with a Wii game controller to produce a multiuser VR training program. Users were able to practice safe crane dismantling procedures.
Guo et al. [24]	Designed a collaborative, multi-user game that allowed trainees to navigate and perform construction operations for safety education in tower crane, mobile crane, and pile driver activities.
Dickinson et al. [25]	Conducted a robust experiment engaging trade students in a serious game on trench safety, which included fall, struck-by, and caught-in hazards.
Lin et al. [26]	Developed a serious game aimed at being immersive, interactive, and entertaining to test on users' hazard identification skills
Le et al. [27]	Created a collaborative platform that replicated real-world accidents. Students learned common industry safety practices while roleplaying and social interacting in the digital environment.
Pedro et al. [28]	Devised a serious game for university students to learn of safety material, rules, regulations, and hazards through the interaction using VR and smart devices.
Bosché el at. [29]	Employed a head-mounted display simulation in conjunction to real-world prompts to simulate jobsite conditions. Scaffolds or beams situations were replicated to train students how to react to hazards.

Although these VR simulations mediate to replace real-world conditions – time, physical space, and material properties, these environments are uncapable of presenting a full experience of real working conditions. VR has limited capabilities of delivering high degrees of realism on which trainees might not perform with the same proficiency in real world operations as they do in the simulated realm [30]. Additionally, VR requires large amounts of resources from the development perspective and from the end-user perspective. Modelling close-to-reality settings necessitates significant efforts in terms of time to achieve a sufficiently realistic representation of reality and often entails high computational cost for the rendering of all the elements on each scene [9,19,26]. Consequently, VR suffers from a low agility in the face of evolving work environments.

Why Use 360-Degree Panoramas?

360-degree panoramas create an unmodeled view of real environments that looks identical to reality, which provides inherent benefits over traditional virtual reality techniques. VR's complex, real-world simulations are very computationally intensive and time consuming, since computer-generated representations of the environment are modeled from a user's perception of reality. Furthermore, while

VR's 3D computer graphics allow users to synthesize an environment for arbitrary representations, the rendering quality and scene complexity are often limited because of real-time constraints [31]. Alternatively, the capturing technologies for building 360-degree panoramas provide unbroken views of a whole region surrounding an observer, giving a "sense of presence, of being there" [32] to the observer. Thus, 360-degree panoramas offer low computational-cost, easy-to-capture, non-computer-generated simulations that are beneficially immersive to the user due to the realism embedded in the photography and videography data.

Interactive panoramic scenes have also been used for several applications by researchers in the construction domain. Early research focused on addressing the technicalities of creating, capturing, interpreting, and navigating 360-degree images and video: Finch and Wing [33] employed video-still images on a computer-based system to produce a navigable simulator for students in built environment disciplines. Mei and Wing [34] used a series of interconnected 360-degree panoramic images that enabled users to navigate from one image to another through an interface to visit virtual construction sites. Dickinson et al. [35] developed a computer-based learning resource that used overlapping images to explore a virtual panoramic site.

Several research projects have used 360-degree scenes as a reality backdrop upon which to augment mainly 3D models [36,37,38,39]. In one such example, Côté and his colleagues [36] used a panorama of the surface of a street to augment a virtual excavation and illustrated underground utilities over the images. Other forms have used augmented panoramas in architectural and real estate domains to create virtual walk-throughs of real environments for clients; in these applications, panoramic images or videos were taken of an interior and were then augmented with various types of information (e.g., virtual 2D signs, audio, or 3D models) to create a natural tour of the building for potential buyers. Additionally, 360-degree panoramas have been used as method to provide construction managers with a method to record the building process in the jobsite. Eiris et al. [40] described the process of using modern capturing methods for 360-degree panoramas to create virtual tours of complex construction projects for asset management and documentation.

More recently, 360-degree panoramas have been used as safety-training tool to enables visualization of hazards. Table 2 illustrates each of these applications used to deliver an immersive experience of interacting with a real space in a virtual environment using this technology in the construction-safety area.

Table 2: 360-Degree Panorama Applications for Safety Training.

Authors	Purpose
Jeelani et al. [41]	Used of 360-degree panoramic images for simulating personalized accidents to train construction workers. The pilot system showed that such 360-degree panoramic images provided high degree of presence.
Eiris et al. [42] and Eiris et al. [43]	Developed a virtual safety training environment using augmented panoramas of reality. The platform enabled trainees to traverse a construction site, obtaining comprehensive information about the environment.
Pham et al. [44] and Pham et al. [45]	Created a learning system for improving the safety education. In the learning system, a virtual site visit was conducted to identify hazardous situations in construction jobsite employing 360-degree panoramas.

Although the contribution of studies found in the literature in the creation of training materials and contents is outstanding, none of the methods found provide a realistic connection between the virtual training and work environment of the construction jobsite. This limitation stems from the fact that replicating the complex conditions of an as-built work environments in virtual reality setting is computationally expensive and time-consuming [1]. To address this limitation, 360-degree panoramas of reality have been used in recent research studies to provide immersive representations of construction jobsites for safety-training purposes. This project utilizes 360-degree panoramas of reality with layers of augmented information and defined a graphical user interface that is conducive for improving workers' hazard-identification skills within the complex context of real construction projects. Within the platform, trainees actively practice identifying hazards in a highly engaging and realistic environment. These low-cost, simple-to-capture representations of real settings provide unbroken views of a whole region surrounding an observer, thereby allowing for an interactive look-around experience with a strong sense of presence. The contribution of this research is to present an alternative method for practicing hazard identification using 360-degree panoramas of the actual construction jobsite, thereby enabling training opportunities that better train users to recognize four sample types of hazards.

Research Objectives and Scope.

This research project will improve recognition and awareness of construction hazards among construction workers and professionals by developing and validating *PARS*, a hazard-identification training tool based on panoramas of reality, which enables learners to navigate, observe, and identify focus-four related hazards in the complex context of construction sites. To achieve our specific aim and to address the identified knowledge gap and research questions, we will have two research objectives:

- Objective 1: Develop *PARS* and define a set of *PARS* affordances that are most conducive to developing hazard identification skills within the complex context of real construction projects
- Objective 2: Assess the influence of the *PARS* approach on the development of hazard identification skills within the complex context of real construction projects

Occupational Safety and Health Administration (OSHA) has identified the four leading causes of fatalities in the construction industry: fall hazards, struck-by hazards, caught-in or -between hazards, and electrical hazards. In this study we will focus on these four hazards and a short description of them are provided here:

