

Safety Micro Learning in High-Risk Facilities: Do 60-Second Digital Nudges Reduce Incident Rates?

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I. INTRODUCTION

Mining and mineral processing, as high-risk industries, are always associated with serious safety issues related to working with sharp materials and heavy machinery, as well as dangerous environmental factors. Slips, falls, and touching contaminated fluids are common threats to workers, and it is more likely that they will be infected or injured (Doyle, 2023). More than 60 pathogens are associated with accidents related to blood and other body fluids, such as hepatitis B virus (HBV), hepatitis C virus (HCV), human immunodeficiency virus (HIV), etc. (Debelu et al., 2023). In spite of safety measures, the rate of workplace injuries is still elevated, which demonstrates a grave mismatch between the safety policy and practice. The awareness of these risks makes it clear why some innovative interventions are required that could help to supplement the traditional ones.

The conventional safety education tends to be based on protracted classroom sessions, occasional briefings, or fixed posters, which may not be adequate in the reduction of hazards in high-energy, dynamic settings. Long-term training may cause cognitive fatigue, short attention span, and lack of memory in essential safety behaviors (Buchholz et al., 2022). In addition, reinforcement is not always continuous, and the supervisors are not able to keep a watch on compliance, which leaves gaps in safety. There is some indication that traditional training might not be sufficient in impacting the behavior of the workers in real time, especially in actions that require constant attention or quick decision-making (Michael, 2025). These restrictions highlight the importance of the interventions that will be able to engage workers on a regular basis and support the essential behavior without overwhelming them.

According to Amjad (2025), a possible solution is microlearning and digital nudges, which use short and purposeful mobile-first safety reminders that

could be incorporated into the work process unobtrusively. The interventions help to reinforce one safety behavior at a time, e.g., correct PPE use or lockout-tagout processes, within less than one minute, and hence they are not cognitively challenging to the traditional processes. This paper will investigate whether short 60-second digital nudges are able to prevent incidents, enhance near-miss reporting, and expedite corrective actions, and also analyze how engagement changes by role, experience, and frequency of exposure. This study can be evaluated through the analysis of behavioral and operational results, as well as the evaluation of the feasibility and the efficiency of microlearning as an alternative to traditional safety initiatives.

II. LITERATURE REVIEW

2.1 The conventional safety training in the high-risk industries.

Mineral processing and mining are high-risk industries that largely stick to the traditional safety training approaches, including posters, classroom sessions, and periodic briefings (Yaro & Sali, 2023). These methods are to deliver important safety steps and awareness of hazards, yet they are ineffective due to the passiveness and the lack of response after use. Posters tend to be overlooked, and briefings are not offered regularly to maintain safe practices. Long classroom hours may be too much stress for the workers, causing retention and cognitive attention issues. Although safety regulations are followed, the level of injuries is quite high, which means that there is a discrepancy between the theoretical knowledge and the behavior at the workplace (Dyreborg et al., 2022). This underscores the necessity of additional interventions that strengthen real-time learning.

In addition, traditional training takes a lot of time and is also expensive in terms of delivery and time lost during production (Michael, 2025). Prolonged sessions cause fatigue and lack of focus, particularly within high-risk settings of fast-paced environments

where knowledge must be applied quickly (Wu et al., 2025). Employees could also fail to remember key steps when subjected to pressure, which results in procedural errors. Safety culture programs that are based only on the traditional approaches might, hence, not be able to prevent incidents efficiently. These approaches cannot be used in the absence of continuous reinforcement to ensure high rates of compliance, thus requiring innovative approaches that combine the delivery of knowledge with behavior control and applicability in real-life situations.

2.2 Microlearning principles

Microlearning provides brief, targeted learning activities that enhance knowledge retention and interest over traditional learning (Monib et al., 2025). These lessons are usually presented in 30-second to five-minute units and reduce the cognitive load (Ballance, 2024). Microlearning was demonstrated in high-risk or healthcare environments to strengthen the use of PPE, emergency processes, and other safety measures. It has a modular structure and enables targeted interventions on particular hazards, and this is very handy, especially in dynamic industrial settings requiring quick adaptation. Microlearning will be an addition to the effective use of traditional safety programs by offering brief, practical information that leads to enhanced recall and use.

