Assessing Impact of Training Programs for Highway Work Zone Employees

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ABSTRACT

Work zone safety, especially amidst increasing highway construction and repair, is paramount in ensuring the well-being of construction workers. Between 2003 and 2019, road construction sites saw a total of 2,103 worker fatalities, averaging 131 deaths annually. During this period, Texas had the highest number of road construction-related worker deaths. With traffic congestion intensifying and a rise in on-site hazards, there is a pressing need for workers to be adequately educated on the multitude of risks they face, from physical injuries to exposure to toxic substances. However, the efficacy of current training programs in inculcating proper safety practices remains under-explored. This study seeks to develop comprehensive training materials highlighting the myriad of hazards in work zones and the preventive measures to be adopted. An experimental highway construction worker group in Texas underwent this tailored training. Their knowledge was gauged before and after the session through a standardized questionnaire comprising ten questions aligned with the training content. The data was rigorously analyzed, unveiling a marked elevation in the participants' safety awareness post-training. These findings can guide construction firms and regulatory bodies in instituting training measures that heighten the safety quotient in work zones.

Keywords: Hazards, occupational safety, training, employees, work zone

INTRODUCTION

The heavy construction industry in the United States, particularly highway and street construction, is a significant economic contributor, valued at about $237 billion in 2017 and employing approximately 1 million individuals (US Department of Commerce, 2019). Despite representing a mere 0.8% of the working population, it accounted for 3% of the fatalities within the industry (BLS, 2018; US Census Bureau, 2019). The Federal Highway Administration reports that there is a work zone injury every 13 minutes and a fatality every 11 hours, with 2,103 workers losing their lives at road construction sites from 2003 to 2019, averaging 124 fatalities per year (BLS, 2022). Fatal accidents are not confined to unfavorable weather or road conditions. In 2008, it was found that 29% of fatal crashes took place on dry roads, while 35% happened on wet roads (Traffic Safety Facts, 2008). These figures highlight the persistent risks in road construction, which pose dangers not only to workers but also to motorists navigating through these zones (CDC, 2022; Nipa & Kermanshachi, 2022).

The intricacy and variety of dangers present in roadwork zones have notably risen because of the growing number of highway projects and the swift emergence of large-scale highway endeavors globally (Li et al., 2018). A work zone, as defined by the Federal Highway Administration, is an area of trafficway with construction, maintenance, or utility work activities.

These zones can vary in duration and type of activity, ranging from long-term stationary construction to short-term mobile maintenance tasks (FHWA, 2018; Kermanshachi et al., 2020). The review of existing research indicates that the existence of a work zone is probable to lead to a higher rate of accidents (Yang et al., 2015). The hazards in these zones are multifaceted, including the risk of being struck by vehicles or construction equipment, falls, electrocutions, and caught-in-between accidents, collectively known as the "Fatal Fours" in construction safety which accounted for 58.6% of the construction deaths in 2018 (OSHA Education Center, 2023; Subramanya et al., 2020).

Falls consistently rank as one of the primary causes of fatalities and severe injuries in the construction industry. To combat this, the implementation of effective fall protection systems is paramount. These systems, which include both passive (such as guardrails and safety nets) and active (like harnesses and lifelines) measures, play a crucial role in ensuring worker safety. It is imperative that these systems are not only chosen wisely but also installed correctly. Moreover, workers must receive thorough training to understand and utilize these systems effectively. This comprehensive approach to fall safety is essential to prevent accidents and injuries (Highway worker safety program, 2022; Safapour et al., 2021). Electrocution hazards represent another significant concern in construction settings. These dangers can emerge from either direct contact with live electrical components or indirect contact through tools or other conductive materials. To mitigate these risks, it is crucial to provide robust safety training focused on electrical hazards. Additionally, the deployment of appropriate personal protective equipment (PPE), such as insulated gloves and dielectric footwear, is vital to safeguard workers against electrical injuries (Long et al., 2014; Rad & Kermanshachi, 2018). Struck-by-object incidents are also a major contributor to construction-related deaths. Heavy equipment like trucks, cranes, and excavators often play a role in these accidents. To protect workers from these hazards, it is essential to enforce the use of protective gear, including hard hats, safety glasses, and high-visibility clothing. Such PPE helps in minimizing injuries from flying or falling objects and increases worker visibility around heavy machinery (Rashad, 2022; Pamidimukkala & Kermanshachi, 2023).

