



Original Article

Promoting the Quarry Workers' Hazard Identification Through Formal and Informal Safety Training

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ABSTRACT

Background: The surface mining industry has one of the highest fatality rates among private industries in the United States. Despite recent decreases in the fatality rates of comparable industries, the fatality rate in the surface mining industry has increased. Meanwhile, a lack of safety research in surface mining has hindered efforts to improve safety strategies in the surface mining workplace.

Method: This study examined quarry workers' hazard identification skills by conducting a case study of a surface mining facility in the Mid-Atlantic region of the United States. Semistructured interviews were conducted with eight quarry workers who were employed at the mine facility. In addition to the interviews, data were collected through field notes, notes from an expert meeting with safety managers, and site photographs to explore quarry workers' safety behaviors in the workplace.

Results: The results showed that quarry workers identified hazards and improved their safety performance by translating safety knowledge learned from training into practice, acquiring hands-on work experience, learning from coworkers, and sharing responsibilities among team members.

Conclusion: This study contributes to understanding quarry workers' safe performance beyond what they have learned in safety training to include their interaction with other workers and hand-on experience in the workplace. This study informs practitioners in the surface mining industry to build a safe work environment as they design effective safety programs for employees.

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1. Introduction

Despite efforts to reduce occupational injuries in the surface-mining industry, the rate of fatalities increased from 10.0% to 15.5% per 100,000 workers in 2017 in the United States [1]. According to the US National Institute for Occupational Safety and Health [2], the surface mining industry recorded 242 fatalities and 36,172 nonfatal work injuries in the United States from 2008 to 2018. A review of fatal accidents in US surface mining industry by Mine Safety and Health Administration (MSHA) indicated that most surface mining accidents occurred when workers were operating quarry equipment and machines [3–6]. Statistics show that the greatest number of fatalities is caused by powered haulage (31.4%), machinery (23.5%); falling, rolling, or sliding rock or material (12.8%); and electrocution (4.5%). These data indicate the importance of tailoring safety programs to these types of equipment and operations.

Identifying risks associated with the equipment and accessing workers' hazard identification/prevention skills are important for managers to fully address potential hazards in safety programs. As stated by Occupational Safety and Health Administration, safety training and education aim at improving workers' and managers' awareness of work hazards and developing their full participation in the process of eliminating hazards before an accident occurs [7]. The goal of safety training in the surface mining industry is to equip quarry workers and managers with skills and knowledge to perform quarry-related operations safely by covering different types of hazards that quarry workers may face in the workplace. The activities of safety programs may include formal classroom training, safety inspection, peer-to-peer training, and worksite demonstration [7].

However, safety training can be too broad and vague [8,9]. Although the MSHA inspects mine sites regularly, the teaching materials for the safety training they bring to a site will not always be helpful, as only a portion of the work hazards addressed in safety

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training may be found in a particular workplace. Especially when a dynamic, complex work environment hampers workers' adequate awareness of work hazards, it is possible that multiple work hazards simultaneously hinder workers from employing safety knowledge and skills learned in safety training [10]. Therefore, increased emphasis on work hazards specific to each work environment could improve workers' hazard identification skills through safety training.

To increase workers' awareness of hazards, scholars have suggested implementing specialized safety training [11–13]. Their studies allude to the importance of understanding factors that cause workers' unsafe performance and the environmental challenges in making safe decisions. To explore these factors and challenges, it can be useful for safety management to understand workers' perceptions of safety and experiences in the workplace [14,15]. Safety management administrators self-assessments of safety activities and evaluations performed at the work site by quantifying some of the factors that can directly and indirectly promote a safer work environment as a corporate value [16].

