



## Original Article

# An Analysis of Trainers' Perspectives within an Ecological Framework: Factors that Influence Mine Safety Training Processes



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## ABSTRACT

**Background:** Satisfactory completion of mine safety training is a prerequisite for being hired and for continued employment in the coal industry. Although training includes content to develop skills in a variety of mineworker competencies, research and recommendations continue to specify that specific limitations in the self-escape portion of training still exist and that mineworkers need to be better prepared to respond to emergencies that could occur in their mine. Ecological models are often used to inform the development of health promotion programs but have not been widely applied to occupational health and safety training programs.

**Methods:** Nine mine safety trainers participated in in-depth semi-structured interviews. A theoretical analysis of the interviews was completed via an ecological lens. Each level of the social ecological model was used to examine factors that could be addressed both during and after mine safety training.

**Results:** The analysis suggests that problems surrounding communication and collaboration, leadership development, and responsibility and accountability at different levels within the mining industry contribute to deficiencies in mineworkers' mastery and maintenance of skills.

**Conclusion:** This study offers a new technique to identify limitations in safety training systems and processes. The analysis suggests that training should be developed and disseminated with consideration of various levels—individual, interpersonal, organizational, and community—to promote skills. If factors identified within and between levels are addressed, it may be easier to sustain mineworker competencies that are established during safety training.

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## 1. Introduction

One component of mineworker preparedness is the possession of competencies needed to self-escape from a mine quickly and safely during an emergency [1]. One way in which the mining industry prepares employees to respond to emergencies is via standards developed by the Mine Safety and Health Administration (MSHA) that include provisions on who needs to be trained, how much training is needed, who can provide training, and subject areas to be covered [2]. These requirements are included in the Code of Federal Regulations (30 CFR, section 48) on the training and retraining of mineworkers.

Although mine safety training occurs frequently and includes a vast amount of information that mineworkers need to know,

documents that analyze previous coal mine disasters indicate that improvements in training content and assessment are needed to better prepare the mining workforce to self-escape from emergencies [3–9]. These analyses, such as a report by the Mine Safety Technology and Training Commission, often assert that assessment of self-escape competencies is lacking in the current system of mine emergency preparedness [5]. Most recently, a comprehensive document compiled by the National Academy of Sciences about methods through which to improve self-escape indicated that current safety training is more focused on frequency and duration rather than on mastery of the knowledge, skills, abilities and other attributes (KSAOs) needed by mineworkers to sustain personal safety in the mining industry [3]. Research also illustrates that content about mine-specific knowledge is not included nor

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assessed enough during mine safety training sessions to guarantee the mastery of individuals' skills [10].

These comprehensive reviews determined that resources for the implementation and evaluation of realistic mine safety training are insufficient. A recent analysis of 12 mine rescue training facilities supports these findings in their conclusion that realistic scenarios, such as those within simulated mine settings where mineworkers can practice applying self-escape skills, is most desirable for accurate and sustainable learning [11]. The authors indicate, however, that these specific resources are not available to all mine organizations, and as a result classroom settings are used more often to teach and practice the necessary safety topics. Due to the abundance of literature that notes the problems with current mine training processes, it is especially important for the mining industry to be conscious of additional or innovative training strategies that may improve and maintain mineworkers' KSAOs while working underground. Subsequently, assessing and making feasible changes to training processes may increase the ability of mineworkers to self-escape during mine emergencies.

To probe the content and assessment of current mine safety training, researchers from the National Institute for Occupational Safety and Health interviewed nine mine safety trainers between November 2012 and March 2013 [12]. These safety trainers were considered to be subject matter experts (SMEs) in the area of mine safety training. When trying to elicit knowledge in a specific area, such as training assessment, engaging SMEs in issues related to the domain of interest is a common empirical approach [13]. Importantly, trainers noted problems similar to those identified in the prior documents including a lack of individual-level assessments and the need for more hands-on practice to master and maintain KSAOs.

As similar problems and recommendations were reiterated in the above-cited documents, a new analysis of the data was considered to further examine the trainers' interview content. This article focuses on the results of this analysis, which applied a five-level ecological framework in an effort to reveal training deficiencies and provide practical recommendations to improve training processes. The social ecological model (SEM; Fig. 1) considers this interplay between intrapersonal, interpersonal, organizational, community, and societal factors to better understand and target specific behaviors [14,15]. Using this specific analysis on trainers' perspectives is novel in the mining industry and the factors that may influence stronger training processes warrants exploration.