Caught-in-between hazards, often involving cranes, heavy equipment, and masonry walls, pose significant risks to construction workers. These dangers necessitate strict compliance with safety protocols and the implementation of effective engineering controls. Safety measures may include proper training, ensuring machinery is adequately guarded, and maintaining a safe distance from moving equipment to prevent these types of accidents (Namian et al., 2020; Safapour et al., 2023). Additionally, working conditions during nighttime and in low-visibility environments present distinct challenges in highway construction. These conditions require heightened safety measures, such as enhanced lighting, reflective clothing, and increased awareness of surrounding hazards. This is particularly important for workers operating at night, who must be highly visible and vigilant to avoid accidents (Pamidimukkala & Kermanshachi, 2022). Lastly, overexertion, though often underestimated, is a significant risk factor in the construction industry. It can lead to a multitude of nonfatal and fatal accidents. Factors contributing to overexertion include heavy lifting, repetitive motions, and prolonged periods of strenuous activity. Addressing this issue requires a focus on ergonomic practices, adequate rest breaks, and training in proper lifting techniques to reduce the occurrence of strain-related injuries (Rathnasiri et al., 2023; Kermanshachi et al., 2018).

Safeguarding against hazards in the workplace typically follows a tiered approach, beginning with the most effective strategies and concluding with the least (Ammar & Dadi, 2023). At the top of this hierarchy are engineering controls, which either eliminate the hazard entirely or create a physical barrier between the worker and the hazard. Following this are administrative controls, which entail alterations in work practices aimed at minimizing the time, frequency, and intensity of exposure to occupational hazards (Highway worker safety program, 2022; Kermanshachi & Safapour, 2019). The last line of defense in this hierarchy is the utilization of PPE, which serves as a crucial measure in hazard control. It is imperative that workers receive thorough training to understand and utilize these effectively (Huebschman et al., 2003; Subramanya et al., 2022).

The Occupational Safety and Health Act (OSHA) of 1971 has been pivotal in shaping safety protocols in high-risk zones. Prior to 1970, there were no comprehensive and uniform provisions governing the protection of workers against occupational safety and hazards. The number of work-related accidents was alarmingly high, with as many as 14,000 deaths and 2 million injuries annually (OSHA Education Center, 2023; Nipa et al., 2022).The introduction of OSHA marked a significant turning point, mandating employers to maintain a hazard-free workplace and ensure their workforce is trained in hazard recognition and control (Safapour et al., 2017). Despite these regulations, construction sites, particularly work zones on highways and streets, continue to confront various safety challenges, highlighting the ongoing need for vigilance and improvement in occupational safety measures. The over 25,000 work zone accidents annually in the state of Texas proves there is a need for increased safety measures regarding roadway construction areas (U.S. Department of Labor, 2004; Pamidimukkala et al., 2020).

Despite the significant number of fatalities, recent reports anticipate a consistent rise in infrastructure investment in the upcoming years (FMI, 2018). As the number of highway projects increases, employees will face greater safety hazards, leading to a higher likelihood of accidents, injuries, and fatalities. Consequently, it is crucial to implement appropriate measures to effectively reduce the heightened safety risks. Therefore, the objectives of this study are to (1) develop training materials for employers and employees, (2) deliver training sessions and educate them about the recognition and prevention of hazardous situations associated with work zones and roadway construction that result in injuries and fatalities, and (3) evaluate the training sessions. This initiative is crucial for enhancing the overall safety of construction sites, particularly in high-risk areas like roadways and highways. This study aims to create a safer work environment in construction zones by equipping workers and employers with the knowledge necessary to identify and mitigate risks effectively.

METHODOLOGY

As illustrated in Figure 1, a three-step methodology was designed to fulfill the objectives of the research. The first step was to review related published documents and collect materials on safety and health challenges of the workforce active in work zones and roadway construction. In addition, strategies and best practices which were adopted to prevent and/or overcome hazardous situations during roadway, highway, and bridge construction were identified and collected. In this regard apart from scholarly publications, two of the major and primary sources used were OSHA and National Cooperation Highway Research Program (NCHRP) published documents. The review and collection of the existing documents were divided into (1) guidance for workers/labours/engineers active in roadway construction fields and sites, and (2) guidance for construction employers of roadway workforce. In the second step, the training modules and supplementary materials were developed and in the last step the training materials were pilot tested on several workers and employers working in roadway construction.