In addition to management's role in providing safety training, prior work has suggested that workers' commitment to safety improves safety in the workplace [17–19]. Owing to the nature of their duties on-the-job (e.g., hands-on activities, frontline tasks), workers experience a higher chance of accidents when not supervised and left to their own judgment to make important decisions regarding safety. As a result, workers must make independent decisions in the workplace by using the information gained through education and training [20]. This statement pinpoints the responsibility of frontline workers who must use their knowledge and skills to identify and interpret work hazards. Recent studies emphasized the need for shared safety responsibility in which the workers are empowered with the knowledge and authority to promote organizational safety [21–23]. By bolstering workers' involvement, organizational safety is perceived as a priority and responsibility shared among all members of the workplace. Therefore, further research is needed to investigate how workers perceive work hazards and employ strategies to prevent accidents in the workplace.

Motivated by the increasing fatality rate and need to improve quarry safety, this study explored workers' hazard identification skills in the operation of three common pieces of equipment (i.e., hydraulic excavator, blade saw, breaker) to better understand surface miners' hazard perceptions and prevention skills in the workplace. Although previous studies have investigated and developed safety management controls to enhance workers' safety behavior by providing safety training [6,24], little is known about how workers use the skills learned in the training. This study will help practitioners to understand workers' hazard identification skills and the tools and experiences they draw on to develop those skills. This approach will be particularly useful for companies to encourage the involvement and participation of workers in safety. This study explored quarry workers' perceptions of work hazards to help companies improve safety programs in their workplace.

2. Methods

This research used a case study methodology to address the following research questions: 1) What work hazards do quarry workers identify in their workplace? 2) How do quarry workers identify work hazards in their workplace?

2.1. Case study

To explore these research questions, this study used an inductive, qualitative methodology with a single, descriptive case study. A single, descriptive case study is helpful for researchers to fully address the research context and observe implicit dynamics and interactions [25]. This study used interview transcripts as the primary data source and incorporated data from other sources including field notes, notes from an expert meeting with safety managers, and site photographs. The multiple sources of data were used to support the emergent findings from the interview responses and to fully understand the worker interactions and daily operations at the quarry site [25].

2.2. Case description

The case was a surface mining organization of a corporate entity in the Mid-Atlantic region of the United States. The quarry was located near a residential area but surrounded by dense forest. About 16 workers were onsite at a time to meet daily production goals and each individual worked in teams. The three main operations involved running a hydraulic excavator, a breaker, and two saws. Although the hydraulic excavator and two saws required specialized operators to run the machine, each operation involved, at least, an assistant quarry worker to work in teams, watch for blind spots, and improve safety. All quarry workers were capable of working on the breaker.

The researcher recruited eight participants who volunteered to participate in the study. Participants represented a range of length of employment. Four participants had been working for 0-5 years (one participant was a new hire when the research was conducted), two had 10-15 years at the company, and the other two had been with the company for more than 20 years. Seven participants were male and one was female. Six participants identified as quarry workers with some describing their specialized role as stone mason and saw operator. Two identified themselves as supervisors and managed the rest of the quarry workers under the leadership of the site coordinator (who was not a participant in this study).

The researcher observed that safety was prioritized by the top management. When the researcher sought to receive consent to participate in study from the facility, the executive board, including the vice president, safety managers, supervisor, and human resource manager, showed willingness and interest to participate in the study because they believed that the findings of this study could help improve the safety of the quarry workers. For example, the data collection for this study was conducted in summer which is the busiest season of the year for the facility. Owing to several rainy days, it might have been challenging for the facility to meet the production goals while participating in the research. However, their support for the researcher's data collection, such as field observation, an expert meeting, and interviews with quarry workers, alluded to their prioritization of safety in the workplace. As a result, the researcher was able to obtain data from multiple sources at the facility.

2.3. Company-provided safety training

The researcher arranged an expert meeting with two safety managers and one site coordinator to have a better understanding of work hazards at the quarry and various types of safety training quarry workers received from the company. It was found that quarry workers received several safety-related trainings provided

by the company. MSHA inspectors visited and examined the quarry at least twice a year. In addition, new hires were provided with field training where they observed experienced workers operate the machines used on site. Safety managers, including the site coordinator and supervisors, provided a refresher course, which is an eight-hour classroom training once a year for all workers. Plus, each quarry worker was required to take an individual computer-based safety training provided by Environment, Health, and Safety Services in the quarry. As a result of these ongoing trainings, safety managers believed that the quarry workers had acquired the knowledge necessary to identify all workplace hazards.