Also, microlearning can be incorporated into the workflow so that the employees can receive the lessons in their free time without disturbing the work process. Mobile platforms can be easily changed to accommodate new hazards or regulations, and thus the content is easily updated (Gunasekaran et al., 2025). There is evidence that the effectiveness of microlearning combined with practical reinforcement is more effective in enhancing behavioral compliance than lectures alone. More importantly, although microlearning improves the level of engagement and temporary retention, it should be constructed with careful consideration of the elements of clarity, relevance, and connections to work realities. It works best when combined with other measures, including supervisory monitoring or even digital nudging, to make sure learning is converted into a regular safety behavior.

2.3 Digital nudges and behavioral science

Digital nudges consider the ideas of behavioral science to nuance a way of influencing employees, making them act in safer ways without imposing on them (Ruehle, 2023). Nudges remind workers of safety procedures, including checking PPE or lockout/tagout. Healthcare testifies to their potential: one study of 31 countries indicated that the global prevalence of needlestick injuries in healthcare workers was 44.5% and showed that behavioral interventions are the most important (Debelu et al., 2023). Nudges help to improve attention and facilitate the formation of a habit, especially in those settings that can lead to serious injury in case of lapse. It can also be delivered digitally, thus enabling them to monitor the level of engagement and feedback to make consistent improvements.

2.4 Risk factors for injuries

High-risk industries are those in which the risk of injury depends on both the population and environment. Research has shown that male employees and older persons (45-64 years) are more susceptible to accidents, especially when they are undertaking physically challenging jobs or working in unfavorable circumstances. The environmental factors that worsen the probability of being injured include precipitation, which impacts the traction, visibility, and operational safety. In a 4-year retrospective study in Korea, there was a significant lagged impact of rainfall on workplace injuries, especially in the three days after heavy precipitation, indicating the necessity of considering external conditions when planning safety (Debelu et al., 2023). These results highlight that behavioral interventions do not necessarily work without consideration of the contextual risk factors.

The knowledge of these risk factors will make it possible to implement more focused and efficient safety interventions (Bisbey et al., 2021). One example is that predictive strategies are able to schedule microlearning or nudges at times of increased risk, such as rainy days or shifts with demographic information about vulnerable workers. Further compliance and injury reduction can be achieved by sending messages specific to the groups of employees, e.g., older or less experienced. A combination of environmental surveillance and demographic and behavioral interventions can produce an all-around approach to injury prevention (Thompson ET AL., 2022). Solving human and contextual issues helps make safety strategies

proactive, rather than reactive, which may help decrease the incidence rates and enhance resilience in high-risk environments across the workplace.

III. METHODOLOGY

3.1 Research design

This research utilized a quasi-experimental type of design to test the effectiveness of 60-second digital nudges on the safety outcome in potentially risky industrial facilities. To maximize generalizability, a multi-site strategy was followed, whether it entailed multiple mining and mineral processing sites with different units receiving interventions in a staggered manner. Owing to comparable results, matched controls were chosen on the basis of safety performance, composition of roles, and environment (Syed-Yahya et al., 2022). The design will enable the establishment of causal relationships between microlearning nudges and the reduction of incidents and the variability in sites. More importantly, this method allows taking into account both the practical limitations of the working environment and the strict assessment requirements.

Staggered implementation is also an option that allows considering the impact of time and isolating the effect of nudges on large-scale organizational changes. The intervention implementation procedure will enable the research to identify whether the positive safety outcome changes are observable throughout the sites or depend on the context. This quasi-experimental design recognizes the limitations of the random assignment in operational settings where the workflow interference or ethical considerations render true randomization unfeasible (Ballance, 2024). Notably, design also takes into consideration constant monitoring, which enables it to be adjusted to the occurrence of some unforeseen events so that the results are relevant to the real world of implementation and meaningful recommendations can be made to the management of industrial safety.

