SAVES: A SAFETY TRAINING AUGMENTED VIRTUALITY ENVIRONMENT FOR CONSTRUCTION HAZARD RECOGNITION AND SEVERITY IDENTIFICATION

Ao Chen

Virginia Tech, Vecellio Construction Engineering and Management Group, Via Department of Civil and Environmental Engineering and Myers-Lawson School of Construction, USA

Mani Golparvar-Fard

University of Illinois at Urbana-Champaign, Urbana, Department of Civil and Environmental Engineering, USA

Brian Kleiner

Virginia Tech, the Myers-Lawson School of construction,USA

ABSTRACT: *One of the most challenging aspects of health and safety (H&S) management for construction sites is ensuring that workers can predict, identify, and respond to potential hazardous conditions before they are exposed. While OSHA addresses the need for enforcement of comprehensive H&S training programs, many safety training programs still do not include hazard recognition or systematic preparations for the avoidance of unsafe conditions. From a scientific standpoint, we currently lack the knowledge of discovering the most efficient training styles for safety and also understanding why and how these styles of training can influence the post-training activities. To address these needs, an Augmented Virtuality(AV) training environment named System for Augmented Virtuality Environment Safety (SAVES) was designed and is presented in this paper. SAVES which integrates a Building Information Model (BIM) with photographs of typical energy sources on a jobsite, allows trainees to control and navigate an avatar within such AV environment. Within the AV environment, the user can conduct a set of interactions with the environment and accomplish multiple instruction and task-based training scenarios. These scenarios include detection of ten types of hazard and/or energy sources at three levels of severity. The energy sources which in SAVES are embedded in forms of 3D elements and 2D imagery are designed to elevate the safety awareness of the users, enable them to predict and identify various types of hazards, and assess their level of severity. To fully document the experience of the users, during each exercise, trainees' choices, time for decision-making and corresponding prevention plan are documented in the system. The complete process of design, development, implementation and results analysis of SAVES is presented.*

KEYWORDS: *Safety, Training, Virtual Reality, Hazard Recognition*

1. INTRODUCTION

Construction is one of the most dangerous and hazardous industries in the world. According to the Bureau of Labor Statistics released in 2012, 780 construction related fatalities and more than 4,000 recordable accidents were reported in the United Sates. Even though the total number of fatalities and ratio of injuries are keeping decreasing since 2009, construction still ranks the 3rd most unsafe industry after agriculture and transportation. Most accidents and injuries were caused by human error and unsafe actions due to the failure of following safety programs. Whereas, the rate of safety program improvement has slowed substantially in recent years. Many construction companies which treat safety as their central value have stated strong desire for any novel method that speed up safety improvement. Carter and Smaith (2006) and CDC (Center for Disease Control and Prevention 2012) have stated that construction workers are lack of rapid hazard recognition ability in a complex working environment. Hazard recognition is the prerequisite to build all other safety procedures. Without a sufficient awareness of hazard recognition, even the best safety program will not touch its expectation.

Construction workers are highly vulnerable to on-site accidents. Recent reports show that fatality rate in construction site is about three times higher than the overall national average (OSHA 2012). Such high rate

somehow happens due to the inadequate skills of hazard recognition and low respond efficiency to potential hazards in a complex environment. As shown in figure 1, a framework of the typical safety program which focusing on hazard recognition is presented. As one can see, an injury will actually occur when 1) a hazard is presented and 2) worker just happens to be exposed under the range of hazard, and 3) S/he is in the absence of adequate hierarch controls. As indicated in Figure 1, those hazards that not included in the perception and risk assessment process will not be preemptively recognized. This often causes the accidents even though the safety program was well planned. Typically, hazards in construction usually are associated with jobs and most workers will use their experience to identify and make the decision. Unfortunately, new workers usually are lack of adequate hazard predicting expertise and skilled workers adapt unsafe procedures to meet the productivity demands. For the purpose of enhancing their awareness of hazard recognition, company often offers formal hazard recognition training programs. Current training methods are usually based on conformist teaching instructions that already proofed making limited engagement with workers, especially for those younger workers.

