

Enhancing Mine Workers' Self-escape by Integrating Competency Assessment into Training



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Enhancing Mine Workers' Self-escape by Integrating Competency Assessment into Training

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ACRONYMS AND ABBREVIATIONS

ART	Annual Refresher Training
ASPH	Association of Schools of Public Health
ATLDP	Army Training and Leader Development Panel
BARS	Behaviorally anchored rating scales
CDC	Centers for Disease Control and Prevention
DCAP	Demonstration Competency Assessment Program
IRB	Institutional Review Board
KSA	Knowledge, skills, and abilities
KSAO	Knowledge, skills, abilities, and other personal attributes
MSHA	Mine Safety and Health Administration
MSTTC	Mine Safety Technology and Training Commission
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
OMSHR	Office of Mine Safety and Health Research
SCSR	Self-contained self-rescuer
SEC	Self-escape competencies
SMEs	Subject matter experts

Enhancing Mine Workers' Self-escape by Integrating Competency Assessment into Training

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Executive Summary

Mine workers' self-escape competencies (SEC) need to be better assessed during mine safety training to be sure that every underground mine worker possesses the competencies needed to successfully escape from emergencies that could occur in their mine. In response, researchers from the National Institute for Occupational Safety and Health (NIOSH) sought to learn how mine safety trainers are teaching and assessing SEC in mine safety training. To accomplish their objectives, NIOSH researchers completed in-depth interviews with nine coal mine safety trainers about teaching and assessing SEC. Based on the results of these interviews, recommendations are provided in this document for mine safety trainers and mine operators to improve the training, assessment, and maintenance of SEC.

Recommendations for Mine Safety Trainers

1. Incorporate or Enhance Simulated Training Activities

All mine safety trainings should include simulated activities or hypothetical scenarios whenever applicable to teach and assess SEC. Incorporating more hands-on activities and spending more time probing what students learned is important to increase the effectiveness of trainings. Additional research both inside and outside of the mining industry also recommends realistic, scenario-based activities within simulated environments to help cultivate effective decisionmaking skills during an emergency or stressful situation [e.g. Beilock 2010; McKinney and Davis 2003]. However, if access to a simulated mine environment is not possible, trainers can still set up activities in classrooms that require demonstration of skills. For example, one trainer said that he sets up a lifeline in the hallway outside the classroom and has students maneuver the path of the lifeline and indicate what each signal means. Therefore, options are available for trainers with more limited resources.

2. Draft Assessment Tools for Simulated Activities

Trainers did not reference an assessment tool for consistently evaluating and documenting competence while watching students. Other fields have made efforts to develop robust work-based assessment tools such as checklists, behaviorally anchored rating scales (BARS), and behavioral observation scales [Muchinsky 1990]. These tools have helped improve the rater reliability evaluations of individual performance. The same methods should be employed in the mining industry for a variety of scenario-based training activities that may be necessary during an emergency such as taking refuge, wayfinding, or reading a mine map.

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If behavioral checklists exist for more skills, trainers may be able to quantitatively assess each individual during trainings with more ease. Subsequently, if a cumulative sheet for each mine worker documented scores for each activity, this recording could be provided to the mine. This information would allow mine management to have more accurate documentation about individual skill sets. For instance, although an individual could demonstrate donning an SCSR, he/she may have had trouble ventilating a mine. Then, this deficiency could be further developed on the job.

3. Assess the Most Critical Self-escape Competencies

Because there are often only 8 to 32 hours to cover training content, depending on the type of training, tasks should be prioritized and, at the least, mine workers may be able to participate in hands-on activities for the most crucial SEC. According to safety trainers interviewed, competencies in which mine workers are in need of more training and assessment include: SCSR donning, switching, and expectations; shapes of lifeline signals; firefighting skills; ventilation; escapeway training and escape routes from mines; reading a mine map; communication systems; and barricading and refuge shelters.

4. Include Individual Assessment and Debriefings when Possible

Even though there is a trend toward conducting assessments during group-based activities, especially in simulated activities, it is crucial that each individual participates in each training activity [Gredler 1992]. A common fault in using group activities or simulations is that a trainer primarily examines the group and overlooks the experiences of each individual [Vernon 1990]. Because simulated activities are not self-teaching, trainers need to debrief the activities so that students can reflect on their decisions and subsequent actions in a similar future situation. Structured debriefings, in the form of a standard set of questions, questionnaires, discussions, etc., are useful. These activities should consist of empowering dialogue to help and support mine workers' self-escape skill development.