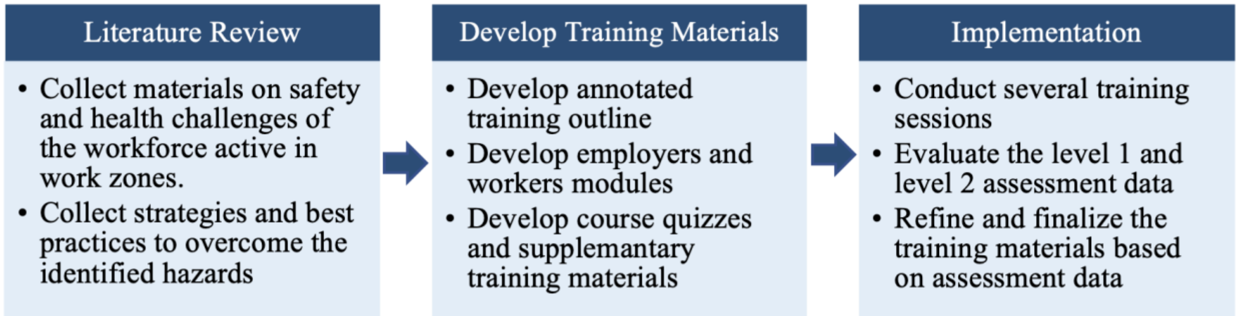


Figure 1. Methodology

RESULTS

Develop Training Materials

The team developed new modules for the following two sets of courses: 4-hour training for workforce in roadway and highway construction (e.g., labours, inspectors, heavy machine operators, etc.) and 3-hour training for small contractor employers active in roadway and highway construction industry. The organized outline for the training materials instructing construction employees and employers is presented in Table 1.

Table 1. Outline of Occupational Safety and Health Training Materials for Roadway Construction Employees and Employers

Type	Name	Description
Modules	Module 0	Introduction to the Program
	Module 1	General Information
	Module 2	Accidents in Construction
	Module 3	Personal Safety
	Module 4	Falls
	Module 5	Struck-by
	Module 6	Electrocutions
	Module 7	Caught-in/between
	Module 8	Soft Tissue Injuries
	Module 9	Night Work Hazards
	Module 10	Fire Protection and Prevention
	Module 11	Signs, Signals and Barricades
	Module 12	Workers' Rights/ Employers' Responsibilities
	Module 13	OSHA's Construction Safety Programs
	Module 14	Summary
Supple mentary	Pre-training Assessment	Assessment of the participants at the beginning of training session
	Post-training Assessment	Assessment of the participants at the end of training session
	Training Evaluation Form	Evaluation of the training event

As presented in Table 1, the research team has developed modules on hazards associated with work zones and roadway construction in the training materials to instruct workers on the exposures to such hazards and their preventive methods along with hierarchical controls. The hierarchy of controls is a way of determining which actions will best control exposures; therefore, the team included controls to prevent such hazards at work zones in roadway construction. As it is very important that all workers receive thorough training on how to work next to motor vehicle traffic at nights in a manner that reduces their risk of experiencing a safety hazard, a module on night work hazards was developed. The research team has also developed a module on workers' rights, and employer responsibilities to instruct workers and their employers about their rights and responsibilities at construction work zones. All the modules were developed in the PowerPoint and each of the slides have a footnote consisting of key message, background, interactivity, notes, and references. The research team has also developed and included class handouts for all training modules. Class handouts contain multiple quiz questions based on the topic of the module. These questions were also included in the PowerPoint presentations of the modules. Figure 2 presents the layout of the modules developed in the PowerPoint. Both PDF and PowerPoint versions of the modules were developed and stored. Next, the team has developed supplementary training materials including instructor and participant guides and training assessments.