In response to this urgent need, this paper explored a new hazard recognition training strategy in a multi-phase study. An augmented virtuality (AV) environment was developed and tested with essential psychology, information cognition and behavioral theories. To study how this training method improve the hazard recognition ability, this paper employed qualitative survey, quantitative hit-matrix and multiple baseline testing methods. The following sections will illustrate the development of such AV environment, filed experiment, data analysis, discussions and conclusions in detail.
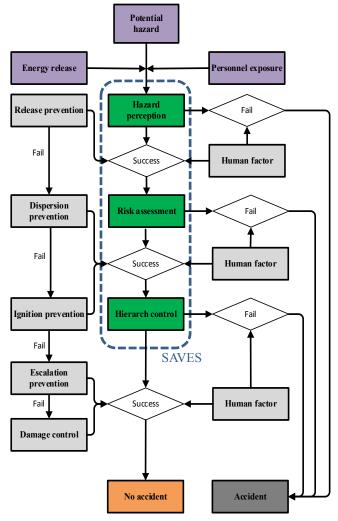

Fig.1 Framework of Hazard Recognition

2. BACKGROUND

Many methods have been studied and a lot of tools are developed to improve the awareness of hazard recognition in construction. Such methods and tools can be categorized either predictive methods or reactive methods. The first method contains scenario-structure that workers mentally construct and visualize the activities then completing detailed work missions. Based on the different activities, workers attempt to identify all hazards. Such method includes job hazard analysis, task analysis, and safety planning. Despite the huge contributions they offered, such methods have some inherent limitations like isolation, biased assumption and higher safety knowledge requirement. These methods focus on the isolated activities fail to recognize additional hazards that may arise because of the job change, complexity in construction and working environment variations (Rozenfeld et al. 2010). Besides, those methods make a pre-judgment that assume all the workers can correctly predict the work procedures and associated hazards with those procedures as well (Fleming 2009).

The reactive method usually relies on experience to determine potential hazards for a given work-setting. Often, company summarizes the reports from past projects and disseminates the material through training which involves conventional instruction. Like the first method, the reactive methods have various drawbacks. First, such methods usually do not include near miss and latest incidents (Dong et al. 2011) and reports are not thorough enough for future improvement. Second, such accident records reflect only a small subset of potential scenarios (Rozenfeld et al. 2010). Third, in a fully complex environment like construction site, specifying accidents across different setting is impossible. Finally, transferring this enormous amount of information to workers using inefficient instructional methods is unrealistic (Fleming 2009).

Thus, in order to ensure effective learning, hazard recognition training programs must be tailored to the learning styles of the workers. Unfortunately, traditional lecture-based training such like videos and lectures only keep 5% retention rate. And the trainee stays in a passive role to receive such safety information which leads to ineffective training outcomes. Workers learn better when the principles of andragogy are applied and they are involved in building context, setting objectives, cooperatively and interactively delivering instructional material, and form plans (Knowles et al. 2012). Methods that encourage active participation and visual learning are particularly effective and brings at least 75% retention rate. Given these factors, many public agencies and companies address the urgent needs and seek more positive methods to approach the effective safety training. NIOSH had mentioned this necessity that construction workers needed new training materials. Videos or lectures could not be the only resources (NIOSH, 2002). Other industries like Mine H&S Administration (MSHA), already adapted VR as training tool for safety. The information and skills obtained from VR training could be transferred to the real world in a more expressive and realistic way than acquired by applying more conservative, didactic training methods. Moreover, the biggest convenience was that VR permitted the trainees to experience situations that were hard or impossible to be shown in the real world. Another advantage of using VR was that it could systematically offer a wide range of possible training scenarios without suffering the high cost and risk of fielding personnel, equipment, and vehicles (Zeltzer et al., 1996).