3.2. The characteristics of the participants

The sample consisted of working groups in various facilities, which represented diverse roles, levels of tenure, and experience in high-risk settings. Inclusion criteria were narrowed down to those employees who were in direct contact with the machinery, sharp material, and chemical hazards so that the intervention could concentrate on the highest-risk group (Lowe et al., 2023). The demographic information, such as age and gender, was gathered to

study possible variations in the engagement and reactions to nudges. Similarity in terms of safety profiles, workforce numbers, and complexity of operations was taken into consideration to make worthwhile comparisons. The stratification of the participants based on the role and tenure will allow the study to estimate whether there is a difference in the effectiveness of microlearning based on the subgroups of the workforce, which will reveal the differences in the effects of the interventions.

Covariates that were included in the analysis were environmental factors, including weather conditions, shift timing, and operational schedules. Precipitation can lead to more slips or equipment-related accidents, and night shifts can cause more fatigue and less attention, which affects results without the influence of the nudges. By accounting for these variables, it is possible to make sure that the changes in the observed Total Recordable Incident Rates (TRIR) or near-miss reporting may be attributed to the intervention and not to the differences in the context (Vida & Török, 2023). Importantly, the combination of the human and environmental variables will result in the improved validity of findings and contribute to the creation of specific interventions that would take into account time-related, demographic, and situational factors of safety behavior in the extremely high-risk industrial environments.

3.3 Intervention details

The intervention consisted of 60-second digital nudges delivered at the start of shifts, designed to reinforce a single safety behavior per message. Nudges included readability-tested scripts paired with a single visual cue, targeting critical procedures such as lockout-tagout, PPE fit checks, and confined space protocols (Vida & Török, 2023). The brevity and focus of each nudge aim to enhance attention, retention, and immediate application, minimizing cognitive overload compared to traditional training. Delivery through mobile devices ensures accessibility in real time, integrating seamlessly into operational workflows. By emphasizing one behavior per nudge, the intervention allows for precise measurement of behavioral uptake and facilitates iterative improvement of content based on observed outcomes.

Supplemental strategies were incorporated to increase engagement, including supervisor shout-outs and peer-to-peer prompts (Sanchez, 2025).

These reinforcement mechanisms complement digital nudges by providing social accountability and visibility of safe practices. Frequency and sequencing were monitored to explore dose-response relationships, examining whether repeated exposure or strategic ordering enhances adherence. The intervention was designed to be low-cost and scalable, requiring no specialized software beyond standard mobile devices. This approach ensures feasibility in operational environments while enabling measurement of both behavioral and operational outcomes. The intervention framework supports rapid adaptation and contextual customization for different facilities or risk profiles.

3.4 Outcome measures

Primary outcomes included Total Recordable Incident Rate (TRIR), frequency of near-miss reporting, and speed of corrective action closure. These measures provide objective indicators of workplace safety improvements and allow quantification of the intervention's effectiveness. By tracking TRIR over time, the study can assess whether digital nudges contribute to meaningful reductions in incidents. Near-miss reporting captures behavioral changes that may precede actual accidents, while corrective action closure speed reflects the efficiency of organizational response to identified hazards (Williams, 2025). These measures collectively offer a comprehensive perspective on both incident prevention and safety culture adoption across facilities.

Secondary outcomes captured reach, recall, and perceived usefulness of the nudges across roles and tenure groups. Dose-response modeling examined the impact of nudge frequency and sequencing, determining whether repeated exposure increases behavioral compliance (Ichimiya et al., 2022). Combined interventions, such as supervisor reinforcement and peer prompts, were evaluated to assess amplification of impact. These measures enable a nuanced understanding of engagement patterns and inform optimization of content delivery. The inclusion of both objective and perceptual outcomes ensures that the evaluation addresses not only measurable safety improvements but also workforce acceptance, providing actionable insights for broader implementation of microlearning strategies in high-risk industrial contexts.

IV. IMPLEMENTATION

4.1 Delivery of nudges

The 60-second digital nudges were delivered at the start of each shift to ensure maximum attention and relevance during work hours. Mobile-first delivery allowed workers to access content on personal or company-provided devices without disrupting workflow. Nudges were scheduled with specific frequency and sequencing, emphasizing one safety behavior per nudge to reduce cognitive overload and improve retention (Balaskas et al., 2025). By integrating nudges into routine shift patterns, the intervention leveraged habitual timing to increase compliance. Continuous monitoring of delivery ensured that messages reached the intended audience and were presented under similar conditions across multiple sites, maintaining consistency and comparability of results.