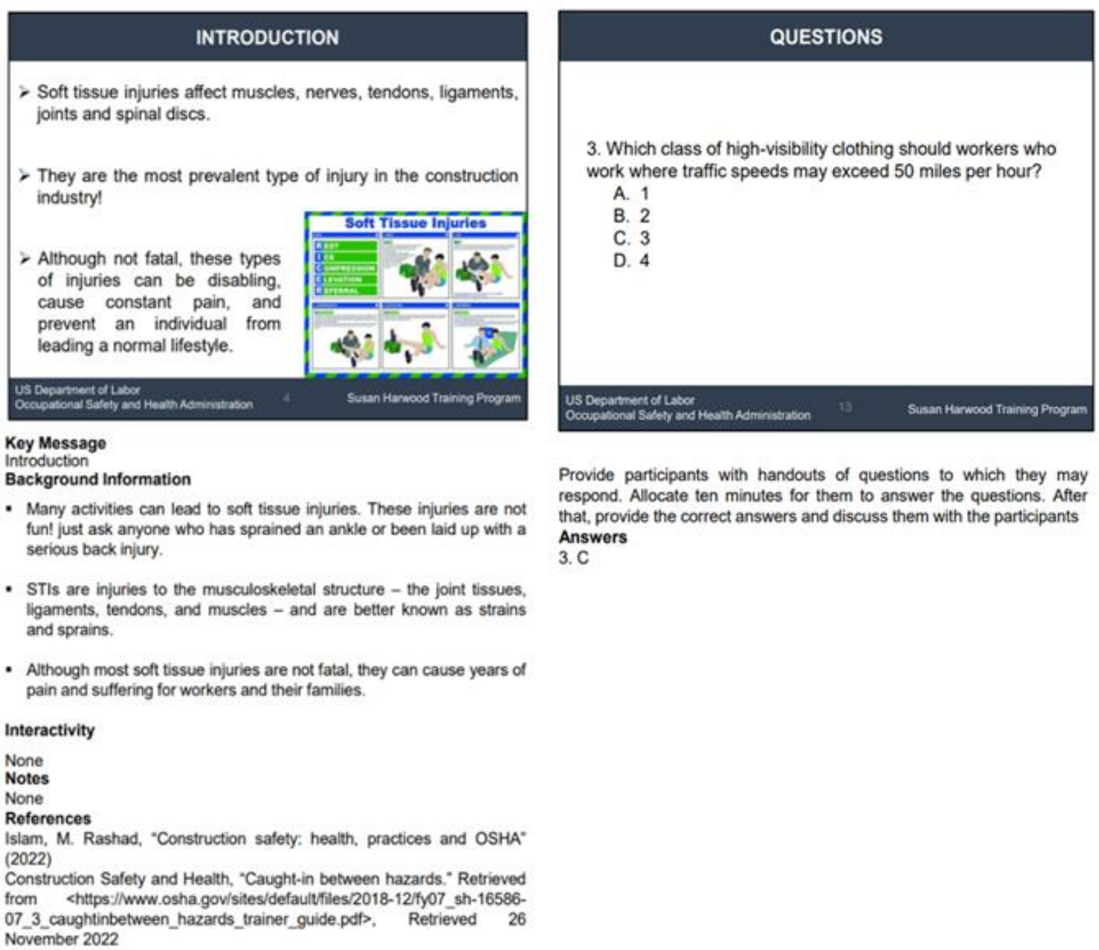
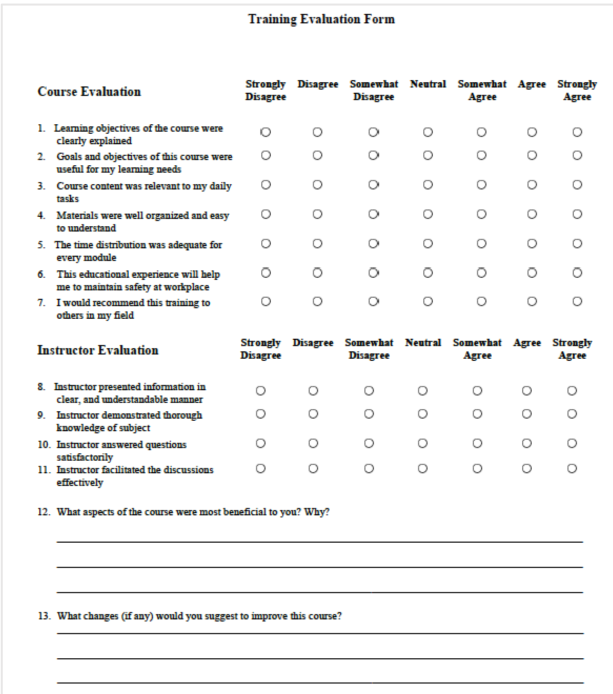


Figure 2. Example PowerPoint Slides

In order to assess the efficacy of the training program and improve the contents, two assessment methodologies were devised. Level 1 training session evaluation assesses trainees' responses to the training, including their perceptions of the training environment, instructors, and the overall quality and usefulness of the training. In level 2 learning assessment, the team measures the skills, knowledge, and safety attitude the trainees acquire and retain. The team implemented the pre- and post-test assessment by distributing the 10 case examples before and after the workshop. This method of assessment yields a more accurate results regarding the effectives of the training materials. Figure 3 presents an example of Level 1 and Level 2 assessments.