Some VR applications were developed to help workers experience the standardized safe work procedures and specific single mission scenario was provided in such applications. (Grant and Daigle 1995, Lucas et al. 2008, Zhao et al. 2012). Besides their advantages in novelty and positive interaction, such applications didn't provide adequate freedom to users to experience diverse situations and they were lack of sufficient validations. Ku and Mahableshwarjer (2011) proposed a framework of BIM engaging with Second-Life to teach students integrated construction process. Such application maintained a well-designed stage with detailed conditions, but meanwhile, such applications attempted to bring too much information and scarified realism in display. Also, validation of correlation between designed training contents and raw data was not explained. Comparing with the natural drawbacks of Augmented Reality (AR) (e.g. impossible to put trainee to a real fully hazardous area, lack of interactive feedback) and VR (e.g. lose many realistic practice and display), Augmented Virtuality (AV) which have the advantages from both sides is proposed to answer the research questions. This research plans to examine the areas of safety in construction, hazard recognition and human centric AV development. The pedagogical goal of developing such AV environment focuses on providing some of the learning outcomes versus purely scenario driven learning outcomes such as lectures and safety videos.

3. RESEARCH METHOD

The objective of this research was to develop and examine new transformative hazard recognition strategies for safety improvement. This research aimed to develop a system that united industry best practices, BIM model and relevant theories from information cognition. This research conducted in the way of developing an AV

environment system that addressed current weaknesses in safety training, planning, and execution. The proposed AV environment named SAVES(Safety for Augmented Virtuality Environment System), as shown in Figure 2. The research method and implementation plan of this study included four phases. In the first phase a comprehensive list of hazard data were collected from different resources and they were categorized and identified through knowledge-based method and safety expert meetings. In the second phase clients brought their training needs to the team and a proper BIM model was refined and imported to the SAVES. Such BIM model was the exact construction site where the trainees were working in. Once the BIM model was properly inserted to the environment, the third phase, development of training scenarios was conducted. Combining with the comprehensive benchmarking from safety regulations, best practice in industry, safety experts in the team and identified hazard data from first phase, a set of well-designed training scenarios were developed and integrated to the BIM model. The final phase the SAVES was field tested to determine its impacts on hazard recognition skill. The overall aim of this research was to experimentally test the hypothesis that a given AV training system such as SAVES could lead to a measurable increase in the proportion of hazards identified and communicated before work begins.
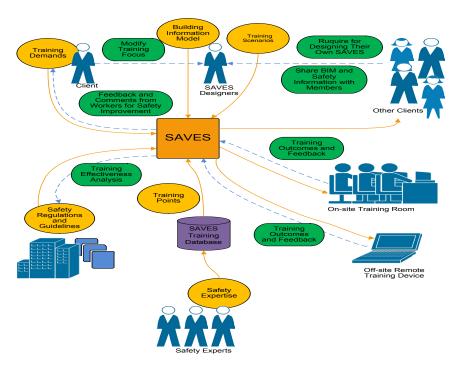

Fig. 2: Research structure of SAVES

4. DEVELOPMENT OF SAVES

4.1 Inventory of Hazard in SAVES

Safety hazards widely and randomly distributed around the whole construction site. It is hard to simply recognize the causality from each injure or fatality due to the unique and multi-factors overlapping. The meaning of the word hazard can be confusing. Often dictionaries do not give specific definitions or combine it with the term "risk". The definitions of hazard in academia are various. E.g., Rivara (2000) defined hazard as the in favor of loss. Zohar (1980) defined hazard as a combination of the possibility of unfavorable results and the related loss of a chosen decision plan due to various uncertainties in the decision making process. In this research, hazard was defined as a condition or action that had the potential for an unplanned release of, or unwanted contact with, an energy source that might result in harm or injury to people, property, or the environment (Kleiner 2012, Chevron 2012).The research team went through the documents, case studies, reports and had delivered top 10 energy source types that most easily lead to accidents and fatalities in construction. Table 1sumrizes those 10 energy types in detail.

Table 1: Definitions of energy source types

Energy Type	Definition	Energy Type	Definition
Biological	Living organisms that can present a hazard	Motion	The change in position of objects or substances
Chemical	The energy present in chemicals that inherently, or through reaction	Pressure	Energy applied by a compressed or vacuum liquid or gas
Electrical	The presence and flow of an electric charge	Radiation	The energy emitted from radioactive materials
Gravity	The force caused by the attraction of all other masses to the mass of the earth	Sound	A vibrating-cause force the energy is transferred through the substance in waves
Mechanical	The energy of the components of a mechanical system	Temperature	The measurement of differences in the thermal energy