- *Fall hazards*: are the leading cause of fatalities in the construction industry [46,47] and account for approximately a third of the injuries in the US construction industry as a whole [47]. Additionally, falls usually lead to severe injuries [48] and require long, costly periods of recovery [49]. Therefore, falls became a key target area for intervention and prevention in construction. Compliance with fall-protection regulations is low, particularly in residential building construction [50]. One of the main reasons for this lack of compliance—particularly among small and medium sized companies—is the large presence of limited-English-proficiency workers, low-literacy workers, young workers, and temporary workers [51]. Therefore, providing a solution to help these hard-to-reach workers receive proper training is promising.
- *Struck-by hazards*: According to the Occupational Safety and Health Administration (OSHA), struck-by injuries result from "forcible contact or impact between the injured person and an object or piece of equipment" [52]. Struck-by accidents accounted for 22% of all construction-related fatalities between 1985 and 1989, and while the percentage of caught in/between and electrocutions have decreased between 1997 and 2000, the percentage of struck-by accidents has increased slightly since that time [47]. Although struck-by accidents are one of the significant proximal causes of injuries, few studies have directly examined this topic.
- *Caught-in or –between hazards*: According to OSHA, caught-in or -between hazards are defined as: Injuries resulting from a person being squeezed, caught, crushed, pinched, or compressed between two or more objects, or between parts of an object. This includes individuals who get caught or crushed in operating equipment, between other mashing objects, between a moving and stationary object, or between two or more moving objects.
- *Electrocution hazards*: Contact with electric current often is the fourth leading cause of work-related deaths – after falls, transportation incidents, and contact with objects and equipment [53]. In addition, the construction industry typically have 20% more fatalities due to contact with wiring, transformers or other electrical components than would be expected statistically [54]. The most common reasons for electrocution accidents are [54]: contact with overhead power lines (47.2%); contact with wiring, transformers or other electrical components (34.3%); contact with electric current of a machine, tool, appliance or light fixture (12.4%); followed by some minor causes like contact with electric current, unspecified (2.6%); struck by lightning (2.4%); and contact with underground, buried power lines

(1.1%). To reduce risk of these kinds of accidents, previous studies suggested a permission process for people who are working on live circuities, along with personal locks and training sessions [55].

Methods.
This study is a collaborative effort between the University of Florida (UF) and the George Mason University (GMU). We developed and evaluated PARS to establish a benchmark for the use of augmented panoramas of reality in improving hazard identification skills of construction workers and professionals. An institutional review board (IRB) protocol has been approved by UF IRB (Study#: IRB201701616) to satisfy human-based requirements for the experimental evaluation phase of this proposed research.

Phase I: Content Development for a Focus Four Hazard Identification Scenario: The first step for the research team was to identify training material related to the focus four. Text and images were derived from the Susan Harwood training grants, accessed through the OSHA website. Reviewing the Susan Harwood content led into the capturing of 360-degree panoramic images. The researchers visited local construction jobsites, seeking to capture scenes similar to those used in Susan Harwood materials. Both training content, in the form of text and 2D images, and 360-degree panoramic images were developed for construction scenarios involving the focus four hazards. From August 15, 2017, through February 11, 2018, the researcher team conducted ten site visits and captured over six hundred 360-degree panoramic images of real construction sites (Figure 1). The researchers walked the sites under the supervision and guidance from project superintendents or field engineers. The visits to different job sites allowed the research team to capture a variety of scenarios of projects under different stages of construction.

Figure 1: 360-degree panoramic images captured on the site

Sixteen panoramas which were the better representative of focus four hazard scenarios were selected out of the pool of previously captured scenes and then were analyzed to identify all focus four hazards in each scene. Eight scenes were selected for the training (Appendix A) and the other eight for the assessment part (Appendix B) of the PARS platform development in the next phase. Also, Appendix C illustrates the augmentation content in each panorama.

Phase II: PARS Technical Development: PARS safety training platform contains three distinct layers: application, service, and hardware (Figure 2). The layers represent the basic elements required by the platform to function.

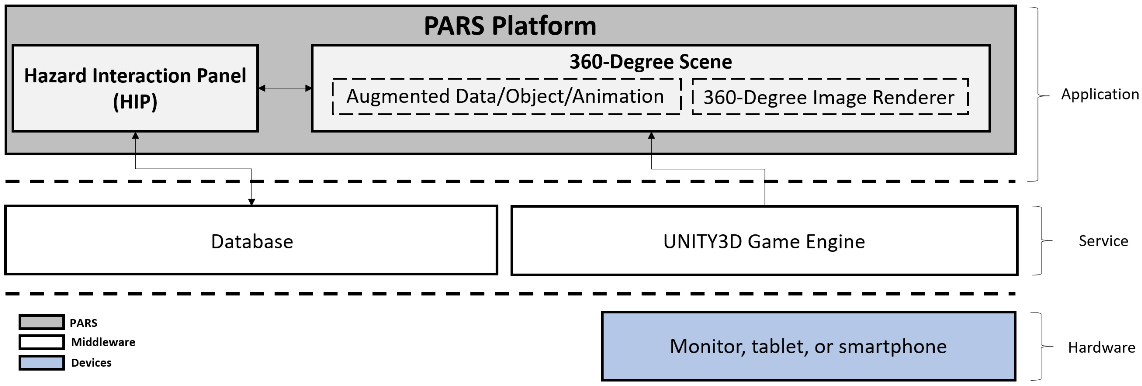


Figure 2: Platform Architecture—Application, Service, and Hardware Layers.

The trainee only has access to the application layer, where all the training interactions occur. In this layer, the trainee observes and identifies hazards, and then receives feedback about the hazard-recognition tasks. The service layer consists of the digital tools employed by the application layer to enable and support the platform's activities. Specifically, the platform utilizes the Unity3D® game engine, and a database that contains trainee information for each session (e.g., time spent reading information, interactions with an interface, hazard selections). The last layer contains the hardware devices that allow the trainees to engage with the platform physically. Currently, the platform supports the visualization with a monitor, tablet, or smartphone, and the platform functions as a standalone, locally executed software.

As illustrated in Figure 3, the data management of the platform proceeds according to an activity-based unified modeling language (UML) diagram that runs within the Unity3D application and is supported by the database. By utilizing the architecture described in this section and following the UML data management procedure, the Unity3D application can be used to create PARS.

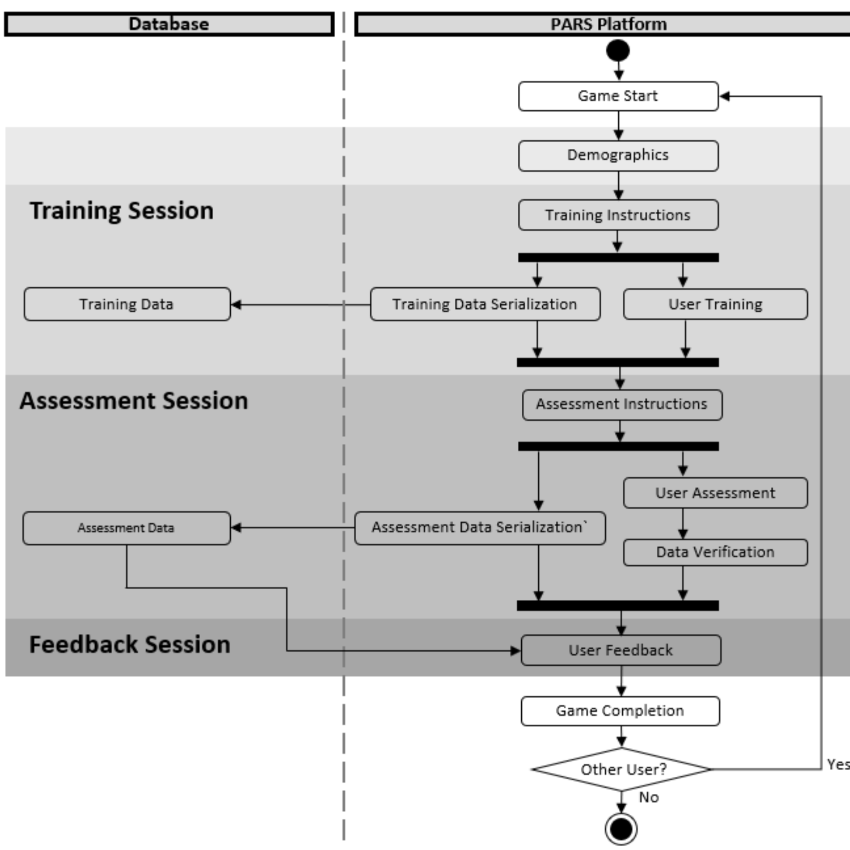


Figure 3: Platform Data Management using an UML diagram.