It should be noted that this paper does not address the current regulatory practices that define mine safety training. Rather, we analyze training by way of an established model grounded in an ecological perspective. This new viewpoint may provide a means to help recognize and expose limitations that exist in mine safety training and to understand why individual mastery and maintenance of self-escape KSAOs continues to be identified as a problem in follow-up reports of mine disasters.

### 1.1. Applying an ecological perspective to safety training

Although individuals are responsible for developing and maintaining behaviors that reduce safety and health risks, individual behaviors are simultaneously influenced by factors at external levels. Some experts argue that an ecological approach is better suited for at-risk populations [16], such as mineworkers whose environment increases their vulnerability to certain injuries and diseases [17]. In the case of mine safety training and skill maintenance, the SEM is an informative framework because mineworkers first learn and then apply competencies in different environments (i.e. the training facility and actual mine site, respectively). The SEM therefore allows for a focused analysis of how these various environments might influence the mastery and maintenance of critical skills. Each level of the SEM is discussed below.

The intrapersonal or individual level includes characteristics that influence behavior, such as knowledge, attitudes, skills, and beliefs [18]. Current mine safety training takes an intrapersonal level approach in which the individual is the target for developing competencies [14,19]. The interpersonal level provides role definitions and personal relationships, such as contact with family, friends or coworkers, which may influence behavior [19]. For example, because mineworkers often work together in crews on a consistent basis, whether peers encourage or discourage safety behaviors could have a significant influence on behavior. The organizational level also can facilitate and support individuals' willingness to change behaviors [14]. The organization itself can be a target for many health and safety initiatives, including local rules and policies to ensure employees' safety and health. An example includes adopting worksite practices that support preventative care, such as a smoking cessation program to assist in the prevention of respiratory problems. The community level includes social norms and values that exist among collective groups that can impact structures and the behaviors within those structures, such as the propensity to take risks and willingness make safer decisions [18,19]. Strategies at this level are typically designed to impact the processes and proximal rules within a given work system. Examples specific to the mining community include nonverbal communication signals with cap lamps or task training for a particular machine. Last, the societal level includes cultural context and regulatory policies that facilitate healthier behaviors [19]. State mining agencies and the MSHA are societal-level factors that influence worksite policies and ultimately the work behaviors of mine site personnel. For instance, the required training we discuss throughout this paper is one of the regulatory factors within the mining industry.

Some researchers argue that, although theoreticians often express interest in and use the SEM, practitioners rarely take advantage of this model's utility [14,15,20]. Using the SEM to consider potential shortcomings in self-escape training processes is an applicable and novel approach within the mining industry. The

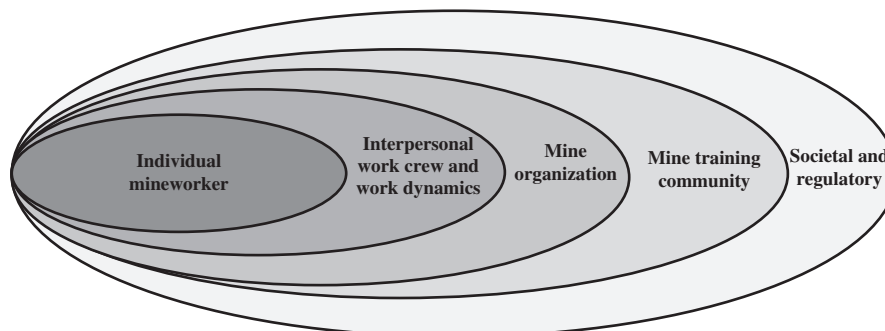


Fig. 1. Social ecological model for mine safety training.

five-level framework allows for an examination of various factors within an individual's environment, including peer networks and organizational rules [21]. In addition, because a combination of both individual-level and environmental resources are needed to promote the mastery and maintenance of self-escape KSAOs, it is particularly important to understand where problems exist within the contextual levels of an ecological system in order to offer appropriate recommendations [15].

