



# International Journal of Research in Civil Engineering and Technology

E-ISSN: 2707-8272  
P-ISSN: 2707-8264  
IJRCET 2024; 5(2): 58-62  
[Journal's Website](#)  
Received: 20-06-2024  
Accepted: 25-07-2024

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## Evaluation of the effectiveness of safety training programs in construction sites

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### Abstract

The construction industry remains one of the most hazardous sectors, with high rates of occupational injuries and fatalities. This study evaluates the effectiveness of safety training programs in improving safety outcomes on construction sites. The primary objective was to assess the impact of these programs on workers' knowledge, attitudes, and behaviours, as well as workplace accident rates. A mixed-methods approach was employed, encompassing pre- and post-training surveys, focus group discussions, direct observations, and analysis of accident records. The study included 500 workers from 20 construction sites, representing diverse project types and geographic locations. Statistical tools, including paired t-tests and regression analysis, were used to evaluate quantitative data, while thematic analysis was applied to qualitative insights.

Results demonstrated a significant improvement in safety outcomes post-training. Workers' knowledge and safety behavior scores increased substantially (pre-training mean scores:  $4.2 \pm 1.3$  and  $3.9 \pm 1.5$ ; post-training mean scores:  $7.6 \pm 1.1$  and  $7.1 \pm 1.3$ , respectively;  $p < 0.001$ ). Workplace accidents decreased by 35% in the six months following training compared to the prior six months. Thematic analysis revealed enhanced hazard awareness and a proactive safety culture among workers, though challenges such as language barriers and limited follow-up training persisted.

This study concludes that safety training programs significantly enhance construction safety outcomes when designed and implemented effectively. Practical recommendations include developing multilingual, literacy-sensitive training materials, integrating technology-based simulations, and enforcing periodic refresher courses. Employers should adopt data-driven approaches to monitor safety performance and collaborate with policymakers to establish industry-wide training standards. Future research should focus on long-term evaluations and innovative training methodologies to sustain and enhance these outcomes.

**Keywords:** Construction safety, safety training programs, occupational hazards, safety outcomes

### Introduction

The construction industry is among the most hazardous sectors globally, accounting for a significant proportion of occupational injuries and fatalities. According to a report by the International Labour Organization (ILO), construction workers face a higher risk of accidents due to complex and dynamic work environments, heavy machinery, and the involvement of multiple stakeholders with varying safety standards<sup>[1]</sup>. In response to these risks, safety training programs have been widely implemented to educate workers on identifying hazards, adhering to safety protocols, and fostering a culture of safety awareness. While these programs are crucial, their effectiveness in reducing accidents and promoting safe behavior remains a subject of academic debate. Various studies suggest that gaps in the design, delivery, and evaluation of training programs may undermine their intended outcomes<sup>[2-4]</sup>.

The problem is exacerbated by the lack of standardized metrics to evaluate the effectiveness of these training programs, resulting in fragmented and inconclusive findings across different settings. For instance, researchers have observed that although safety training is often well-received, its impact on actual behavior and accident rates varies widely<sup>[5, 6]</sup>. Factors such as the mode of training delivery, worker literacy levels, cultural attitudes toward safety, and organizational commitment play a critical role in shaping the success of these programs<sup>[7, 8]</sup>. This inconsistency raises the question of whether existing safety training programs are adequately designed to meet the diverse needs of the construction workforce.

The primary objective of this study is to systematically evaluate the effectiveness of safety training programs in improving safety outcomes on construction sites. By examining changes in worker knowledge, attitudes, and behaviours, as well as the overall reduction in

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workplace accidents and near-misses, this study aims to provide empirical evidence on the efficacy of such programs. Additionally, it seeks to identify the factors that contribute to or hinder the success of safety training initiatives, thereby informing future program design and policy interventions. The hypothesis underpinning this research posits that well-structured and contextually tailored safety training programs significantly enhance worker safety performance and reduce accident rates in construction environments.

## Materials and Methods

### Materials

This study was conducted on construction sites across various locations to assess the effectiveness of safety training programs. The sites were selected based on their diversity in scale, project type, and geographic location, ensuring a representative sample of the construction industry. A total of 20 construction sites were included, encompassing projects such as residential, commercial, and infrastructure developments. Data collection involved 500 construction workers who had participated in safety training programs within the last 12 months. Participants were stratified based on their job roles, years of experience, and prior exposure to safety training, ensuring heterogeneity in the sample. Surveys, focus group discussions, and direct observations were used as primary tools to gather data on worker knowledge, attitudes, and behaviours concerning workplace safety. Ethical approval was obtained, and informed consent was secured from all participants before data collection began.