360-Degree Panoramas: Capture, Visualization and Augmentation in PARS

Assembling 360-degree panoramas requires capturing images of the real environment to populate the virtual environment, as illustrated in Figure 4. In this study, the purpose of these augmentations is to communicate safety concepts using supplemental features that enhance users' understanding of a written description from OSHA's manuals. The resulting augmented 360-degree panoramic scenes can be visualized on different devices. This process provides trainees with access to the 360-degree panoramic imaging in a variety of devices such as PCs, laptops, handheld devices, and head-mounted displays (HMD). For this research, PCs were targeted as the primary device of analysis, as these are easily accessible and do not require any particular setup. A mouse-and-keyboard setting was utilized to enable trainees to explore using drag-and-drop gestures in the 360-degree images interface and point-and-click gestures in the hazard identification panel (HIP) of the interface.

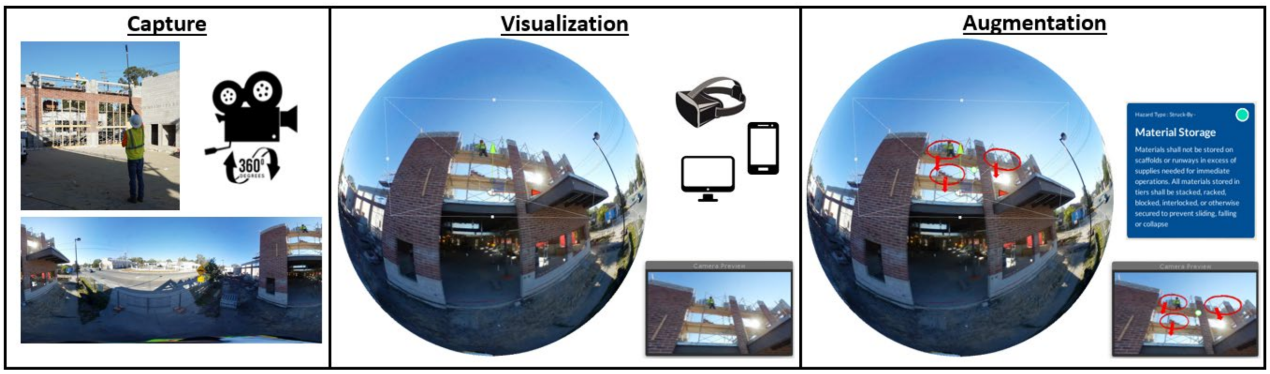


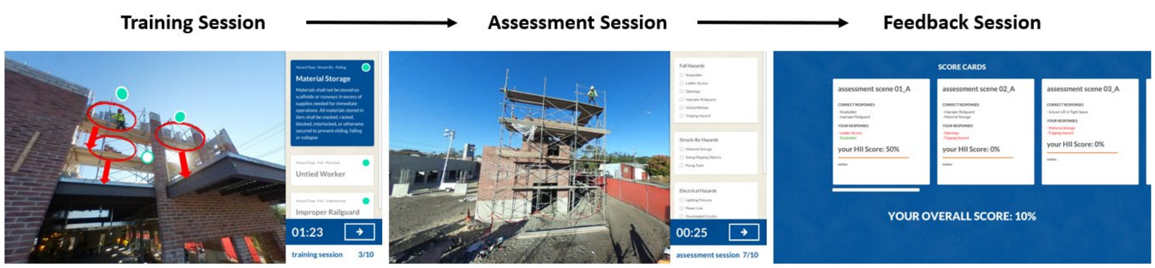
Figure 4: 360-Degree Panoramas Capture, Visualization, and Augmentation.

Figure 5 illustrates an example of the augmentations the research team undertook. To annotate the Struck-By hazards—specifically, scaffold material storage—visible in the 360-degree image, the research team used the OSHA's regulation—descriptive text—to define the material storage hazard (See Appendix 3). Concurrently, the team used SHG-type visualizations—hot-spots or graphical markers—to locate points of interest in the scene (See Appendix 1). In the PARS platform, these descriptive and graphical augmentations appear superimposed over the image to demonstrate the potential direction of a material stack collapse. By combining the graphical elements and the descriptive elements in the safety augmentations, the trainee can observe a unified perspective of a commonly disaggregated, complicated hazardous situation, such as the scaffold material storage.

Descriptive Information	Graphical Representation	
OSHA Regulation	Susan Harwood Grant	PARS
29 CFR 1926 Subpart H, Materials Handling, Storage, Use, and Disposal **1926.250(a)(1)** All materials stored in tiers shall be stacked, racked, blocked, interlocked, or otherwise secured to prevent sliding, falling or collapse. **1926.250(b)(5)** Materials shall not be stored on scaffolds or runways in excess of supplies needed for immediate operations.	  	

Figure 5: Safety Augmentation, An Example of Material Storage

Hazard Recognition Sessions: Training, Assessment, and Feedback
To effectively utilize the 360-degree panoramas and the safety augmentations as a hazard-recognition training platform, the content developed was structured into three distinct sessions: Training, Assessment, and Feedback (Figure 6). The Training Session (Figure 6a) focuses on leveraging the augmentations contained in the 360-degree panoramas to facilitate the retrieval and retention of safety-related information. Each image includes visual cues—such as dots, circles, or arrows—that alert the user to augmentations within the image. By allowing trainees to freely explore safety content in the panoramic spaces, the platform fosters active learning. The Assessment Session (Figure 6b) concentrates on utilizing the 360-degree panoramas to evaluate the knowledge acquired by the trainees in the Training Session. In the Assessment Session, trainees are asked to identify hazards in a series of 360-degree images that do not show any types of augmentation. There, the hazard recognition is left entirely to the trainee by not providing the visual cues presented on the previous session. Once the trainee concludes the evaluation, instantaneous feedback appears in the Feedback Session (Figure 6c). In this final session, users evaluate their successful responses from the Assessment Session alongside any incorrect or missed hazards to improve comprehension of the safety hazards.