The SEM has been applied to help develop, implement, and evaluate training at the community level in an effort to promote health and safety behaviors within specific populations. Examples include smoking cessation programs, safer-sex practices, and addressing community violence from multiple levels [14–19]. We considered SEM as a potentially valuable evaluative tool in the case of mine safety training as the SEM has been efficacious in revealing barriers to knowledge transfer and behavior change in other health and safety issues. Interviews with mine safety trainers were therefore analyzed in an effort to reveal potential weaknesses in relation to training content, skill development and assessment, and skill maintenance within and among the five ecological levels.

### 1.2. Research questions

The research questions posed in this study emerged from two key issues: (1) mastering and maintaining self-escape KSAOs during and after training; and (2) consideration of whether an ecological framework can be used to identify limiting factors across various levels of training systems. With this perspective in mind, this study sought to utilize the SEM as a lens through which to analyze interviews with mine safety trainers to reveal factors that hinder mineworkers' mastery and maintenance of self-escape KSAOs.

## 2. Methods and materials

MSHA requires that mine employees complete both new miner training and annual refresher training. The 40-hour new miner training includes classroom instruction and covers 14 content areas. Training topics include donning and transferring self-contained self-rescuers, escapeways and emergency evacuation, hazard recognition, mine gases, and communications [2]. After completing new miner training, mineworkers are required to attend an 8-hour annual refresher session to help maintain these skill sets [22]. There are approximately 45 self-escape competencies that trainers are encouraged to include in mine safety training, although not all of these have to be included [1]. As the aforementioned reports focus on the lack of self-escape competencies that are covered and assessed during mine safety training, the data collection instrument developed for this study probed these 45 competencies and the training processes used to establish mineworkers' KSAOs relative to these competencies.

### 2.1. Instrument and data collection

A semi-structured interview guide was developed that asked participants to respond to questions related to: (1) methods for teaching and assessing self-escape competencies; (2) best methods and the feasibility of these methods; (3) self-escape competencies on which mineworkers need better training, assessment and remediation; and (4) obstacles to stronger assessment methods. The interview questions were developed from a review of materials from mine safety training regulations and the literature, and input from mine safety training SMEs [1]. Participants were asked the same set of questions, but the interviews were flexible in that

participants could discuss the specific mine safety issues that they perceived to be the most critical in terms of training competence and emergency preparedness.

The semi-structured interview guide was reviewed and approved prior to data collection [23]. Existing contacts were utilized to recruit participants, employing a convenience sampling method [24]. Potential participants were contacted either by telephone or e-mail. No one who was contacted declined to participate. Once the agreement to participate was secured, two researchers traveled to the participant's place of employment to conduct the interview. Informed consent was obtained prior to each interview. Participants were assured that their responses would be confidential and that their responses were voluntary.

### 2.2. Participants

The participants were nine mine safety trainers, considered to be SMEs in the area of mine safety training, and they had a combined training experience of 154 years. The participants resided in four states and had experience conducting new miner training and annual refresher training. Five participants were trainers for specific training institutions, one for a safety department within a mine, and three for state or federal organizations. Personal training experience ranged from 4 years to 40 years (mean experience, 17.1 years; standard deviation, 10.8).

Two researchers were present for each interview. One researcher conducted the interview and took hand-written notes while the other researcher observed and took hand-written notes. Each interview lasted 2–3 hours. After the third interview, responses started to become repetitive and little new information was presented, indicating early saturation of content [25]. Due to the specificity of the content and the homogeneity of the sample, this was not unexpected. For this reason, after all of the participants who were initially recruited to participate completed their interviews, recruitment ended.

### 2.3. Qualitative data analysis

Interview notes were typed by the note-taker immediately following each interview to form a loose transcript for each participant. Transcripts were cross-referenced with the interviewers' notes for content accuracy. In order to assess how the ecological model could be used to reveal gaps and inform ideas for improving the self-escape portion of mine safety training, each interview transcript was analyzed and coded. Three researchers worked concurrently during the coding process to develop a codebook that consisted of themes, codes, categories, and examples. Prior to the coding process the researchers met to discuss data analysis steps and coding rules to ensure consistency of interview coding. Upon drafting the data analysis framework, researchers read through and coded the interviews independently. Researchers continued to meet to confirm that the coding process was going smoothly and to discuss any new themes or codes that were emerging. Four data analysis meetings were held prior to when the codebook was finalized. This iterative process helped to ensure reliability of coding across each interview.