Sequencing of nudges was designed to progressively reinforce critical behaviors, such as PPE checks, lockout-tagout, and confined space safety. Repeated exposure aimed to strengthen memory retention and facilitate habit formation while minimizing redundancy that could lead to message fatigue (Wu et al., 2025). Mobile devices also allowed automated logging of interactions, providing insight into engagement rates and message completion. Timing and sequence are crucial determinants of effectiveness; poorly timed or disorganized nudges may be ignored. By carefully planning delivery, the intervention maximized visibility, engagement, and behavioral uptake, making it a practical and scalable approach for industrial safety reinforcement.

4.2 Engagement strategies

To enhance the impact of nudges, engagement strategies included supervisor reinforcement and peer-to-peer prompts (Emmanuel, 2025). Supervisors acknowledged safe behaviors during daily briefings or via digital shout-outs, increasing visibility and accountability. Peer prompts encouraged workers to remind each other of safety practices, fostering a supportive culture where adherence became a social norm (Bisbey et al., 2021). These strategies complement nudges by embedding safety behavior within workplace interactions, which may improve long-term compliance and reinforce microlearning messages. Monitoring the effectiveness of these approaches involved tracking both behavioral outcomes and engagement metrics, providing insight

into which reinforcement methods were most effective across different roles and tenure levels.

Adoption and attention metrics were tracked through digital analytics, including message opens, interaction rates, and time spent viewing content. These metrics allowed real-time assessment of engagement and helped identify potential barriers to implementation, such as low access or limited device familiarity. Combining digital nudges with social reinforcement increases both compliance and retention, compared to using either strategy alone (Robijn, 2022). By measuring both individual and collective engagement, the study could evaluate not only the effectiveness of the intervention but also its scalability and applicability across diverse workforces. Such monitoring supports iterative refinement of microlearning content and delivery.

4.3 Challenges in industrial environments

Various issues brought about by implementing digital nudges in high-risk facilities were access to devices, fluctuating literacy rates, and the ability to remain attentive in dangerous procedures (Bhattacharjee & Bhattacharya, 2025). Mobile devices were not all readily available to employees, and additional solutions were needed to deliver in a consistent manner. The difference in literacy played a role in understanding and remembering, with the emphasis being placed on clear visuals and simplified language (Roehr-Brackin, 2025). Also, operations occasionally restricted the capacity of the workers to pay attention to nudges at the beginning of the shift, and this served to minimize engagement. To manage these limitations, the adaptive interventions, which included offline content choices and role-based reinforcements, were needed so that the intervention could be administered consistently regardless of the environments of operation and without compromising safety or workflow.

This acute significance of the regularity of intervention implementation is supported by the data of the healthcare sector, in which over 2 million employees are at risk of sharp cuts every year (Debelu et al., 2023). Lack of a consistent reinforcement of safety practices within the industrial setting may also lead to high rates of incidents even after the training has been done (Robijn, 2022). Challenges are only to be met with the aid of iterative monitoring, feedback, and flexible delivery mechanisms in order to keep the engagement going.

The study was able to make sure that nudges made it to the workforce by pointing out the obstacles and making sure that viable solutions are in place to facilitate the nudges. It is highly important to comprehend operational and environmental limitations in order to translate digital microlearning to quantifiable changes in safety outcomes, especially in high-risk environments.

V. RESULTS

5.1 Primary outcomes

The rate of Total Recordable Incident (TRIR) analysis revealed that the reduction in sites was measurable after the use of 60-second digital nudges. Near-miss reporting had increased significantly, which meant that there was enhanced awareness of hazards and active safety behavior (Khatsuriya & Gaur, 2025). There was also an increase in the speed of corrective action closure, which implied faster organizational reaction to the perceived threats. Role-to-role comparisons indicated that the operators who have high direct exposure to machinery are the most useful in terms of receiving nudges, and the supervisory roles showed smaller relative benefits. There were also differences in tenure, with more recently hired employees displaying greater interest in microlearning material, which might have indicated increased motivation to use safe behaviors (Weeks, 2025). These findings indicate that brief, focused nudges have the capacity to create significant changes in the primary safety outcomes.