4.2   Development of Training Scenarios

After defining the hazard types and categorizing all raw data, the next phase was to build and refine the hazard recognition scenarios. Based on the discussions of the research team, each identified hazard type was recategorized to a scale index system from 1 to 3 which indicating different severity. The smaller the number the construction behavior assigned the better safety level it had. Level 1(green) presented no observable issues been presented in the training scenario. Level 2(yellow) showed that potential hazard or/and poor practice stated in the training scenario. The last level, level 3(red), required an instant work stop to avoid foreseeable serious accidents. This color coded system could provide easy, directive signals in human information cognition process. All the information of such training elements were integrated together and those completed data were saved to the hazard information database for the use in data analysis. Figure 3 indicated a sample of training interface inside SAVES. Besides this principle criteria, the research team also realized the need to incorporate theories from human information processing and data cognition to facilitate retention of new information, motivate workers to actively participate in the hazard recognition process and improve worker hazard recognition skills. Table 2 presented the various techniques that were integrated to design the training scenarios in SAVES.

Table 2: Techniques that were incorporated in developed SAVES training scenarios

Theories	Application inside SAVES
Retrieval Mnemonics (Scruggs T.E. et al. 2010)	Users will be taken to a separate interface to view the hazard scenarios when they active the triggers through the navigation.
Goal-Setting (Locke et al. 1981)	A score bar always presents the current accumulated score in the main interface. Such approach is to motivate individuals to direct action towards goal attainment
Feedback (Renn and Fedor 2001)	A feedback section is placed in each training scenario to allow users input their feedback and plan of hierarch controls.
Self-regulation (Latham 2007)	A total of 68 scenarios are inserted to SAVES and a hint system is available for users. It ups to users to choose whether they can rely on the helper or use their own experience
Game-theory (Zyda 2005)	SAVES is a game engine-based system which making learning process more fun and more engaged.
Situational awareness (Endsley et al. 2011)	A augmented real hazardous picture is integrated in each scenario which fully enhancing user's capacity to perceive, comprehend and respond to hazardous stimuli
Visual Cues (Hsiao and Simeonov 2001)	A master key answer of each training scenario is given in the end of the completion. It prompts individuals to respond to such signal sensors in the feedback section.
Real-time signal detection	Facilitates responding to specific stimuli when detected, thus reducing the need to forecast or predict future conditions

Fig. 3: Snapshot of developed training scenario

4.3 Development of SAVES Environment

The main research objective was to develop and test whether the SAVES improve workers' awareness of hazard classification, severity identification and ability of taking proper reaction plan. In order to approach such goals, the first key part was designing proper avatar which containing essential features and complete gestures tree. One hypothesis of this research was that a fully realistic and open-to-search BIM construction site provides greater benefits than a purposely constrained virtual training scenario. Besides, for the purpose of highly presenting the life replica in the AV environment, it was important to design a proper avatar for trainee to interact with all virtual contents. Thus, research team had reviewed the documents from OSHA regulations and extracted the safety information about entering to construction site as well as required Personal Protective Equipment (PPE) for working in the job site. As shown in Figure 4, the finalized avatar was a well-designed highpoly character with all PPE patterns including hard hat, construction boots, safety goggles, safety vest, ear muff and long sleeve working uniform, etc. This highploy avatar had more than 98,206 polygons and additional about 80,000 polygons for PPE. Such high-quality polygons maximized the realism in 3D and optimized performance in SAVES.

The second key part included a well-constructed BIM model as a training stage. Comparing with traditional VR scene, Building Information Model provides more realistic display and vivid experience. In order to correctly make BIM project to SAVES, the traditional 2D construction plan needed to be converted to 3D in Revit firstly. The building plans were converted to appropriate sizes and formats then they were imported to Maya to be assigned the texture rendering ID. The model pieces were built up in a sequence of sections which reflecting the construction stages. By structuring the environment in this approach it permitted the construction site to be linked with more detailed texture and material information as well as other diverse exterior recourse. This was exploited through the use of "UV mapping" and GFX method. All elements which correctly having texture ID were rendered and represented with UE3 in SAVES. Also, by linking the separate parts together via dynamic loading flow, it is easy to upgrade SAVES accompanying with the real construction schedule and progress in the future.