2.3.1. Data collection

In the data collection phase, the researcher took 50 photographs of different operations during two separate site visits before the participant interviews. This procedure was taken as part of the photo elicitation method [26]. Photo elicitation helps both the researcher and participants to better communicate the perceptions and experiences in the workplace by using photographs. In the expert meeting, the researcher and the safety managers at the quarry selected three photos (Figs. 1–3) and identified and verified different types of hazards in each photo. The notes taken during the meeting were used to compare the hazards identified by the managers with the responses in the participant interviews.

A semistructured interview was conducted with each quarry worker to explore individual experiences and perceptions of safety in the workplace. Each interview was about-an-hour long and audio-recorded for data analysis. The researcher asked a series of questions relating to their general perception of workplace safety, such as “What do you think is most important in your workplace?” or “how do you think safety is prioritized in the workplace?” To understand their ability to identify work hazards, the researcher used photos to help participants reflect on work experiences. Questions used in photo elicitation phase included “Describe any potential hazard you see in the photo.”

Fig. 1 illustrates a quarry operation using a hydraulic excavator. This operation required two quarry workers where an operator runs the machine and another operator watches for the cracks and seams on the rock.

The blade saw in the quarry did not require operators to run it because it was automated with button controls, as shown in Fig. 2. While the other two operations captured in the photographs (the hydraulic excavator and breaker) needed operators on site to run and control the machines, the blade saw was remotely operated

from a secure saw room locked by authorized personnel, such as the site supervisors and coordinator.

The breaker, as shown on Fig. 3, is operated by more than two workers and requires teamwork and cautiousness to safely break and cut rock.

Interviews were divided into four phases: opening phase (perception-focused), eliciting phase (photo-focused), closing phase (experience-focused), and demographic survey. In the opening phase of the interview, participants were asked about general perceptions of safety to grasp a broad understanding of the perceived value of safety in the workplace. During the eliciting phase, the researcher showed three photos of the workplace to each participant. The photos were provided in the same order to each participant and the next photo was shown when the participant indicated that they found all hazards in the current photo. The eliciting phase helped participants to reflect and share their experiences and thoughts about the photos. The closing phase included interview questions about participants' experiences with accidents in the workplace and about their most memorable safety training. These questions were asked to understand the contextual variables (e.g., history of accident) that may have influenced their safety perceptions and behaviors. The demographic survey was distributed to participants at the



Fig. 2. Blade saw.



Fig. 1. Hydraulic excavator.



Fig. 3. Breaker.

end of the interview to obtain their cultural backgrounds and experiences in the workplace.

2.4. Data analysis

For data analysis, the researcher coded all the hazards identified by the safety managers and participants to answer the first research question. *A priori* codes included the work hazards identified by the safety managers in the expert meeting and emergent codes were identified by the participants during the interviews.

For the second research question, the participants' responses were inductively analyzed to develop and categorize emergent codes [27]. Ten emergent codes were clustered together based on shared attributes and meanings to generate themes. From this process, four themes were generated. To increase the transferability and validity of the data, the researcher used two validity strategies suggested by Creswell JW and Creswell JD [27]: triangulation of data and peer debriefing. Different sources of data were examined to develop the findings into coherent themes (i.e., triangulation of data) and the researcher checked the emergent codes and themes with a second researcher throughout the study (i.e., peer debriefing).