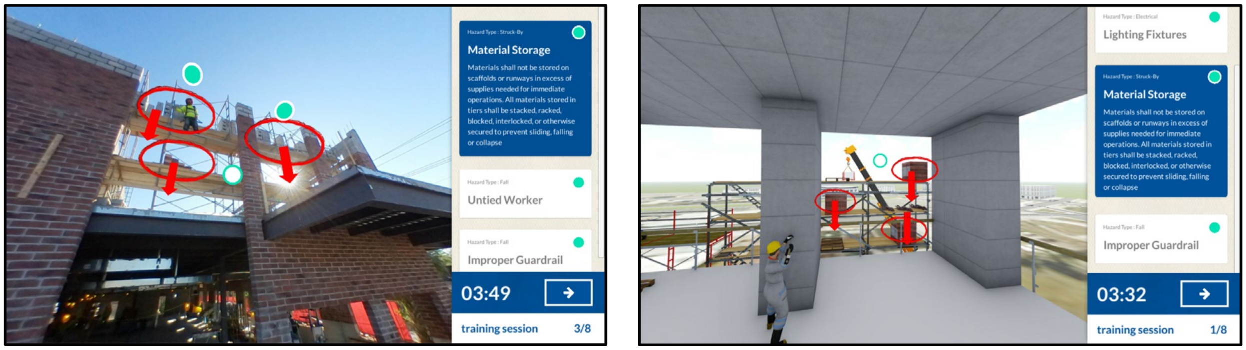
(a) Training (b) Assessment (c) Feedback

Figure 6: Hazard-Recognition Sessions: Training, Assessment, and Feedback.

Phase III: Experimental Assessment and Evaluation: The objective of this phase is to evaluate the impact of using PARS on improving hazard identification skills of construction workers and professionals. As previously discussed, PARS can create highly realistic and detailed representations of the real construction sites while giving users a sense of immersion. This realistic representation of environments is a feature [56] that would make PARS a robust tool for developing safety training materials in comparison to other platforms that use traditional virtual reality (VR) and provide an unrealistic computer-generated simulation of the environment. PARS environment would be used to create a focus four training scenario and then building information models of the same projects would be used to create a traditional VR experience of a similar scenario:

- **PARS** Condition: scenario scenes are panoramic augmented reality presentations of construction projects and were captured on site using advanced high-precision 360-degree cameras.
- **VR** Condition: scenario scenes are traditional virtual reality representations of the projects and would be created using building information models of the same sites.

The technical development of the PARS process was discussed in the previous section. For the VR condition, Trimble Sketchup, Autodesk Revit®, and Infraworks 360® were used to arrange different building models into a single scenario. The composition of the scenarios was carefully crafted to resemble hazardous conditions existing at actual construction sites in the PARS condition. The software Lumion® was employed to render the 2D projections from the crafted scenario in a 360-degree format, and finally, the very same user interface for PARS was used for leveraging interaction mechanisms to explore and interact within the VR conditions. Figure 7 displays an example of augmentations for a struck-by hazard, specifically, a scaffold material storage hazard under PARS and VR conditions. Both scenes visually present different jobsite configurations but maintain consistency within the scope of the hazards content for this topic.



(a) PARS Condition (b) VR Condition

Figure 7: An Example of a Struck-By Hazard: Material Storage for PARS and VR Conditions.

Hazard Recognition Evaluation: Hazard Identification Index and Grading

The evaluation of the trainees' hazard-recognition skills is performed using the hazard identification index (*HII*) developed by Carter and Smith [57]. The *HII* (1) offers a method to score hazard identification quantitatively in the context of both the identification and the assessment of hazards. The *HII* is calculated for each trainee as the ratio:

$$HII_j = \frac{H_i}{H_{total}} \tag{1}$$

where H_i is the number of identified hazards, and H_{total} is the total number of hazards present in each 360-degree image (*j*). The number of hazards identified by the trainee (H_i) will be impacted by the level of conceptual comprehension the trainee gained during the Training Session.

The proposed hypothesis to be tested is formulated as follows:

H_o: The means of the hazard-identification index for users under VR & *PARS* conditions are equal

H_a: The means of the hazard-identification index for users under VR & *PARS* conditions are not equal

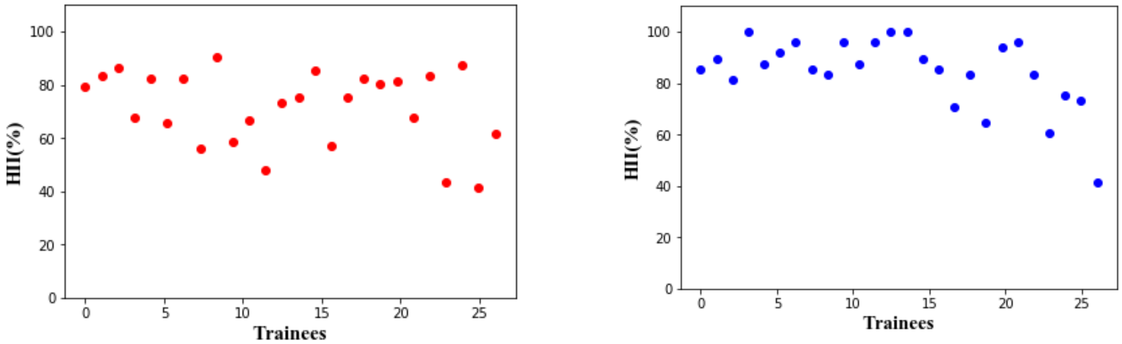
Data Collection through Experiment.

The objective of the experiment was to expose users to PARS and VR conditions and evaluate each system's ability to train users to identify construction hazards properly. A total of 52 trainees participated in the experiment. The experiment was conducted using a between-subjects' methodology, exposing half of the trainees to the PARS condition, and exposing the remaining half to the VR condition. The experiment required trainees first to complete a demographics survey. It was observed that most trainees were male (69%) and over half of the trainees had an OSHA-30 certificate (52%).

Subsequently, trainees were asked to interact with one of the two conditions. The hazard identification in each condition had three consecutive sessions: (1) training, (2) assessment, and (3) feedback. The training session required active exploration and interaction with each scene to learn about the hazards presented. In the assessment session, trainees were asked to identify all visible hazards and correctly classify the focus four hazards under their respective subcategories. Finally, once the trainees finished identifying the hazards in the assessment session, instantaneous feedback was presented to them on their previous hazard selections.

Experiment Results.

Using the collected data for the conducted experiment, the trainee's HII was computed using the techniques described in previous section. Figure 8 displays the resulting average HII for each trainee (26 in total) for each condition respectively. It was found that for the PARS condition, trainees had an average HII score of 71.6% with a standard deviation of 13.8%. The maximum value found for PARS condition trainees was 90.6% and the minimum 41.6% (Table 3). For the VR condition, trainees presented an average HII score of 84.5% with a standard deviation of 13.4%. The maximum value for the VR condition was 100% and the minimum 41.6% (Table 3). As observed in the Figure 8 and the obtained results, the PARS condition scores present a higher dispersion in comparison to the VR condition.