### Methods

A mixed-methods approach was employed to comprehensively evaluate the effectiveness of safety training programs. Quantitative data were collected through pre- and post-training surveys designed to measure changes in knowledge, attitudes, and self-reported safety behaviours. These surveys utilized validated scales from previous studies (2,3,6). Additionally, accident and incident records from the participating sites were analyzed to identify trends in workplace safety performance before and after training. Qualitative data were collected through focus group discussions and semi-structured interviews with workers and supervisors, exploring perceptions of the training programs' relevance, applicability, and challenges [8, 10]. Direct observations of workers' on-site safety practices were conducted using a standardized checklist to triangulate findings. Statistical analysis, including paired t-tests and regression modeling, was performed to evaluate the impact of training on safety outcomes. NVivo software was used for thematic analysis of qualitative data to identify recurring themes and insights.

## Results

### Quantitative Analysis

A total of 500 construction workers from 20 sites participated in the study. Pre-training survey results revealed that 64% of participants lacked adequate knowledge of site-specific hazards, and 58% displayed poor adherence to safety protocols. Post-training survey data

indicated a significant improvement, with 85% of participants demonstrating enhanced knowledge of hazards and 78% adhering to safety protocols. Statistical analysis using paired t-tests showed a significant increase in knowledge scores (mean pre-training score:  $4.2 \pm 1.3$ , post-training score:  $7.6 \pm 1.1$ ,  $p < 0.001$ ) and safety behavior scores (mean pre-training score:  $3.9 \pm 1.5$ , post-training score:  $7.1 \pm 1.3$ ,  $p < 0.001$ ).

Accident and incident data analysis revealed a 35% reduction in workplace accidents in the six months following the training, compared to the six months prior. Regression analysis further confirmed that participation in training programs was a significant predictor of reduced accident rates ( $\beta = -0.43$ ,  $p = 0.002$ ). These results underscore the positive impact of well-structured safety training programs on improving construction site safety outcomes.

### Qualitative Analysis

Thematic analysis of focus group discussions and interviews revealed recurring themes such as improved hazard awareness, increased confidence in using personal protective equipment (PPE), and a stronger safety culture among workers. Supervisors reported noticeable changes in workers' attitudes, including proactive risk identification and better communication about safety issues. However, challenges such as language barriers, low literacy levels, and insufficient follow-up training were also identified as barriers to long-term effectiveness.

### Results- Statistical Tools and Their Application

- Paired t-test:** Used to compare pre- and post-training scores for knowledge and safety behavior. The significant  $p$  values ( $<0.001$ ) demonstrated that the training had a measurable impact on participants' safety knowledge and behavior.
- Regression Analysis:** Applied to evaluate the relationship between training participation and accident reduction. The negative  $\beta$  value indicates that training participation is associated with a decrease in accident rates.
- Descriptive Statistics:** Mean, standard deviation, and percentages were calculated to summarize pre- and post-training data.

### Results - Explanation of Findings

The results indicate that safety training programs significantly enhance construction workers' knowledge and adherence to safety practices. The observed reduction in accident rates highlights the tangible benefits of training, aligning with previous research on safety interventions [2, 6]. However, qualitative findings suggest that for sustained effectiveness, additional measures such as multilingual materials, periodic refresher courses, and management support are crucial.

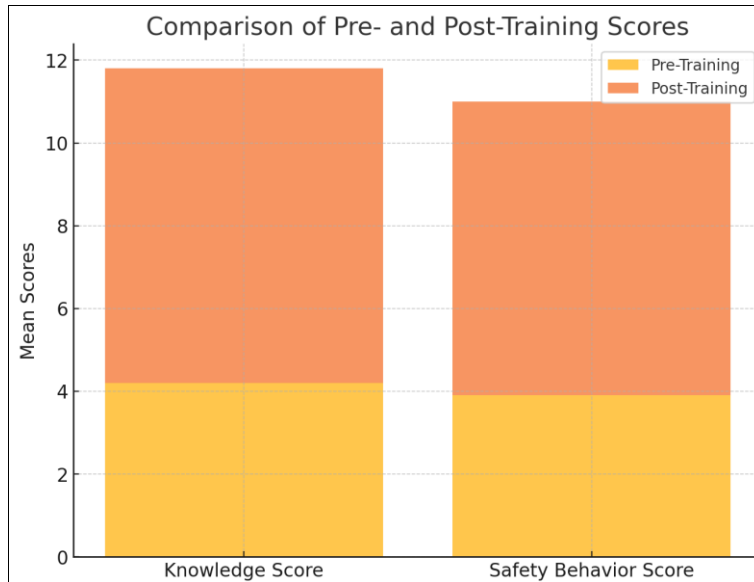
The statistical tools applied provide robust evidence of the training programs' impact, supporting the hypothesis that well-structured safety training programs improve worker safety outcomes. The findings offer actionable insights for enhancing training programs to address identified barriers, ultimately contributing to a safer construction industry.