3. Results

3.1. RQ1: Work hazards identified by the participants

To answer research question 1, the participants identified different types of hazards in each photo taken by the researcher and examined by the safety managers and site coordinator. These photographs were composed of different work such as operating a hydraulic excavator (Fig. 1), blade saw (Fig. 2), and breaker (Fig. 3). All participants had experience in working on each of the three operations. Emergent hazards were identified by the participants

Table 1
Types of hazards in Fig. 1 identified by participants

Types of hazards	P1	P2	P3	P4	P5	P6	P7	P8	Total
Blast from an air hose*	0	0	0	0	0	0	0	0	7
Fall from a ledge		0	0	0	0		0	0	6
Machine slipping	0		0	0	0	0			5
Blast from a hydraulic line*		0	0	0	0				4
Tripping over pallets*				0			0		2
Dust						0		0	2
Noise									0
Total	2	3	4	5	4	3	2	3	

* An asterisk (*) indicates a hazard identified by the workers and not the safety managers.

Table 2
Types of hazard in Fig. 2 identified by participants

Types of hazards	P1	P2	P3	P4	P5	P6	P7	P8	Total
Saw segment projectiles	0	0		0	0	0	0		6
Slipping on the floor	0	0	0	0	0		0		6
Noise			0	0				0	4
Dust	0			0				0	3
Tripping over a water hose	0		0		0				3
Flyrock		0			0			0	3
Weather	0			0			0		3
Shock from an electric line					0				1
Total	6	3	3	5	5	1	3	3	

through their daily experience at the operation, as shown on Tables 1–3 below.

3.1.1. Hydraulic excavator

Detailed information on types of hazards identified by the quarry workers is presented in Table 1. As an example, Participant 1 (P1) identified the machine slipping and the blast from an air hose in Fig. 1. The number of hazards each participant identified is shown in the bottom row next to "Total." The number of participants, five, who identified the machine slipping as a hazard is shown in the left column under "Total."

In addition to the hazards identified in the expert meeting, participants identified three more hazards in Fig. 1. Participants recognized not only the hazards specifically related to the machine (i.e., a blast from an air hose as a hazard and a blast from hydraulic lines) but also the hazards experienced in the workplace, such as two participants noted tripping over pallets. These worker-identified hazards are marked with an asterisk (*) and shown in Table 1.

3.1.2. Blade saw

Because the quarry workers were restricted from entering the saw room, participants identified hazards they saw when they cleaned the saw room for maintenance every day. Their description of hazards was supported by their observations (e.g., trail of a saw segment on the wall/rooftop) while cleaning the saw and the floor. A total of eight hazards were identified by participants in Fig. 2, and there were no emergent hazards in addition to those identified by safety managers.

3.1.3. Breaker

Fig. 3 received the most attention from interview participants and motivated them to fully describe their lived experience with the breaker. One participant expressed particular excitement, describing Fig. 3 as "the famous breaker." In this portion of the interview, the researcher also observed that most participants leaned toward the table and observed the photo, which might also indicate their familiarity with, and greater knowledge of, this operation. As the breaker requires hands-on operation, the quarry workers were highly exposed to a number of hazards as identified by the safety managers and presented Table 3.

3.2. RQ2: Quarry workers' approaches to identify the work hazards

Thematic analysis of the transcripts revealed that participants identified work hazards using four approaches: 1) recalling knowledge learned in safety trainings; 2) acquiring hands-on, personal experience with quarry-related operations; 3) learning from coworkers; and 4) sharing safety responsibilities among team

Table 3
Types of hazards in Fig. 3 identified by participants

Types of hazards	P1	P2	P3	P4	P5	P6	P7	P8	Total
Flyrock	0	0	0	0	0	0	0	0	8
Dust	0	0	0	0	0	0	0	0	8
Pinch by the breaker	0	0	0	0	0	0	0	0	8
Full bucket of trash rocks*	0	0	0	0	0	0	0	0	8
Hydraulic line leak		0	0	0	0	0			5
Noise	0			0				0	3
Shock from an electric line				0		0		0	3
Repetitive posture								0	1
Total	5	5	5	7	5	6	4	7	

* An asterisk (*) indicates a hazard identified by the workers and not the safety managers.

members. Although fundamental safety knowledge was primarily obtained through safety training, the participants described that they continuously reminded themselves of the work hazards in day-to-day operations.