General rules and procedures for qualitative analysis from a theoretical framework were used as guidance [26,27] throughout the following steps. (1) *Familiarization of the data*: Researchers became acquainted with the raw data by reading and re-reading the transcripts to identify key ideas and recurring topics. (2) *Identification and application of a theoretical framework*: Researchers used an ecological framework to identify the key issues and concepts by which the data could be analyzed and referenced. The text was coded according to SEM levels: individual, interpersonal,

organizational, community, and societal. Identifying the five ecological levels within each interview resulted in data that were in “manageable chunks for subsequent retrieval and exploration” [27]. (3) *The assignment of initial codes*: After researchers identified and agreed on the assignment of SEM levels, they noted patterns within the data chunks that were subsumed within the SEM levels. Researchers wrote notes in the margins of the interview transcripts to begin identifying factors that trainers referenced within each ecological level. The researchers regularly met to discuss the patterns that were emerging. (4) *Focused codes and organization*: The researchers reread their handwritten notes and assigned codes and categories based on the repetition of text within each interview. Quotes from each interview were collated to help support saturation of the pattern and eventually conceptualize a theme to summarize the factors that were present across the levels of the SEM. Once the researchers agreed upon the patterns and codes that were emerging throughout the interviews, these themes became part of the codebook. Refer to Table 1 for an excerpt from the codebook. (5) *Interpretation*: Researchers used the final codebook to look for connections between themes and illustrate factors in safety training that need attention to improve self-escape training systems and processes.

### 3. Results

The ecological analysis of interview data revealed training limitations within several levels of the SEM that may affect mine-workers’ abilities to master and maintain the KSAOs needed to self-escape from an emergency. Three overarching themes emerged: collaboration and communication; leadership; and responsibility and accountability.

#### 3.1. Collaboration and communication

Results indicate that effective communication and collaboration may be lacking within the mining system. These results are debriefed within each SEM level.

##### 3.1.1. Individual: mineworker development and inquiry

Starting with the individual mineworker, trainers mentioned that it is important for individuals to ask trainers and mine site leadership for help in mastering certain skills. Due to time constraints and lack of resources, trainers expressed, “Unless someone is really having problems, you couldn’t tell” (Trainer 7). For this reason, communication needs to be initiated by the individual who is experiencing problems. For example, when discussing self-escape competencies, Trainer 3 said: “Some of this is mine-specific. [We] talk about this in the training and encourage them to ask in the mine.” Then, it is up to the individual to communicate with personnel about mine-specific issues.

##### 3.1.2. Work crew: establishing and practicing action plans within work crews

The interpersonal communication gap that emerged was the importance of enabling students to practice and communicate in groups during training scenarios. Trainers noted that during training activities their students often communicate and participate better in class than during a simulated activity. Simulated group activities should therefore be facilitated by trainers to allow students to practice and develop decision-making processes that might occur on the job. This perception was discussed by all trainers, including Trainer 5, who stated: “You don’t know how you’ll work together until you’re tied together, in smoke.”

##### 3.1.3. Organizational: participation and follow-up in training protocols

An evident gap illustrated by trainers was the need for mine organizations (i.e., high-ranking managers or safety personnel) to have presence or participation during mine safety training. Participating in training allows organizations to observe skills that are difficult for students to master while also showing their support for and validating the importance of training. Trainer 8 summarized this concept when he said: “Mine management—it’s good practice. At [mine] the superintendent goes through the training with the masses. It shows a level of importance and that he’s a miner not just a super.”

##### 3.1.4. Community: trainers as communication liaisons

A common thread discussed throughout the interviews was the need for all mine safety trainers to proactively communicate with mine sites about skills that students, collectively, have trouble mastering during safety training. Most states do not require mineworkers to pass a test at the end of training, therefore there is no solid reason to hold a student back from “graduating.” For instance, one trainer said: “Assessing all of these competencies takes time in training. What do you do if someone doesn’t pass?... It would be hard for me to say a person should not be allowed to work in the mine” (Trainer 1).

##### 3.1.5. Society: facilitating supportive environments

On the societal level, trainers felt that more communication from agencies, including MSHA and state mining departments, would help facilitate effective training and training outcomes. In addition, trainers thought a greater presence by the agencies during training would help the agencies to experience the state of the industry’s training. For example, Trainer 6 said: “They can see the barriers we have to initially accomplishing a new law. We can ask them for help in working it out.”