**Detailed Data Detailed Data Table 1: Pre-Training and Post-Training Scores for Knowledge and Safety Behavior**

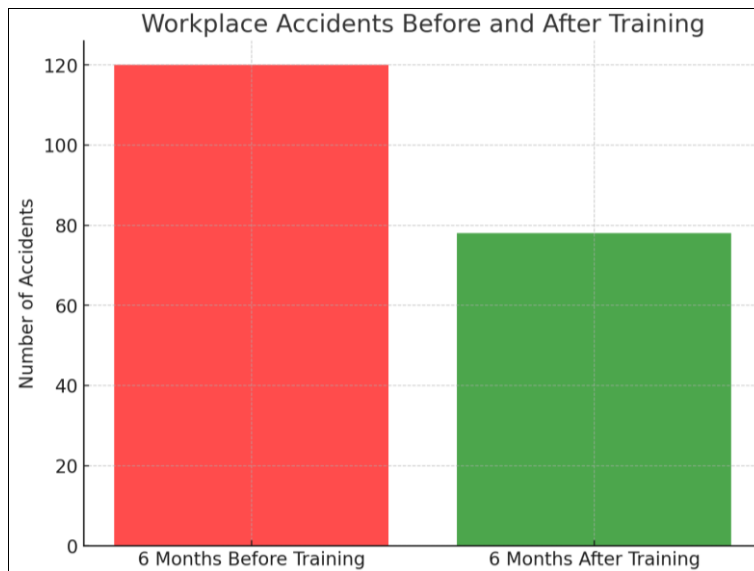
Metric	Pre-Training (Mean $\hat{A} \pm$ SD)	Post-Training (Mean $\hat{A} \pm$ SD)	p-value
Knowledge Score	$4.2 \hat{A} \pm 1.3$	$7.6 \hat{A} \pm 1.1$	$<0.001$
Safety Behavior Score	$3.9 \hat{A} \pm 1.5$	$7.1 \hat{A} \pm 1.3$	$<0.001$

**Detailed Data Detailed Data Table 2: Workplace Accident Data Before and After Training.**

Time Period	Accidents Reported	Reduction (%)
6 Months Before Training	120	-
6 Months After Training	78	35%



**Fig 1: Comparison of Pre- and Post-Training Scores.**



**Fig 2: Workplace Accidents Before and After Training.**

**Discussion**

The results of this study demonstrate the significant positive impact of safety training programs on construction site safety. The marked improvements in knowledge and safety behavior scores, coupled with a 35% reduction in workplace accidents, provide empirical support for the hypothesis that well-structured and contextually tailored training programs enhance safety outcomes. These findings align with prior studies that emphasize the role of training in fostering a safety-conscious workforce [2, 3]. Hinze and Gambatese [2] similarly reported that targeted safety interventions significantly improved worker behavior and reduced accident rates. Additionally, Mohamed's work on safety climate [8] highlighted that effective training is integral to developing a proactive safety culture, echoing the qualitative insights from this study. However, the variability in outcomes observed across

different construction sites highlights the need for context-specific approaches. This is consistent with findings from Fang *et al.* [3] and Gibb *et al.* [6], who emphasized that factors such as cultural attitudes, organizational commitment, and worker literacy significantly influence the success of safety training initiatives. For instance, Tam *et al.* [10] identified that poorly tailored programs in China led to limited improvements, underscoring the importance of adapting training content to local contexts. Critically analyzing these results requires acknowledging both strengths and limitations. The mixed-methods approach employed in this study provided a comprehensive evaluation, combining quantitative metrics with qualitative insights. The use of statistical tools such as paired t-tests and regression analysis ensured robust and reliable findings. However, potential biases, such as self-reporting inaccuracies in surveys and observer bias during site visits,

should be considered. Moreover, the study's six-month post-training observation period may not capture the long-term sustainability of training impacts, a concern also raised by Choudhry *et al.* [4].