Fig. 4: View of Avatar and SAVES

5. EXPERIMENT SETUP AND FIELD TESTING

To emerge the designed safety training elements to the environment, a total number of 600 hazard datum were successfully decided and categorized. Around 300 hazard datum of sub-energy types have been recorded as well. These datum were used to develop the training scenarios which aided to be set up in SAVES for different needs. SAVES let trainees interact in situ in a manner similar or even exact to the situations as they would be on-site. Training scenarios were envisioned as small set exercises under the OSHA regulations and best industry practices. Comparing with such instruction-based module, task-based training module required trainees to use their safety knowledge to search through the whole stage for training spots and then recognized the hazards types, severity levels and corresponding action standards inside each training scenarios. In addition, trainees were tested to make a proper plan of hierarch control in each scenario. SAVES was divided into 3 training stages which were indoor-work environment, outdoor-work environment and construction equipment zone. Figure 4 presented two partial views of the completed training system. The SAVES contained 68 training scenarios in total around all three stages. All the training modules were scored and score was shown to the trainee in main screen in real time.

The field testing were taken in two different facilities located in south of the United States. Each time the testing was performed as a group training. Each group had at least 5 persons and everyone was asked to fill out the questionnaire after training. Their pre-activities and post-activities were also recorded for effectiveness analysis.

6. DISCUSSION

A qualitative and a quantitative analysis have been conducted after field testing. A survey was sent to the trainees who experienced SAVES. A total number of 36 replied questionnaires were received. The survey had five major categories of questions which included the attitudes of such AV system as a training method, the degree of such training involvement, agreement of training scenarios inside SAVES, confidence of safe working after such training, and comparison with other training methods they had before. The feedback and comments of SAVES were also collected for the purpose of new version development. After analyzing all received questionnaires, statistical results showed that 98% users had positive attitudes about SAVES and 100% users indicated that they were highly engaged with this AV system. As for training effectiveness, 94% users agreed the training contents that presented in SAVE fitting to their real job situations. About 97% users believed that they had more safety awareness and confidence after implementing SAVES.

The quantitative analysis was conducted based on the training results stored inside SAVES. In this research, Signal Detection (SD) theory was used to measure the hazards or energy sources which lead to the most incorrect discriminations during training session and how the workers to detect such hazardous cues in their real job environment after implanting SAVES.

SD theory provides a precise language and graphic notation for analyzing a target stimulus from random energy patterns and exploring the decision making under difficult perceptual judgments due to a great amount of complexity and uncertainty. Such applications of SD theory can be referred to the worker's safety awareness of hazard recognition ability and what energy sources could mislead workers to make incorrect safety decisions in real job environment. SAVES studies SD problem in construction industry through research the ability of a worker

to identify a potential injury or hazard in such complex environments. As shown in Equations 1 and 2, SD_t was measured the proportion of stimuli that were incorrectly discriminated. The goal was to minimize such proportion and maximize the correct identification and rejection (see Table 3 for details). SD_{t1} was the measurement to measure the accuracy under the situation of all signals were presented when the value SD_t was too high.

$$SD_t = (b + c)/(a + b + c + d) \quad \text{(Eq.1)}$$

$$SD_{t1} = a/(a + c) \quad \text{(Eq.2)}$$

Table 3: Signal Detection Matrix (SDM)

	Signal Present	Signal Absent
Signal Detected	Correct identification (a)	False Alarm (b)
Signal NOT Detected	Miss (c)	Correct rejection (d)

As summarized in Table 4 and 5, the average accuracy of overall training was 84% and the average hazard responding time was 1.5 minutes. However, among 36 users in total, they often made incorrect discriminations with mechanical hazard (level2), chemical hazard (leve2), electrical energy (level1), sound energy (level1) and gravity energy (level1). This suggested the research participating companies should pay more particular attentions to train their employees in such weak points in their next training cycle.