PARS Condition VR Condition

Figure 8: Average HII per Trainee

Table 3: Descriptive Statistics for the Hazard Identification Index (HII)

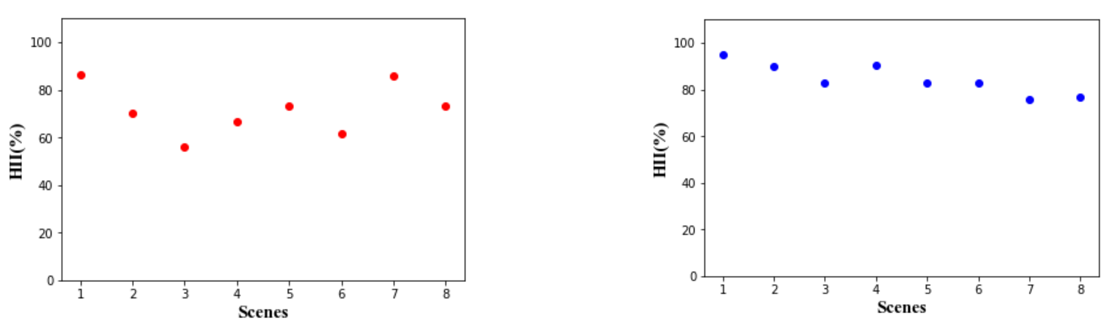
Quantitative Variable	**Pilot Study Conditions**	
	PARS (%)	VR (%)
Mean	71.6	84.5
Standard Deviation	13.8	13.4
Maximum	90.6	100
Minimum	41.6	41.6

To statistically validate this comparison, the Mann Whitney U test was conducted to find if the differences between the two conditions were significant, as shown in Table 3. This test was used due to non-normal behavior observed in the collected data. The Mann-Whitney U test resulted in a statistic of 147.0 with a p-value of 0.00024. This p-value is lower than the threshold value of 0.05, indicating a rejection of the null hypothesis (H0). This finding reveals that the HII scores for trainees under each condition (PARS and VR) are significantly different.

Table 3: Non-Parametric Test for difference in mean between groups – Mann-Whitney U Test

	PARS vs VR	
	U-Statistic	P-Value
Average HII by Trainee	147.0	0.00024
Average HII by Scene	10	0.01171

The averages of the HII scores were also computed for the average trainee scores in scene-by-scene basis. Figure 9 illustrates the results of the analysis. The PARS condition average score across scenes was 71.6% with a standard deviation of 10.1%. The maximum HII score was found on scene 1 with 86.5%, and the minimum score was on scene 3 with 55.8% (Table 3). For the VR condition, the average score was 84.5% with a standard deviation of 6.3%. The maximum score found in the VR condition was on scene 1 with 94.5%, and the minimum score was on scene 7 with 75.8% (Table 3).



PARS Condition VR Condition

Figure 9: Average HII per Scene

The Mann Whitney U test was repeated the scene-by-scene basis as shown in Table 3. It was found that the statistic value was 10.0 with a p-value of 0.01171. This resulting value is also lower than the threshold value of 0.05, indicating that HII scores means are not equal across the scenes for each condition.

In addition, comments provided by trainees during the experiment were also reviewed to offer additional insight into the differences between the two conditions. One trainee commented that VR was "easier" and another trainee indicated that it was "so much clearer to see hazards" in the VR condition. One trainee also described scenes in the PARS condition, which reflected the actual reality of construction job sites, as "chaotic" environments, where "materials and equipment spread in many directions". Another trainee considered the PARS condition "so messy" and that there was "so much noise." In contrast, the VR scenes featured fewer of the "messy" construction site items such as different boards, scraps, electrical cords, water puddles. In another comment, a trainee attempted to sum up the differences between the two platforms, saying that "PARS is dirtier. Virtual is too clean, it seems like it is for children." Thus, the trainee seemed to agree that environments in VR were "cleaner" than in PARS condition, but that factor was viewed either positively (easier for training and learning) or negatively (not realistic or relatable) by the trainee.

Final Remarks.

In this study, 360-degree panoramas were proposed as an alternative to traditional VR-based safety training, which suffers from a limited sense of presence and realism, high computational costs, and long development times. Unlike the unrealistic computer-generated context of VR environments, 360-degree panoramas provide a highly realistic and detailed experience of environments while giving users a high sense of presence. In this study, two safety training conditions for Focus Four construction hazards – one employing VR and the other employing 360-degree panorama – were developed based on similar scenarios. Then a comparative user-centered study was conducted to assess their effectiveness and differences for hazard identification under each VR and PARS conditions. Fifty two subjects took part in an experiment, and their hazard identification index (HII) scores showed that, on average, users were able to identify hazards in the VR condition significantly higher than in PARS condition. Some of the qualitative comments provided by participants during the think-aloud process are consistent with the higher HII scores for VR, as they considered VR "easier" or "clearer" and 360- degree panorama a "messy," "chaotic," and "dirty" condition. Although the study participants considered VR to be cleaner and easier than 360- degree panorama, it is worth noting that the latter offers a true-to-life representation of a real construction jobsite which might be dirty or messy – and is better than VR in representing how a construction jobsite and associated hazards might look.

List of publications based on this project.

- Eiris Pereira, R., Gheisari, M., & Esmaeili, B. (2018). Using Panoramic Augmented Reality to Develop a Virtual Safety Training Environment. *2018 ASCE Construction Research Congress, New Orleans LA*
- Eiris, R., Gheisari, M., & Esmaeili, B. (2018). PARS: using augmented 360-degree panoramas of reality for construction safety training. *International journal of environmental research and public health, 15(11), 2452.*
- Frank Moore, H., Eiris Pereira, R., Gheisari, M., & Esmaeili, B. (2018). Hazard Identification Training using 360-degree Panorama vs. Virtual Reality Techniques: A Pilot Study.*2019 ASCE International Conference on Computing in Civil Engineering, Atlanta, GA (Under Review)*
- Eiris Pereira, R., Gheisari, M., & Esmaeili, B. (2018). Hazard Identification Training using PARS vs. VR Techniques .*Automation in Construction (Under Preparation)*