3.2.1. Recalling knowledge learned in safety trainings

The quarry workers realized the importance of taking a refresher course every year and regularly applying what they learned in their work. Safety trainings updated them with new information and reminded them of work hazards they might have forgotten. One participant recalled a video from a safety training and described how drastically it changed his perception of dust hazards, stating that, "The dust and stuff that we have up there, it actually opened my eyes, too. I didn't think it was nothing ..." Then, the participant recalled a scene in the video, stating that, "there was a bunch of people died from it because there wasn't any ventilation in the tunnels ... and that actually opened everybody's eyes to silicosis and the issue that it is." The participant became more cautious and aware of the dust hazard due to the video provided during the safety training. Participants' hazard identification skills could be enhanced by translating the information learned in training into their workplace.

3.2.2. Acquiring hands-on, personal experiences with hazards

Participants identified work hazards by using their past personal experiences and observations. For example, one participant shared an experience of getting hit by the air hose, stating that, "I've seen air hoses bust and I've actually been hit by air hoses that something fell on it and it busted. It will just beat you. You can't get away from it." Participants indicated that a high-pressure blast could make the hose hazardous. Participant also used experience to identify the other hazards related to operating the saw and breaker. For instance, one participant emphasized the possibility of getting injured by a projectile from the saw segment, stating that, "I mean, if it hits a rock wrong, if it hits a really hard spot and breaks, the wheels are not good on it, then there's a chance it can come off." Participants expressed extraordinary caution when discussing these projectiles. Participants also identified work hazards by reflecting on their work experience on the breaker. For example, one participant identified an ergonomic hazard on the breaker due to repetitive posture that they personally experienced. One participant stated, "I mean, you can strain your back too. Hurt yourself with your muscles and all that." Quarry workers identified hazards by having hands-on experience and reflecting on their experiences in the workplace.

3.2.3. Learning from coworkers

This study found that the quarry workers also learned to identify hazards through their interactions with coworkers (e.g., listening to and witnessing others' critical incidents). For example, one participant explained that sharing one's story helps other workers to be cautious stating, "I'll show them things that have happened to me. Cuts, breaks, just things that previously happened ... The biggest thing is telling them and showing them things that have happened." Although such experiences could have discouraged the individual from working at the quarry, they instead shared their experiences with coworkers to empower them to be more preventative and cautious. During one interview, a quarry worker showed a scar from the breaker and explained that workers show scars from the operation to remind others of work hazards. They believed their sharing of critical moments encouraged coworkers to watch out for the work hazards in the operation. New hires particularly demonstrated benefits that they gained by observing experienced workers. Unlike safety instructions and guidelines provided in text or

video, this type of on-the-job training allowed new workers to learn by observing their coworkers.

3.2.4. Sharing responsibility among coworkers

Participants demonstrated that part of their approach to identifying hazards involves working in teams, with this collective approach allowing them to share the responsibility for safety. Participants' responses related to safe performance through teamwork were mostly captured in the operations on the breaker, which requires at least three members to adequately and safely run the machine. Participants emphasized the importance of communicating with team members while on the breaker stating, "Communicating and caution, all that stuff. It's what makes it [safe]." In addition to communication, participants responded that working as a team by being vigilant as other workers completed quarry operations also helped them to identify hazards. One participant explained that watching as others performed work tasks helped to ensure safety by looking for unintentionally overlooked hazards in the operation, stating, "there [is] everybody paying attention and knowing what they're supposed to do and actually doing what they're supposed to do." Furthermore, the participants implicitly demonstrated a trusting relationship among the coworkers as a way to build a safe work environment. One participant described that, "In my head, most people just have to act as a team and you don't have to be best buddies with everybody but care about each other and not doing something that may hurt somebody else ..." Quarry workers cared for coworkers' safety and their mindfulness influenced their behaviors toward safe work performance.