Table 4: Summary of accuracy when all signals presented (SD_{t1})

	Bio	Che	Elec	Gra	Mech	Mot	Pres	Rad	Sod	Temp
Lv1	0.019	0.019	0.019	0.077	0.135	0.038	0.038	N/A	0.019	0.019
Lv2	N/A	0.038	0.019	0.058	0.019	0.135	0.019	N/A	N/A	0.019
Lv3	0.019	0.019	0.019	0.115	0.019	0.019	0.019	0.038	0.019	0.019

Table 5: Summary of incorrect signal detection (SD_t)

	Bio	Che	Elec	Gra	Mech	Mot	Pres	Rad	Sod	Temp
Lv1	0.026	0.013	0.128	0.077	0.051	0.013	N/A	N/A	0.077	0.013
Lv2	0.013	0.064	0.013	0.026	0.115	0.051	0.013	N/A	0.051	0.026
Lv3	0.026	0.038	0.038	0.026	0.013	0.051	0.026	N/A	0.013	N/A

Also, workers seemed like very sensitive to the energy sources of gravity, mechanical and motion. They could make most correct discriminations when such signals were presented and many of them did not make the false alarm for such instances. That might indicate that those workers could be highly aware of falls, slippery, inadequate housekeeping, equipment contact, cave-in and struck-by in their real job environment.

As illustrated before, the post-training activities were recorded and the follow-up observation (see Figure 5) showed that the pre-SAVES and post-SAVES using real hazardous scenarios revealed significant improvements ($p < 0.05$) in the proportion of hazards recognized. Crew 1, 2 and 3 demonstrated an increase in hazard recognition of 41%, 34% and 44, respectively. All those outcomes and results indicate that SAVES could be very efficient in training workers' ability of hazard recognition and it has a huge potential of usage in construction as a novel method to motivate workers and companies having different safety experience.
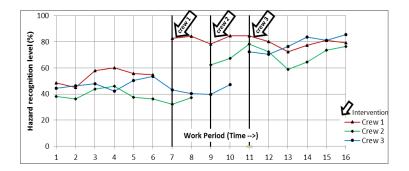
Fig. 5: Post –SAVES intervention results

7. CONCLUSIONS

This research has designed and developed SAVES to study the potential of such AV system as an effective to train and improve workers' hazard recognition skills. Furthermore, out of existing training methods, such practical exercises can provide the most transferable safety knowledge back to the workers. Such "learning by doing" style creates a clean mapping between site hazards and their recognition. The correlation allows practitioners to exercise recognition of site hazards more rapidly and in turn avoid fatalities and injuries through improvement of situational awareness.

SAVES provides a quick bidirectional communication platform to both management and workers. The company can use such results and feedbacks from SAVES to modify their initial training focus in order to improve the missed safety parts. Besides the advantage of short modeling time, SAVES is also expandable and upgradeable alone with construction schedule and real progress so as to provide the best training effort.

The research analysis shows that SAVES is able to provide efficient training effort. Post-SAVES activity observation indicates that all three participating groups can significantly recognize hazardous cues on site and make right actions according to different severity levels. The average of hazard recognition rate can increase up to 40% comparing with pre-SAVES activities. The qualitative questionnaires also show that workers can quickly accept SAVES with little problem and they are confident that safety knowledge are enhanced by interacting with SAVES. Workers can easily recognize the energy sources of gravity, mechanical and motion during the training. Such results imply those workers may have much less risk when their jobs relate to the hazards of falls, slippery, housekeeping, equipment contact, cave-in and struck-by. The top 5 hazards with severity levels which having high ratio of incorrect discriminations are identified as well. SAVES makes safety practical learning more active and engaging since it allows for safe simulation of real-life events in a digital environment that might otherwise be too dangerous or expensive. Construction workers, supervisors, owner representatives, contractors and society will benefit from such advantages.

The limitation of this work could be the lack of across comparison with other hazard recognition training methods. The undergoing research starts to address this limitation and the future work will focus on developing the weighting index and deciding the complexity coefficient for better training accuracy measurement. Also, future work may study the best way to maximize the benefits of SAVES and studying trainees' hazard discrimination tolerance.

8. ACKNOWLEDGEMENT

9. REFERENCES

Carter, G., and Smith S.D. (2006). 'Safety hazard identification on construction projects', *Journal of Construction Engineering and Management*, Vol. 132, No.2, 197-205.