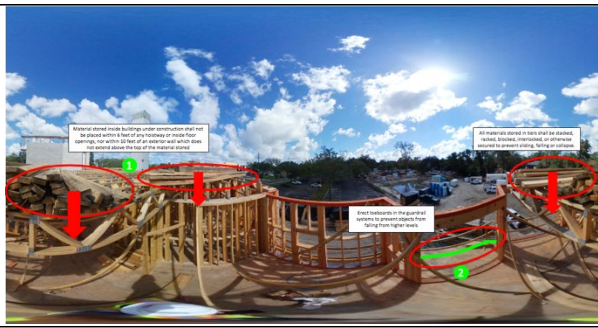
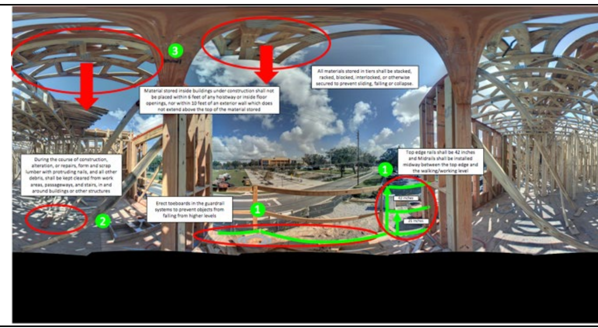
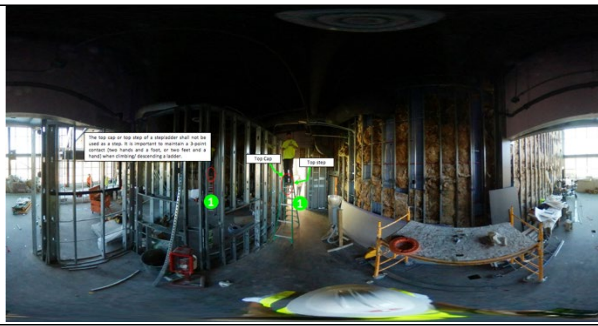
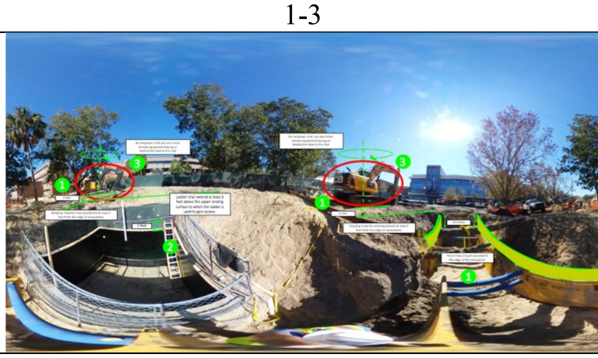
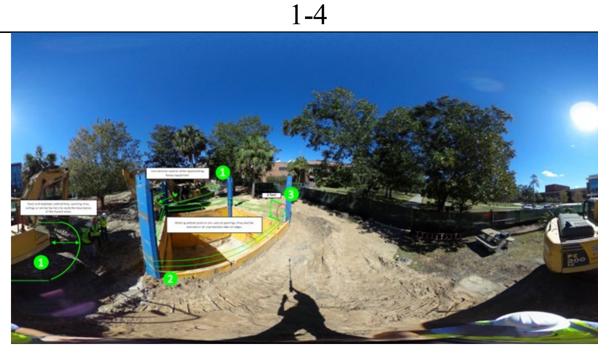
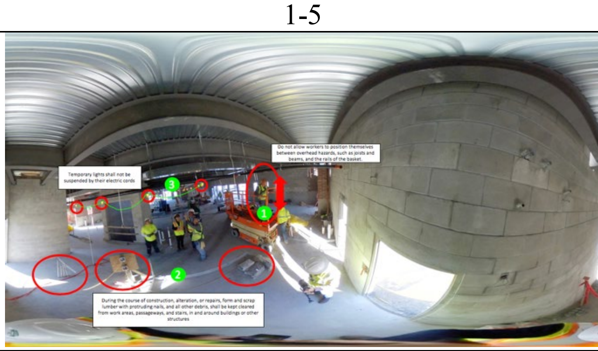
References.

1. Bhoir, S., Esmaeili, B., (2015). “State-of-the-art Review of Application of Virtual Reality Environment in the Construction Safety.” Architectural Engineering Institute (AEI) Conference 2015, Milwaukee, Wisconsin, March 24-27, 2015.
2. Bureau of Labor and Statistics (2013). Census of fatal Occupational Injuries (CFOI). http://www.bls.gov/iif/oshwc/cfoi/cftb0268.pdf.
3. Laurence, D. (2005). Safety rules and regulations on mine sites–the problem and a solution. Journal of safety research, 36(1), 39-50.
4. Sneddon, A., Mearns, K., Flin, R., & Bryden, R. (2004, January). Safety and situation awareness in offshore crews. In SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production. Society of Petroleum Engineers.
5. Goetsch, D. L., and Goetsch, D. L. (1996). Occupational Safety and Health in the Age of High Technology: For Technologists, Engineers, and Managers. Prentice Hall, Englewood Cliffs, N.J.
6. Holt, A. S. J., & Lampl, F. (2006). Principles of construction safety, Blackwell, Oxford, UK.
7. Perlman, A., Sacks, R., Barak, R. (2014). "Hazard Recognition and Risk Perception in Construction". Saf. Sci., 64(0), 22-31.
8. Abdelhamid, T. S., and Everett, J. G. (2000). “Identifying root causes of construction accidents.” J. Constr. Eng. Manage., 10.1061/(ASCE)0733-9364(2000)126:1(52), 52–60.
9. Sacks, R., Perlman, A., and Barak, R. (2013). “Construction safety training using immersive virtual reality.” J. Constr. Manage. Econ, 31(9), 1005-1017.
10. Haslam, R. A., et al. (2005). “Contributing factors in construction accidents.” Appl. Ergon., 36(4), 401–415.
11. Burke, M. J., Sarpy, S. A., Smith-Crowe, K., Chan-Serafin, S., Salvador, R. O., and Islam, G. (2006). "Relative Effectiveness of Worker Safety and Health Training Methods". Am. J. Public. Health, 96(2), 315-324.
12. Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. Safety science, 45(10), 993-1012.
13. Wang, Y., Goodrum, P. M., Haas, C., Glover, R., and Vazari, S. (2010). “Analysis of the benefits and costs of construction craft training in the United States based on expert perceptions and industry data.” Journal of Construction Management and Economics, 28(12), 1269–1285.
14. Holte, K. A., and Kjestveit, K. (2012). “Young workers in the construction industry and initial OSH-training when entering work life.” Work J. Prevent. Assess. Rehabil., 41, 4137–4141.
15. Bahn, S., and Barratt-Pugh, L. (2014). "Safety Training Evaluation: The Case of Construction Induction Training and the Impact on Work-Related Injuries in the Western Australian Construction Sector". International Journal of Training Research, 12(2), 148-157.
16. Demirkesen, S., and Arditi, D. (2015). "Construction Safety Personnel's Perceptions of Safety Training Practices". Int. J. Project Manage., 33(5), 1160-1169.
17. Robson, L., Stephenson, C., Schulte, P., Amick, B., Chan, S., Bielecky, A., Wang, A., Heidotting, T., Irvin, E., Eggerth, D., Peters, R., Clarke, J., Cullen, K., Boldt, L., Rotunda, C. and Grubb, P. (2010). A Systematic Review of the Effectiveness of Training & Education for the Protection of Workers, Institute for Work & Health and National Institute for Occupational Safety and Health, Toronto and Cincinnati, OH.
18. Zuluaga, C. M., Namian, M., and Albert, A. (2016) “Impact of Training Methods on Hazard Recognition and Risk Perception in Construction”. Construction Research Congress 2016, May 31–June 2, 2016, San Juan, Puerto Rico, pp. 2861- 2871.
19. Li, H., Chan, G., and Skitmore, M. (2012). “Multiuser Virtual Safety Training System for Tower Crane Dismantlement.” J. Comput. Civ. Eng., 2012, 26(5): 638-647.
20. Carter, G., and Smith, S. D. (2006). “Safety Hazard Identification on Construction Projects.” J. Constr. Eng. Manage., 132(2), 197-205, 2006.
21. Bahn, S. (2013). “Workplace hazard identification and management: The case of an underground mining operation.” Saf. Sci., 57(1), 129–137.