4. Discussion

This study found that quarry workers recalled knowledge learned in safety trainings, used their personal experiences with quarry operations, learned from observing coworkers, and adopted a team approach to share safety responsibilities to recognize hazards at the operations. These findings suggest that facilitating a safer work environment needs a proactive attitude among employees [9]. Surface mining companies can foster a safer work environment by supporting and engaging workers.

4.1. Importance of gaining safety knowledge and work experience

It is essential that quarry workers are equipped with fundamental knowledge of the hazards through safety training [8]. In this study, quarry workers learned safety knowledge through formal and informal opportunities provided by safety training (i.e., formal classroom training, MSHA inspection, and informal hands-on training). Safety training should capture employees' perspectives and be tailored to the specific work environment. This study found that the quarry workers identified additional hazards that the managers did not immediately recognize in the expert meeting. It may be understood that safety managers overlooked hazards due to a shortage of time or were not as motivated as quarry workers to identify every single hazard in the photos. However, this finding still highlights the importance of integrating worker experience into safety training. As safety managers may have blind spots in the workplace, workers' intimate experience and awareness of the workplace at each operation can assist managers with designing safety trainings that are more relevant to and helpful for their safety concerns. Designing a safety training with workers aligns with Cooper's claim [28] that safety controls are not enacted *at* people, but *with* people. While an organization's safety systems can be designed and established by an employer, employees' compliance with safety

protocols can increase safety-system effectiveness. Therefore, both employers' and employees' commitment to, and involvement in, safety are fundamental in preventing work accidents and promoting safer work environments.

4.2. Importance of learning from coworkers and teamwork

The quarry workers learned from others and shared responsibilities for safety. The data indicated that learning to identify hazards includes a social aspect; it's not just an individual activity. Participants said they learn from others and benefit from teamwork, communication, and trust-building. This finding implies that learning is not just about building safety knowledge and obtaining technical information, but also carrying out socioemotional aspects that come from working with others. Such behaviors were observed in this study as workers watched for each other's operation, shared their own experience with new workers, and expressed concern for others' safety, which alludes to workers' execution of safety leadership. Cooper [28] defined *safety leadership* as a process that aspires for the team to prioritize safety and elicit the team members to put in discretionary efforts beyond the requirement. While leadership is commonly perceived as an individual who effectively manages and administers from atop an organizational hierarchy [29–31], the quarry workers naturally executed a form of leadership among their teams to perform safely and to promote the safety of coworkers. This study indicated that quarry workers internally shared the role of safety leadership by generating a collective mindset of caring for each other. This mindset can be a fundamental step toward developing safety leadership, which may help workers to feel their lives matter and further aspire them to prioritize safety in the workplace.

Along the same line, new workers responded that they felt safer working near the experienced workers. New workers' lack of experience and awareness of the work operation tend to yield a higher risk factor than that of experienced workers [32]. However, their lack of experience was mitigated by workers' safety leadership reflected by the new workers' responses about working with the experienced workers. Because experienced workers had more expertise in the operation, new workers could trust and follow the experienced workers, which generated a safer work environment.

5. Conclusion

The researchers found that quarry workers identified hazards by recalling their safety training and applying hands-on, personal experiences with the operation depicted in each photo. This article pinpoints the importance of workers gaining formal and informal safety training. While prior studies emphasized strategizing and developing formal safety training, less research has focused on facilitating informal safety education and programs. By designing safety programs that address both formal and informal ways of learning safety skills and knowledge, quarry managers can create a safer work environment for employees. The findings of this study suggest that quarry managers should consider reviewing their safety programs and integrating worker perspectives and experiences. As illustrated in this article, photo elicitation can be used a useful tool to help safety managers gain input from workers and develop worksite-specific safety programs. As this article identified informal learning opportunities that quarry workers exercised in the workplace, safety managers can reinforce workers' safe performance by having open communication related to safety, building trusting

relationships, and cultivating safety leadership amongst workers to promote a positive safety culture.

Conflicts of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or nonfinancial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this article.

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