#### 3.2. Leadership

The second theme that emerged from the ecological analysis is the lack of leadership at each level of the SEM. Each level and its respective weaknesses are discussed below.

##### 3.2.1. Individual: leadership obligations and expectations

Trainers emphasized the importance of mineworkers taking on leadership roles during and after training because it is unclear who will take on a leadership role during an actual emergency. For instance, trainers indicated that because they do not always have time to evaluate people individually, peers are expected to help others during training scenarios. Several trainers designed mock scenarios to develop individual leadership skills, illustrated in the following quote: “When you have simulated scenarios you can encourage people to get involved. Everyone needs to be somewhat involved. Also, someone may emerge who you didn’t think would be a leader but does a great job stepping up” (Trainer 5).

##### 3.2.2. Work crew: scenarios for emerging leaders within work crews

Trainers also noted similar leadership issues in groups of students. In response, trainers said that they use hands-on activities that give students leeway on making decisions and, depending on the scenario, taking on different leadership roles. One trainer said: “We observe them during hands on [activities], and assess who are the followers and the leaders” (Trainer 2). Another trainer said: “We do training in crews so people are together inside the chamber. A leader often is identified. Miners should be assessing as a group and watching out for each other. It’s everyone’s job” (Trainer 6). However, trainers noted that many mineworkers do not have a

**Table 1**  
Illustration of the coding process used to develop themes

Text from interview data	Social ecological model level	Category	Leadership
You don't have time to take them one by one and evaluate. So, unless someone is really having problems, you couldn't tell [when they are in the small groups]. Peers in the group are supposed/expected to help a friend. (Trainer 7)	Individual mineworker	Leadership obligations and expectations	Lack of leaders and safety exemplars
We do training in crews so people are together inside the chamber. A leader often is identified. Miners should be assessing as a group and watching out for each other. It's everyone's job. Others in the group told them what they were doing wrong, so we didn't have to. For example, people were reminding each other to put goggles on to protect their eyes from CO. (Trainer 6)	Interpersonal work crew and work dynamics	Scenarios for emerging leaders within work crews	
We will send names on to the mine and let them know if a person is lacking in a skill (e.g., Emily had a hard time donning her self-contained self-rescuers (SCSRs), she needs more practice). We don't follow-up with the mine to see if they further worked with the individual(s), just report who needed more attention. (Trainer 4)	Mine organization	Structures, rules and personnel that facilitate skill development	
Hands on training for trainers is a must. They need to know what they're talking about. It's very important for instructors to have the knowledge base about the SCSRs and other practical experience. It's important for all instructors to have worn the SCSR until expiration. (Trainer 8)	Mine training community	Trainer experience, participation and flexibility	
What are instructor requirements? Instructors need to stay fresh. How can you instruct on modern mining and methodology to go with it if you haven't been underground in 15 years? (Trainer 3)	Societal and regulatory	More resources and standards for developing and maintaining skills	

chance to take on a leadership role and make critical decisions for a work crew until an emergency actually happens.

### 3.2.3. Organizational: structures, rules, and personnel that facilitate skill development

Trainers highlighted specific leadership positions at mine organizations that can help mineworkers master and maintain self-escape KSAOs. Trainer 6 discussed how a specific mine organization conducts its quarterly evacuation drills:

The foreman is responsible for doing the drill. So, if it's water that quarter then we talk about water issues in that area of the mine. The foremen set up the situations in their area of the mine if they can. But generally, the safety department creates a training plan and gives it to the foreman. They know the type of situation and can decide on the escape or alternative shaft, depending on the scenario and their current place in the mine.

This excerpt illustrates the leadership roles of the foreman and safety personnel to create realistic self-escape scenarios for mine-workers to apply their newly-acquired skills.

### 3.2.4. Community: trainer experience, participation and flexibility

Trainers were adamant that every trainer should be aware of current mine-specific details and environments, generational differences and experiences, and different learning styles. Trainers expressed their frustration about the shortage of flexible and adaptable trainers who can lead by example, via their mining experience. Trainer 3 stated: "Their [trainers] skill sets have not been analyzed in years, so trainings haven't been brought up to date in years. Unless we [trainers] create it, there is no section in a training that provides multiple emergency situations." The trainers we interviewed discussed ways that they went above and beyond training expectations, such as writing their own training scenarios and tests and going underground frequently. Despite this, a common statement was, "A lot of these certified instructors have not been underground in years."