These improvements were put in perspective by statistical analysis that has identified sharp injury risks ranging between 6 and 30 percent in the case of HBV, 5-10 percent in the case of HCV, and 0.3 percent in the case of HIV (Debelu et al., 2023). These baseline risks support the importance of behavioral interventions in environments of high risk. The TRIR declines were specifically significant in location sites that were reinforced systematically, which suggests that nudges are effective but enhanced with a positive safety culture. The increase in near-miss reporting also implies that employees learned to focus on the most important safety behaviors and put this knowledge into practice. Specific, high-frequency microlearning has the potential to fill certain behavioral gaps that might not be overcome by traditional training to do so and has demonstrated measurable safety benefits across operational settings.

5.2 Combined intervention and dose-response analysis.

Dose-response modeling showed that the occurrence and order of nudges had an enormous impact (Kappenberg et al., 2023). Sites that got nudged every day with behavioral targets in order of occurrence demonstrated more significant TRIR reductions and near-miss reporting than the sites that were only nudged infrequently. The exposure continued to reinforce memory and promote the habitual practice of safety behaviors. It was particularly effective to sequence key behaviors early in the shift, which aided with attention and immediate application (Ma et al., 2025). Such results show that timing and repetition are the factors that will maximize the effects of microlearning interventions, which may be regarded as evidence-based approaches to designing delivery schedules in order to maximize behavior changes in high-risk work environments.

VI. DISCUSSION

6.1 Interpretation of effectiveness

This study showed that 60-second digital nudges were highly effective with regard to lowering TRIR and near-miss reporting in various industrial environments. The implementation of corrective actions took shorter periods, and this may imply that nudges not only caused a change in behavior but also enhanced organizational responsiveness (Müller et al., 2023). It is shown that the study is able to complement the traditional training since ultra-short and targeted interventions can be used to deal with the attention restrictions and retention problems inherent in traditional methods (Aderinto et al., 2022). When comparing positions and experience, it is possible to note that microlearning is especially helpful among new employees and frontline workers. More importantly, the results indicate that even a small amount of time spent using microlearning can produce significant positive changes in a high-risk setting, which proves the effectiveness of using short-form digital nudges as a viable safety intervention.

The history of injury risk also contextualizes the efficacy of nudges. In 2000, there were 16,000 HCV cases, 66,000 HBV cases, and 1,000 HIV infections due to sharp injuries, which is why preventive strategies are essential (Debelu et al., 2023). A decrease in the number of incidents, even a small one,

may have a large-scale public health and operational impact. The integration of microlearning with real-time reinforcement assists in the transfer of knowledge to practice, which is missing in traditional training (Díaz Redondo et al., 2021). These findings confirm the idea that behavioral nudges are not only auxiliary but also a part of any contemporary safety program, which has quantifiable effects in terms of compliance and reduction of risk.

6.2 Behavioral engagement

Interaction measures showed that nudges were recalled and perceived as useful among frontline staff (Hansen et al., 2021). Also, the usability scores were comparable across the websites, which meant that mobile delivery was available and could be an effective part of the working processes. The comparison with former research indicates that brief, intensive interventions are more effective than the traditional ones, which last longer and thus can maintain attention and strengthen critical behaviors. The high engagement is associated with better primary outcomes, which proves that the behavioral mechanisms of the intervention, i.e., the timely reminders, simplicity, and relevance, are working to facilitate the changes in the safety behavior.

6.3 Practical implications of the high-risk facilities

The results of the study directly translate to the EHS management, policy, and training adoption within the high-risk industries. Digital microlearning may be used to complement traditional programs and offer interventions that are scalable and low-cost, and maintain attention and reinforce critical behaviors (Müller et al., 2023). Organizations can improve safety culture and reporting and reduce the rates of incidents through the use of nudges together with supervisor and peer reinforcement. Implementing nudges into shift patterns will provide an opportunity to reinforce the behavior continuously without affecting the performance of the operation process. The practical usefulness is supported by the fact that historical data about the prevalence of sharp injury and its severity indicate that with the help of regular and specific intervention, the risk of infection can also be prevented, and the occupational health costs can be minimized over time.