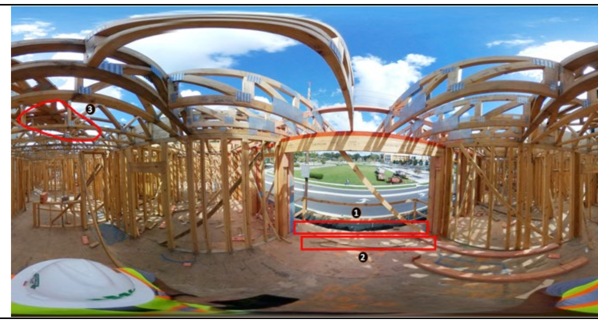
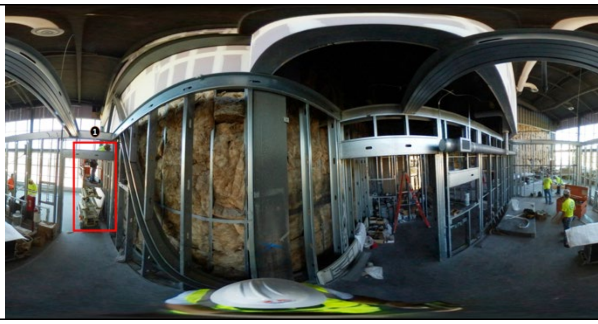
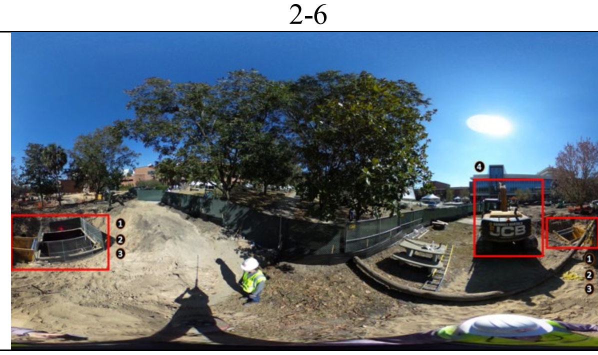
22. Hasanzadeh, S., Esmaeili, B., and Dodd, M., (2017). "Measuring Impacts of Safety Knowledge on Construction Workers' Attentional Allocation and Hazard Detection: Using Remote Eye-Tracking Technology." *ASCE, Journal of Management in Engineering*; 33(5); 04017024.
23. Jeelani, I., Albert, A., Azevedo, R., and Jaselskis, E. (2016). "Development and Testing of a Personalized Hazard-Recognition Training Intervention". J. Constr. Eng. Manage., 2017, 143(5).
24. Guo, H., Li, H., Chan, G., and Skitmore, M. (2012). "Using game technologies to improve the safety of construction plant operations." Accident Analysis and Prevention, 48, 204-213.
25. Dickinson, J. K., Woodard, P., Canas, R., Ahamed, S., and Lockston, D. (2011). "Game based trench safety education: development and lessons learned." Journal of Information Technology in Construction, 16, 119-133.
26. Lin, K. Y., Son, J. W., and Rojas, E. M. (2011). "A pilot study of a 3D game environment for construction safety education." Journal of Information Technology in Construction, 16, 69-83.
27. Le, Q. T., Pedro, A., and Park, C. S. (2015). "A social virtual reality-based construction safety education system for experiential learning". Journal of Intelligent and Robotic systems, 79(3), 487-506.
28. Pedro, A., Le, Q. T., and Park, C. S. (2016). "Framework for integrating safety into construction methods education through interactive virtual reality". Journal of Professional Issues in Engineering Education and Practice, 142(2).
29. Bosché, F., Abdel-Wahab, M., and Carozza, L. (2016). "Towards a mixed reality system for construction trade training". Journal of Computing in Civil Engineering, 30(2).
30. Wang, X. and Dunston, P. S. (2007). "Design, strategies, and issues towards an augmented reality-based construction training platform." ITcon, (12): 363-380.
31. Vanijja, V., and Horiguchi, S. (2001). "360 Interactive Video Scenes with Multi-Directional Moving Capability." Multidirectional Moving Capability". Proceedings from ICAT2001, pp.209-212.
32. Bourke, P. (2014). The Panorama: Applications to Science and Heritage Visualization. Lawrence Wilson Art Gallery, Web. <http://paulbourke.net/papers/lawrencewilson/>.
33. Finch, E., and Wing, R. D. (1996). "A Navigable Walkthrough Simulator for Built Environment Education: Archiwalk." Facilities, (1996) Vol. 14 Iss: 10/11, pp.17 – 24.
34. Mei, Q., and Wing, R. (1999). *Robotic 360^o Photography for Virtual Site Visits*. 1999 IEEE International Conference on Information Visualization, pp. 214 – 219, doi:10.1109/IV.1999.781561.
35. Dickinson, I., Riley, A., Tennant, J., and Ellis, R.C.T. (2004). *Virtualsite: Photo-realism in the Classroom*. COBRA 2004 Proceedings held at Leeds Metropolitan University.
36. Côté, S., Trudel, P., Desbiens, M., Giguère, M., & Snyder, R. (2013). Live mobile panoramic high accuracy augmented reality for engineering and construction. Proceedings of the Construction Applications of Virtual Reality (CONVR), London, England.
37. Gheisari M., Sehat N., and Williams G., (2015) "Using Augmented Panoramic Views as an Online Course Delivery Mechanism in MOOCs." 51st ASC Annual International Conference Proceedings, Washington DC, 2015
38. Gheisari M., Sabzevar M. F., Chen P., and Irizarry J., (2016-a) "Augmented Panoramic Environment to Access Building Information on a Construction Site", 52nd ASC Annual International Conference Proceedings, Provo UT, 2016 Best Paper Honorable Mention
39. Gheisari M., Sabzevar M. F., Chen P., and Irizarry J., (2016-b) "Integrating BIM and Panorama to Create a Semi-Augmented-Reality Experience of a Construction Site", International Journal of Construction Education and Research, Vol. 12, Iss. 4, 2016
40. Eiris Pereira, R., Moud, H. I., and Gheisari, M. (2017). "Using 360-Degree Interactive Panoramas to Develop Virtual Representation of Construction Sites." Proceedings JC3, 2017.
41. Jeelani, I., Han, K., and Albert, A. (2017). "Development of Immersive Personalized Training Environment for Construction Workers." Congress on Computing in Civil Engineering, Proceedings, Seattle, USA (2017), pp. 408-415.