### 3.2.5. Society: more resources and standards for developing and maintaining skills

The discussion about lack of leadership skills for trainers transitioned into a discussion about minimal on-going requirements for

ensuring trainers' competencies and up-to-date training materials. Trainers said that having more training resources would help rejuvenate mine safety training and their outcomes on mine-workers' KSAOs to self-escape, as illustrated in Table 1.

## 3.3. Responsibility and accountability

A third limitation that emerged from an ecological analysis of the data was the amount of responsibility and personal accountability that people are willing to take on in order to ensure that the mining workforce is prepared to self-escape.

### 3.3.1. Individual: guaranteeing self-competence

There is no verifiable individual accountability in safety training. Trainers said that they always provide information to workers and foremen about what they should be doing, but it is the employees' responsibility to follow through on the job. Trainers admitted that "Attitude is a bit of an obstacle; most people think it won't ever happen 'here'" (Trainer 5). Regardless of the probability of a mine emergency, trainers asserted the importance of individuals paying attention on the mantrip, taking turns driving, or quizzing each other on escape routes.

### 3.3.2. Work crew: initiative to keep the work crews safe

Trainers expressed that work crews needed to be more accountable and speak up if they see something unsafe in the environment. Trainers often noted that supervising at a mine site is difficult and everyone needs to be aware of hazards and not be afraid to check and recheck work tasks for each other. Being accountable for the safety of one's work crew is a common expectation that trainers mentioned but that they were not confident it was happening among the mining workforce.

### 3.3.3. Organizational: planning ongoing follow-up training opportunities

A major problem referenced was the lack of ongoing training and skill building at mine organizations after safety training. Regarding annual refresher training, trainers said that there was no accountability or testing. Trainers understood that adding mine-specific training is time consuming but, as Trainer 8 said, "If you're

in smoke you can fall because you don't know the steps on stairs." Others continued to echo that realistic emergency situations were critical at each mine but not habitually incorporated.

### 3.3.4. *Community: maintaining training integrity*

Trainers insisted that the training community needs to evaluate itself to help improve training rigor and methods. In general, they felt that some trainers were unwilling to take on the responsibility and accountability of being a certified instructor. To demonstrate this, Trainer 4 said, "If everyone missed a particular question in a topic, we would go back and change the teaching technique." In addition, interviewees felt that trainers should make more of an effort to update their training to keep up with the dynamic mine environment.

### 3.3.5. *Society: making proactive decisions*

On the societal level, trainers acknowledged that changing regulatory practices is difficult, but also made the observation that if something is not mandated by law the organization will not enforce it and the individual may not learn the skill. One trainer said that the training is designed to "be in a hurry to get people a certificate, so they do the best they can." Another trainer said that he continually makes up his own tests because there are no specific tests available from regulatory agencies for certain competencies.

## 4. Discussion

The results of this analysis revealed newly-defined factors that limit the efficacy of mine safety training. The different strategies that various mine environments can employ to influence the mastery and maintenance of mineworkers' KSAOs is now better understood. The general objective of this study, using the SEM to reveal shortcomings in training and maintaining mineworkers' self-escape KSAOs, was therefore accomplished. The following sections discuss the three overarching factors that emerged in the data.

### 4.1. *Communication and collaboration*

First, the communication and collaboration factors present at each level of the SEM indicate that, rather than placing blame on the individual, trainer, or industry, the collaborative relationships within, among, and between all of these groups are necessary to improve workforce competency and performance. If more communication occurs between mine site leadership and safety trainers, between safety trainers and mineworkers, between mine site leadership and mineworkers, etc., a more accurate view of the knowledge and skill gaps of our nation's coal mineworkers may emerge. Specifically, enhanced communication between leaders of mine organizations and safety trainers may identify gaps in learning and stimulate site-specific training for skills that are more difficult for mineworkers to master. For example, during discussions between safety trainers and mine site leadership, deficiencies in map reading and familiarity with alternative escapeways may surface as a problem. These skills can be addressed in more detail during training, and organizations can specifically discuss alternative escapeways during weekly safety meetings or create a quarterly drill in which mineworkers are forced to use an alternative escapeway.