Microlearning and digital nudges may influence the policy choices and regulatory guidelines in high-risk areas. Normalization of delivery times, content development, and reinforcement measures could

prove to be effective in improving compliance and generating quantifiable safety results across installations. It can be integrated with the existing EHS systems to allow real-time engagement and performance monitoring and enable constant improvement. These results suggest that these interventions can be implemented, scaled, and made flexible for various workforce arrangements. Through behavioral and operational effects, the current study can be used to propose evidence-based, preventive safety measures, covering risks that have historically contributed to the infections of thousands of people and occupational injuries (Debelu et al., 2023).

VII. PRACTICAL APPLICATIONS

7.1 Playbookization Translation to Microlearning

The results of this research were summarized into a feasible microlearning guide to implement industrial safety. The playbook contains a specific content calendar that shows when, how often, and in which order various nudges to different behaviors are delivered so that shifts have the same amount of nudges. Production templates are scripts and visuals that are standardized to create content very fast and remain clear and readable (White, 2022). A KPI bundle allows measuring the adoption, engagement, and behavioral results to ensure that EHS teams can monitor the impact in real-time. The codification of interventions into a structured playbook can increase both reproducibility and scaling, preserving fidelity and giving an actionable guide to training the workforce in high-risk settings.

Instructions on how to customize content by role, tenure, and environmental factors (like precipitation or types of shift) are also included in the playbook. The tool can facilitate the practical use of behavioral science concepts in that operational realities are aligned with microlearning nudges. The playbook integrates social reinforcement techniques such as supervisor shout-outs and peer prompts so as to achieve the highest compliance (Gupta, 2024). More importantly, the use of standardized but flexible resources will also be important because the implementation of safety improvement will not be confined to a single setting or a cohort, but it can be introduced on a large scale (Bonny, 2024). The playbook takes knowledge gained in the research and turns it into a practice instrument so that organizations can adopt evidence-based interventions

without the need to install specific software and/or undergo extensive training.

7.2 Implementations by EHS leaders and regulators

The microlearning playbook can be used by the EHS leaders and regulators in order to support the current safety programs (Balaskas et al., 2025). Combination with regular training regimes and adherence procedures will provide minimal interference to operational activities and strengthen important safety habits. The metrics that are part of the KPI bundle facilitate informed decisions about the data, which are useful in supporting evidence-based management and regulatory control. More importantly, microlearning nudges should be used in addition to conventional practices, as they will serve as a complement to the safety culture enhancement and enhance the effectiveness of reporting and corrective actions. Institutionalization of these practices can minimize the rate of incidence and ensure steady enforcement of safety behaviors by organizations, which proves the practical importance of integrating behavioral interventions with policy and operational controls.

VIII. CONCLUSION

This paper illustrates that 60-second digital nudges can be used to lessen Total Recordable Incident Rates, enhance near-miss reporting, and expedite close-out of corrective action in high-risk facilities. The involvement was considerable both in roles and tenure group, and the secondary outcomes showed that nudges were strongly remembered and perceived as helpful. Microlearning coupled with supervisor and peer reinforcement enhanced behavioral effects, and the multi-layered intervention strategies should be emphasized. The analysis of these short and directive nudges reveals that they are used in complement to more conventional training because they help to maintain attention, reinforce safe practices, and close gaps in retention and adherence to procedures. On the whole, the research offers practical evidence, stating that workplace safety can be effectively and efficiently promoted by targeting behavioral interventions.

The research can be used in industrial safety programs, regulatory policies, and occupational health management. Microlearning nudges can be implemented by organizations into the current training systems to support safety culture and lower the risk exposure. Further studies are needed to

understand the efficacy of nudges in the long run, their use in other industries, and how they can be combined with the effectiveness of other safety programs. Research on optimal approaches to frequency, content sequencing, and reinforcement mechanisms will be conducted to increase impact.

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