Centers for Disease Control and Prevention (2012) *Construction* , viewed 15 March 2012 http://www.cdc.gov/niosh/construction/

Dong, X. S., Fujimoto, A., Ringen, K., Stafford, E., Platner, J. W., Gittleman, J. L., Wang, X. (2011). 'Injury underreporting among small establishments in the construction industry', *Am. J. Ind. Med.*, Vol. 54, 339-349.

Endsley, M. R., Bolté, B., Jones, D. G. (2011). 'Designing for situation awareness : An approach to user-centered design', CRC Press, Taylor & Francis, London.

Hsiao, H., and Simeonov, P. (2001). 'Preventing falls from roofs: A critical review'. *Ergonomics*, Vol 44, No.5, 537-561.

Knowles, M. S., Holton III, E. F., Swanson, R. A. (2012). The adult learner the definitive classic in adult education and human resource development, Routledge, New York.

Ku, K and Mahabaleshwarkar,S, P. (2011). 'Building interactive modeling for construction education in virtual worlds', *ITCon 2010*, Vol.16, 189-208.

Latham, G. P. (2007). Work motivation : history, theory, research, and practice, Sage Publications, Thousand Oaks, Calif.

Locke, E. A., Shaw, K. N., Saari, L. M., Latham, G. P. (1981). 'Goal setting and task performance: 1969–1980'. *Psychol. Bull.*, Vol. 90, No.1, 125.

Lucas, J., McMahan, R., Engle, R., Bowman, D., Thabet, W., Scafrik, S, and Karmis, M. (2008). 'Improving health and safety through conveyor system training in a virtual environment', International Future Mining Conference, 9-11 June, 2008. Sydney, Australia.

Mine Safety and Health Administration (MSHA). (1998). A new focus in MSHA, viewed 23 March 2012,http://www. msha.gov/TRAINING/EPDFS/EPDFS.pdf

National Institute for Occupational Safety and Health (NIOSH). (2002). Recommendations to the U.S. Department of labor for changes to hazardous orders, viewed 18 March 2012, http://www.cdc.gov/niosh/docs/ nioshrecsdolhaz/pdfs/dol-recomm.pdf

Occupational Safety and Health Administration (OSHA). (2012). *OSHA Trade News Release*, viewed 13 March 2012, http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=NEWS_RELEASES&p_id=21636

Renn, R. W., and Fedor, D. B. (2001). 'Development and field test of a feedback seeking, self-efficacy, and goal setting model of work performance'. *Journal of Management*, Vol. 27, No.5, 563-583.

Rivara, F., & Thompson, D. (2000). 'Prevention of falls in the construction Industry: Evidence for Program Effectiveness', *American Journal of Preventive Medicine*, Vol.18, No.4, 23-26.

Rozenfeld, O., Sacks, R., Rosenfeld, Y., Baum, H. (2010). 'Construction job safety analysis'. *Saf. Sci.*, Vol. 48, No. 4, 491-498.

Scruggs T.E., Mastropieri M.A., Berkeley S.L., Marshak L. (2010). 'Mnemonic strategies: evidence-based practice and practice-based evidence'. *Intervention Sch.Clin.Intervention in School and Clinic*, Vol. 46, No.2, 79-86.

Wang, Y., Goodrum, P. M., Haas, C., Glover, R., Vazari, S. (2010). 'Analysis of the benefits and costs of construction craft training in the united states based on expert perceptions and industry data'. *Constr. Manage. Econ.*, Vol. 28, No.12, 1269-1285.

Zeltzer, D., and Pioch, N.J. (1996). 'Validation, verification of virtual environment training systems', *IEEE 1996 Virtual Reality Annual International Symposium,* Dayton, Ohio, 123–130.

Zhao,D, Thabet,W, McCoy,A and Klienr,B. (2012). 'Managing electrocution hazards in the US construction industry using VR simulation and cloud yechnology', *eWork and eBusiness in Architecture, Engineering and Construction*, ECPPM 2012, 759-764.

Zohar, D., (1980). 'Safety climate in industrial organizations: theoretical and applied implications', *Journal of Applied Psychology* , 96-102.

Zyda, M. (2005). 'From visual simulation to virtual reality to games'. *Computer*, Vol. 38, No. 9, 25-32.