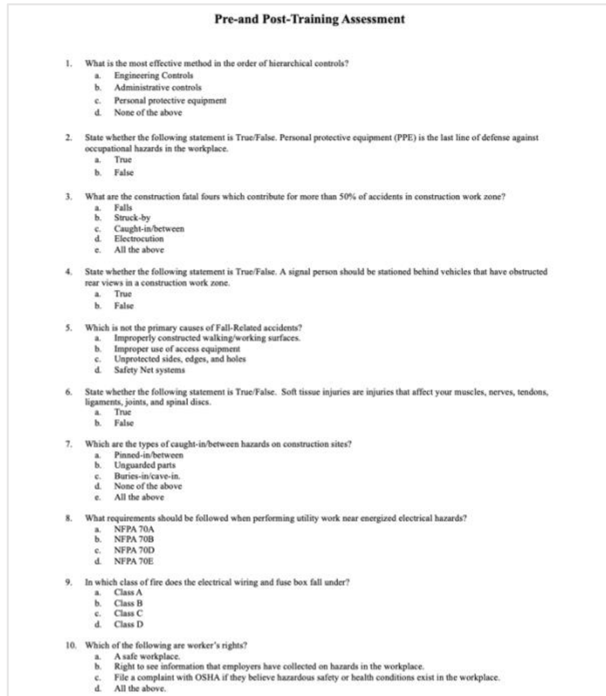
Training Evaluation Form

Course Evaluation	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
1. Learning objectives of the course were clearly explained	○	○	○	○	○	○	○
2. Goals and objectives of this course were useful for my learning needs	○	○	○	○	○	○	○
3. Course content was relevant to my daily tasks	○	○	○	○	○	○	○
4. Materials were well organized and easy to understand	○	○	○	○	○	○	○
5. The time distribution was adequate for every module	○	○	○	○	○	○	○
6. This educational experience will help me to maintain safety at workplace	○	○	○	○	○	○	○
7. I would recommend this training to others in my field	○	○	○	○	○	○	○

Instructor Evaluation	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
8. Instructor presented information in clear, and understandable manner	○	○	○	○	○	○	○
9. Instructor demonstrated thorough knowledge of subject	○	○	○	○	○	○	○
10. Instructor answered questions satisfactorily	○	○	○	○	○	○	○
11. Instructor facilitated the discussions effectively	○	○	○	○	○	○	○

12. What aspects of the course were most beneficial to you? Why?

13. What changes (if any) would you suggest to improve this course?



Pre-and Post-Training Assessment

1. What is the most effective method in the order of hierarchical controls?
   a. Engineering Controls
   b. Administrative controls
   c. Personal protective equipment
   d. None of the above
2. State whether the following statement is True/False. Personal protective equipment (PPE) is the last line of defense against occupational hazards in the workplace.
   a. True
   b. False
3. What are the construction fatal fours which contribute for more than 50% of accidents in construction work zone?
   a. Falls
   b. Struck-by
   c. Caught-in/between
   d. Electrocution
   e. All the above
4. State whether the following statement is True/False. A signal person should be stationed behind vehicles that have obstructed rear views in a construction work zone.
   a. True
   b. False
5. Which is not the primary causes of Fall-Related accidents?
   a. Improperly constructed walking/working surfaces.
   b. Improper use of access equipment
   c. Unprotected sides, edges, and holes
   d. Safety Net systems
6. State whether the following statement is True/False. Soft tissue injuries are injuries that affect your muscles, nerves, tendons, ligaments, joints, and spinal discs.
   a. True
   b. False
7. Which are the types of caught-in/between hazards on construction sites?
   a. Pinned-in/between
   b. Unguarded parts
   c. Buries-in/cave-in.
   d. None of the above
   e. All the above
8. What requirements should be followed when performing utility work near energized electrical hazards?
   a. NFPA 70A
   b. NFPA 70B
   c. NFPA 70D
   d. NFPA 70E
9. In which class of fire does the electrical wiring and fuse box fall under?
   a. Class A
   b. Class B
   c. Class C
   d. Class D
10. Which of the following are worker's rights?
   a. A safe workplace.
   b. Right to see information that employers have collected on hazards in the workplace.
   c. File a complaint with OSHA if they believe hazardous safety or health conditions exist in the workplace.
   d. All the above.