42. Eiris, R., Gheisari, M., and Esmaeili, B. (2018-a). "Using Panoramic Augmented Reality to Develop a Virtual Safety Training Environment." Construction Research Congress, Proceedings, New Orleans, Louisiana, USA (2018), pp. 29-39.
43. Eiris, R., Moore, H.F., Gheisari, M., and Esmaeili, B. (2018-b). *Development and Usability Testing of a Panoramic Augmented Reality Environment for Fall Hazard Safety Training*. In 35th CIB W78 2018 Conference: IT in Design, Construction, and Management.
44. Pham, H.C., Dao, N., Pedro, A., Le, Q.T., Hussain, R., Cho, S., and Park, C. (2018-a). *Virtual Field Trip for Mobile Construction Safety Education Using 360-Degree Panoramic Virtual reality*. International Journal of Engineering Education, Vol. 34, No. 4, pp. 1174-1191.
45. Pham, H., Dao, N. N., Kim, J. U., Cho, S., and Park, C. S. (2018-b). Energy-Efficient Learning System Using Web-Based Panoramic Virtual Photoreality for Interactive Construction Safety Education. Sustainability, 10(7), 2262.
46. Gillen, M., Faucett, J. A., Beaumont, J. J., and McLoughlin, E. (1997). "Injury severity associated with nonfatal construction falls." *Am. J. Ind. Med.*, 32(6), 647–655.
47. Hinze, J., Huang, X., and Terry, L. (2005). "The nature of struck-by accidents." *Journal of Construction Engineering and Management,* 131(2), 262–268.
48. Lipscomb, H. J., Glazner, J., Bondy, J., Leaotte, D., and Guarini, K. (2004). "Analysis of text from injury reports improves understanding of construction falls." *Journal of occupational and environmental medicine*, 46(11), 1166–1173.
49. Janicak C. A., (1998). "Fall-related deaths in the construction industry." *Journal of Safety Research*. 29; 35–42.
50. Johnson, H. M., Singh, A., and Young R. H. F. (1998). "Fall protection analysis for workers on residential roofs." *Journal of Construction Engineering and Management*, 124(5), 418–428.
51. Sa, J., Seo, D. C., & Choi, S. D. (2009). "Comparison of risk factors for falls from height between commercial and residential roofers". *Journal of safety research*, 40(1), 1-6.
52. OSHA (Occupational Safety and Health Administration). (2011). "Construction focus four: Struck-by hazards, instructor guide: OSHA directorate of training and education." ⟨http://goo.gl/354wBz⟩ (March. 31st, 2017).
53. Bureau of Labor and Statistics (2012). Census of fatal Occupational Injuries (CFOI). http://www.bls.gov/iif/oshwc/cfoi/cftb0268.pdf.
54. Janicak, C. A. (2008). "Occupational fatalities due to electrocutions in the construction industry." *Journal of Safety Research*, 39: 617−621.
55. McCann, M., Hunting, K. L., Murawski, J., Chowdhury, R., & Welch, L. (2003). "Causes of electrical deaths and injuries among construction workers". *American journal of industrial medicine*, 43(4), 398-406.
56. Sherif, A., and Mekkawi, H. (2006). "Developing a computer aided learning tool for teaching construction engineering decision making." *In Proceedings of the joint international conference on computing and decision making in civil and building engineering,* Montreal, Canada, 11.
57. Carter, G., and Smith, S. D. (2006). "Safety Hazard Identification on Construction Projects." *J. Constr. Eng. Manage*., 132(2), 197-205, 2006.

Appendix A
Equirectangular projection of eight training scenes

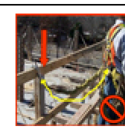
	
1-1	1-2
	
1-3	1-4
	
1-5	1-6
	
1-7	1-8

Appendix B
Equirectangular projection of eight assessment scenes

	
2-1	2-2
	
2-3	2-4
	
2-5	2-6
	
2-7	2-8

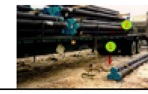
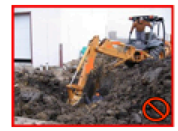
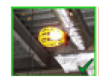
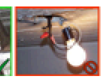
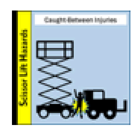
Appendix C

Augmentation contents of different focus four hazards in each training scene and their sources

Focus Four Hazards			Text Content	Source	Example of Augmentation
Fall	Ladders	Stepladder	The top cap or top step of a stepladder shall not be used as a step.	**29 CFR 1926 Subpart X, 1926.1053(b)(13** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10839 OSHA Fact Sheet: https://www.osha.gov/Publications/OSHA3662.pdf	
		Ladder Overextension	Ladder shall extend at least 3 feet above the upper landing surface to which the ladder is used to gain access	**29 CFR 1926 Subpart X, 1926.1053(b)(1)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10839 OSHA Fact Sheet:https://www.osha.gov/Publications/OSHA3660.pdf	
	Floor Openings/Excavations	Openings	Walking/working surface shall be protected from tripping in or stepping into or through holes (including skylights) by covers.	**29 CFR 1926 Subpart X, 1926.501(b)(4)(ii)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10757	
	Unprotected Edges	Improper Railguard	T3, T6 / A2, A4 - Erect toeboards in the guardrail systems to prevent objects from falling from higher levels T6 / A2 - Top edge rails shall be 42 inches and Midrails shall be installed midway between the top edge and the walking/working level A10 / A8 - When guardrail systems are used at holes, they shall be erected on all unprotected sides or edges of the hole T11, A20 / A16 - Guardrail systems shall be installed along all open sides and ends of platforms. Guardrail systems shall be installed before the scaffold is released for use by employees other than erection/dismantling crews.	**29 CFR 1926 Subpart X, 1926.501(c)(1), 1926.502(b)(1), 1926.502(b)(2)(i), 1926.502(b)(11)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10758 **29 CFR 1926 Subpart L, 1926.451(g)(4)(i)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10752	 
	Personal Arresting Gear	Untied Worker	Lifelines, lanyards and deceleration devices should be attached to an anchorage and connected to the body-belt or body harness in the same manner as they would be when used to protect employees.	**29 CFR 1926 Subpart M App C, (1)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10925	
	Housekeeping	Tripping Hazard	During the course of construction, alteration, or repairs, form and scrap lumber with protruding nails, and all other debris, shall be kept cleared from work areas, passageways, and stairs, in and around buildings or other structures	**29 CFR 1926 Subpart C, 1926.25(a)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10611	

Appendix C (Continuation)

Augmentation contents of different focus four hazards in each training scene and their sources

Struck-By	Falling Objects	Material Storage	T3, T6 / A4 - Material stored inside buildings under construction shall not be placed within 6 feet of any hoistway or inside floor openings, nor within 10 feet of an exterior wall which does not extend above the top of the material stored A20 / A16, A12 - Materials shall not be stored on scaffolds or runways in excess of supplies needed for immediate operations	**29 CFR 1926 Subpart H, 1926.250(b)(1), 1926.250(b)(5)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10685	 
	Swing/Slipping Objects (This category might be ground level objects)	Excavator Swing	T15 / A27 - No employer shall use any motor vehicle equipment having an obstructed view to the rear A10 / A25, A8 - Use extreme caution when approaching heavy equipment (Found on a Susan Harwood Presentation but not in OSHA Regulation)	**29 CFR 1926 Subpart O, 1926.601(b)(4),** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10768	
Electrical	Inadequate Wiring	Lighting Fixtures	Temporary lights shall not be suspended by their electric cords	**29 CFR 1926 Subpart K, 1926.405(a)(2)(ii)(F)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10706	 
	Overhead Power Lines	Power Line	The clearance between scaffolds and power lines shall be 10 feet for power lines of 300 volts to 50 kv	**29 CFR 1926 Subpart L, 1926.451(f)(6)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10752#1926.451(f)(6)	
Caught-In/Between	Tools and Equipment	Scissor Lift in Tight Space	Do not allow workers to position themselves between overhead hazards, such as joists and beams, and the rails of the basket.	**29 CFR 1926 Subpart ?, ???** Website Links - OSHA Site: https://www.osha.gov/OshDoc/data_Hurricane_Facts/aerial_lifts.html	
	Trenches and Excavations	Cave In	All - Trench box should be out 18 inches (Dr Esmaili) - Cannot find this in OSHA T15 / A24, A27 - Keeping materials and equipment at least 2 feet (.61 m) from the edge of excavations	**29 CFR 1926 Subpart P, 1926.651(j)(2)** Website Links - OSHA Site: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10775