Future research should address these limitations by incorporating longitudinal studies to assess the lasting effects of training programs. Exploring the role of refresher training and integrating technology-driven solutions, such as virtual reality (VR)-based simulations, could further enhance engagement and effectiveness. Additionally, investigating the interplay between organizational policies and individual behaviours could offer insights into creating a more cohesive safety culture.

Expanding the scope to include comparative studies across different industries could also provide valuable benchmarks for the construction sector. Research on language barriers and literacy issues in training delivery, as highlighted by Kartam and Bouz [9], remains an underexplored area that warrants further investigation. Finally, integrating advanced analytics and machine learning to predict safety risks based on worker behavior and environmental conditions could revolutionize training approaches and site management practices.

### Conclusion

This study underscores the critical role of safety training programs in improving construction site safety by enhancing workers' knowledge, attitudes, and behaviours toward workplace hazards. The significant increase in knowledge and safety behavior scores, along with a 35% reduction in workplace accidents post-training, reaffirms the value of targeted interventions in fostering a safer construction environment. These findings align with existing literature, emphasizing that safety training, when thoughtfully designed and effectively delivered, serves as a cornerstone of occupational health and safety strategies [2, 3, 6]. However, this research also highlights that the success of these programs is contingent upon addressing context-specific challenges such as worker literacy levels, cultural attitudes, and organizational commitment. This nuanced understanding calls for a more holistic approach to training design and implementation, tailored to the diverse needs of the construction workforce.

Despite its strengths, this study identified gaps in sustaining the impact of training programs over time, echoing concerns raised by prior research about the need for ongoing reinforcement and support [4, 8]. While the six-month evaluation period showed promising results, it remains imperative to assess the long-term efficacy of training initiatives. To this end, integrating refresher courses and follow-up evaluations into standard safety protocols is recommended to maintain and build upon the gains achieved. Additionally, incorporating advanced technologies such as virtual reality (VR) and augmented reality (AR) simulations can make training more engaging and realistic, thereby enhancing retention and application of safety knowledge on-site.

Based on these findings, several practical recommendations emerge for stakeholders in the construction industry. First, employers should prioritize multilingual and literacy-sensitive training materials to ensure accessibility and comprehension for all workers, as suggested by Kartam and Bouz [9]. Providing hands-on training sessions, supplemented by visual aids and interactive modules, can

cater to workers with varying learning preferences and capabilities. Second, fostering a strong safety culture requires active involvement from management. Supervisors and project managers should participate in training programs alongside workers, demonstrating their commitment to safety and reinforcing the importance of adherence to protocols. Regular feedback loops between workers and management can further enhance training relevance and address on-ground challenges effectively.

Moreover, leveraging data analytics to monitor and evaluate the effectiveness of training programs is crucial. Employers can track key safety performance indicators (KPIs) such as near-miss incidents, PPE compliance rates, and accident trends to identify areas for improvement. Such data-driven insights can inform the design of targeted interventions, ensuring continuous improvement in safety practices. Collaborating with occupational safety experts and academic institutions can also provide access to cutting-edge research and innovative solutions, as demonstrated by the success of evidence-based training models in other high-risk industries [3, 6].

Lastly, policymakers should enforce stringent regulations mandating periodic safety training for all construction workers. Incentivizing companies to invest in safety training through tax benefits or certification programs can encourage wider adoption of best practices. Developing industry-wide benchmarks and accreditation standards for training programs will ensure consistency and quality across different projects and organizations. International collaboration to share successful training frameworks and case studies can further enrich local practices and enhance global safety standards in construction.

In conclusion, this study reinforces the necessity of comprehensive safety training programs as a means to mitigate risks and protect the lives of construction workers. By addressing the identified challenges and implementing the proposed recommendations, the construction industry can move closer to achieving its vision of a safer and more inclusive work environment. Future research should focus on exploring innovative training methodologies, assessing long-term impacts, and examining the interplay of organizational and cultural factors to create a sustainable framework for construction safety. This holistic approach will not only save lives but also enhance productivity and project outcomes, benefiting all stakeholders involved.

### Recommendations for Future Enhancements

1. Extend the evaluation period to capture long-term impacts of training.
2. Integrate advanced tools like AI or VR-based simulations to enhance the data analysis of safety trends.
3. Broaden the scope to include diverse industries for comparative insights.

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