Trainers were not confident that work crews were proactively communicating with each other after training sessions ended. After starting work at a specific mine, work crews should communicate to establish common knowledge of escape aids. For instance, Trainer 2 said: "All escape decisions should be made prior to a disaster. You work with these people every day so you need to have

that discussion." Increased communication and teamwork may help to prevent the deterioration of skills over time. The leadership at mine sites may need to organize such activities to allow work crews to practice decision-making scenarios together.

### 4.2. *Leadership*

The results from this study indicate that in order for safety training to fulfill their intended purpose to develop self-escape KSAOs, leaders must be present at all levels of the mining system. If mineworkers are encouraged to be positive leaders and are provided with leadership opportunities during and after safety training, they can build leadership skills and model safer behaviors for their co-workers. The respective leadership roles at the mine organizations, however, are critical in terms of refining, mastering, and sustaining mineworkers' KSAOs.

There are too many skills to be effectively taught during training and so they must be acquired on the job at a specific mine. Participation from organizations during and after training may facilitate this follow-up process. For instance, when talking about evacuating during an emergency, one trainer said: "I do not typically teach miners how to decide the best evacuation routes. This is handled by someone from the specific mine" (Trainer 1). Similarly, as the circumstances change at a particular mine, onsite training must occur for mineworkers to maintain mine-specific self-escape KSAOs. As one trainer noted, students must have the ability to escape from primary and secondary escapeways as the mine develops and changes. These results indicate that it is crucial for mine site leadership to take an active role to ensure that skills become second nature through extra training on the job. In one example of this, in Australian coal mines the underground foremen are charged with supervising employees and the mine operations within a designated area of the underground mine. These individuals receive more comprehensive training in self-escape in order to take the lead in evacuating crews of miners [28]. A leadership model that at least targets certain job positions and/or tasks may be a positive start to further develop leadership skills at United States mines. Lastly, trainers said that part of being a leader at a mine site is establishing a culture that holds workers more accountable for unsafe behaviors and empowers workers to make safer choices. Trainers expressed an overall sense that mine safety culture is improving, which leads to the final theme that emerged in the data—responsibility and accountability.

### 4.3. *Responsibility and accountability*

The results across ecological levels showed a gap in the responsibility and accountability that individuals possessed to ensure mastery of the KSAOs needed to self-escape. A process of iterative teaching and learning is needed to build a more competent workforce. First, results indicate that mineworkers need to be accountable for their own self-escape competence. Trainers indicated that mineworkers tend to be reliant on their peers both during and likely after safety training. When an emergency occurs, therefore, some individuals may not know how to escape.

Trainers and organizations also need to hold themselves accountable for providing accurate and usable information to the mining workforce in order to develop and maintain those KSAOs. Organizations should provide ongoing training opportunities for employees to help maintain skills and teach specific nuances of the mine in which they work. In addition, trainers should maintain their own competencies in the mine environment and stay up-to-date with new mining technology (e.g., refuge alternatives, communications, etc.) so they can discuss such information during safety training.

## 5. Conclusion

These results demonstrate that an ecological framework is helpful to begin the process of improving the consistency and rigor of mine safety self-escape training. Distinct interventions are needed at each level of the SEM to enhance individual and group behavior, and to modify organizational and training environments. Tailored interventions can be developed and implemented via a mine's health and safety management system (HSMS) to ensure that all levels of the mining industry are involved with and receive the necessary information and training about critical self-escape competencies. HSMSs provide structure and guidance for the mining industry and organizations to better manage safety and health [29]. As most HSMS include elements relating to the factors identified in this analysis, using an HSMS to improve communication, foster leadership, and increase accountability is a viable and systematic approach to addressing current training limitations. Using a HSMS to disseminate information allows these critical training factors to be recognized and initially addressed at a mine organizational level, which emerged in our study as a critical SEM level that can help improve the mastery and maintenance of certain self-escape skills.

The results of this analysis demonstrated the utility of the five ecological levels and how limiting factors within these levels may preclude the mastery of mineworkers' self-escape skills and behaviors. Subsequently, the same ecological model was used to offer recommendations to the mining industry, organizations, and trainers to help improve individuals' mastery of behaviors and enhance multiple environments—from specific mine organizations to mine safety training centers—that can help influence the maintenance of those same skills and behaviors that are needed to make effective decisions during emergencies.

## Conflicts of interest

The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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