Figure 3. Level 1 Assessment (left), and Level 2 Assessment (Right)

Implementation

After finalizing the training materials, the research team pilot tested the materials to the roadway workers and employers. The training sessions for employers and workers is of three hours and four hours respectively. After the end of each session, the trainees were requested to fill the level 1 and level 2 training assessments. The attendees were instructed to provide their comments on how to enhance and improve the training materials on level 1 assessment. Next, the team has implemented the level 2 learning assessment by distributing ten questions before and after the workshop. After each training session is completed, the responses collected for both level 1 and 2 training assessments were analysed qualitatively and quantitatively. In level 1 assessment, the team evaluated the criteria on quality of the training modules and topics, skills of the instructors, length of the training, effectiveness of supplementary materials including handouts/quizzes and case studies, etc. It was revealed that, the trainees expressed satisfaction with the design and contents of the training materials and no significant feedback was received from the trainees regarding any necessary modifications to the modules.

In level 2 assessment, the team analysed the obtained skills and knowledge of the trainees using pre- and post-training evaluation technique. In this regard, the responses of the attendees on pre- and post-training case studies were comparatively analysed to measure their level of improvements in their knowledge and skills in recognition and prevention of hazards associated with work zones and roadway construction. The results revealed that the average percentage of questions correctly answered by all the participants' during pre-training was 61%, and the average percentage correct responses on the post-training assessment questions were raised to 89%, after the training sessions were delivered. Figure 4. presents the comparison scores of pre-and post-training assessments of each of ten questions.

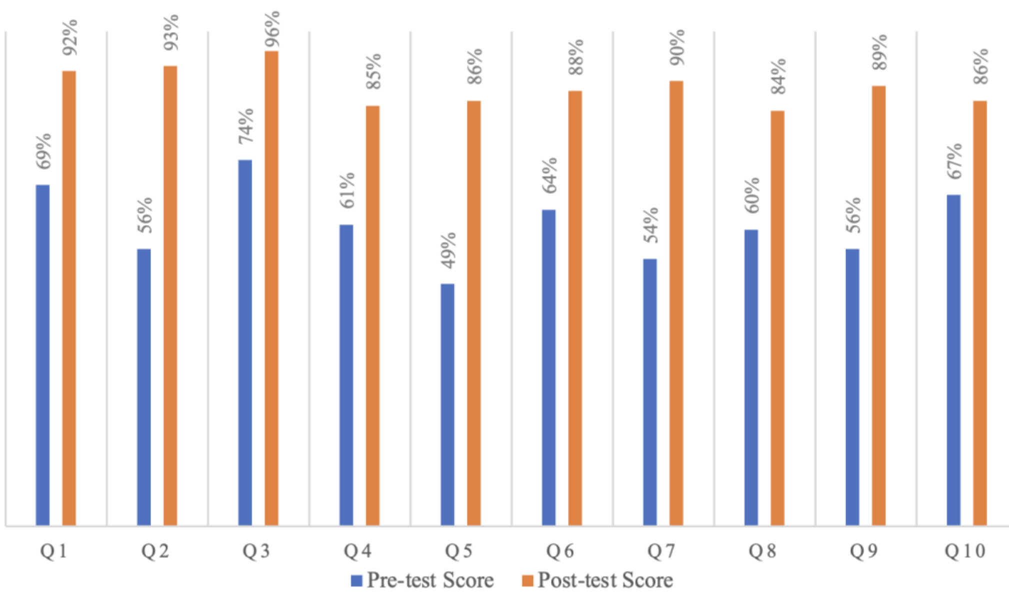


Figure 4. Pre- and Post- Test Comparison Scores

CONCLUSION

The objective of this study was to develop and implement occupational hazard training for workers and employers in roadway construction. An extensive literature review was performed and a training outline was designed based on the reviewed materials. Next, training modules and supplementary materials were developed, and several pilot training workshops were conducted for workers and employers in Texas. After conducting the training sessions, the participants' knowledge was assessed before and after the training sessions through pre- and post-training tests. The questionnaire comprised ten questions regarding the subject matter addressed in the training session. The collected assessments were subjected to quantitative analysis, which demonstrated a statistically significant disparity in the participants' knowledge levels before and after the training. The materials developed in this study may aid highway/roadway construction companies improve the safety of their workforce.

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