In addition, because assessing individual competency can be difficult for one trainer, fellow coworkers should be encouraged to help. Trainers can place a greater focus on group learning and teamwork during debriefings to encourage peers to continue these discussions on the job.

5. Maintain Personal Knowledge of Mine Processes

The trainers who we interviewed noted that the time allotment to prepare for training and to stay current on mining topics is difficult. One trainer exclaimed that the effort to continually provide new topics that are tailored to the specific mine and to that mine's training preferences is challenging. Other trainers had similar feedback, remarking that safety trainers do not know as much as they should about the present mining environment and that better methods are needed in order for trainers to obtain and maintain their certification. Therefore, it is important for safety trainers to keep abreast of new mining processes and technology and, if possible, review the mine layout for a specific organization before the start of an annual refresher training. Obtaining this information would entail a prior visit to each respective mine site and possibly an underground visit to evaluate the training needs for a specific session. Although it may be difficult, knowing more mine-specific information may help guide more informed dialogue with mine workers throughout the training.

Recommendations for Mine Operators

1. Include Remediation and Followup After Safety Training

A mine operator may generally assume that a mine worker who has completed a new miner or annual refresher training may be prepared for an emergency. Although it may be difficult to schedule, followup training within a mine workers' particular mining environment is important after completion of new miner training. Particularly, mine operators could inquire with mine safety trainers to check if a specific student or students had problems demonstrating proficiency in a task so that they could, if necessary, continue to work with employees to further instill specific SEC. Even having a general discussion with their workforce immediately after training about the new skills that mine workers learned, or relearned, could help instill the SEC recently acquired. In addition, followup exercises may allow new mine workers to become more comfortable communicating and making decisions with their coworkers to better manage emergencies.

2. Provide Orientation on Mine-specific Details to New Mine Workers

Although individual mine workers should take personal responsibility to ask questions about the mine upon starting a new job, mine operators should also continue to emphasize the importance of learning about the mine and notifying new miners of questions to ask management and coworkers. The likelihood of the same team that worked together during a training simulation to work together to manage a real emergency in the future is low [Borodzicz and van Haperen 2002]. Therefore, followup exercises would allow new miners to become more comfortable communicating and making decisions with their coworkers to better manage emergencies. Also, providing opportunities for new mine workers and veteran workers to relearn specific SEC whenever mine locations change may help employees to retain a mental map of their specific mine and, as a result, be able to respond quickly and safely during an emergency. An example of such an activity is discussed in Appendix E.

3. Organize Mock Emergencies

Because mine safety trainers may not have access to mines to facilitate such activities, it is recommended that mine operators organize mock emergency drills on a regular basis to help mine workers maintain their SEC. By organizing annual simulated trainings or mock drills, trainers explained during this study that miners could be trained on all possible contingencies like a fire, roof fall, or some other condition that may block their primary escape route. The trainers who we interviewed said this experience is invaluable because it builds self-efficacy and speed in making emergency response decisions. In addition, incorporating regular mock emergency drills would satisfy a recommendation in the National Academy of Sciences (NAS) report that advised the implementation of annual self-escape scenario exercises at every underground mine. Using any state resources that provide scenarios or drills for mock emergencies may help address this need.

Summary

Mine safety trainers in this study were in agreement that improving methods of assessing miners' SEC may not only better prepare mine workers for self-escape, but may also help identify gaps in current training protocols and support the need for additional training resources.

Tracking individuals' proficiency assessments during mine safety trainings and comparing results between different training facilities may provide information about the specific resources that aid in the development of SEC.

Importance of Self-escape Competencies Assessment

Emergencies in underground coal mines that may necessitate rapid self-escape of mine workers include fires, explosions, and inundations of water and gas. During these types of emergencies it is imperative that mine workers possess the necessary knowledge, skills, abilities, and other personal attributes (KSAOs) in order to evacuate from their mine quickly and safely. Several mine disasters in 2006 initiated investigative studies that revealed several deficiencies in coal miner readiness to self-escape. These deficiencies were linked to coal miner safety training on self-escape. The studies identifying these deficiencies were conducted by the Mine Safety Technology and Training Commission [MSTTC 2006], West Virginia Mine Safety Technology Task Force [WVMSTTF 2006], Government Accountability Office [GAO 2007], and McAteer et al. [2006a,b].

For example, MSTTC [2006] identified the failure to assess mine workers' self-escape competencies (SEC) as lacking in our nation's current system of mine emergency training and preparedness. This report suggested three areas of competence that mine workers must possess to successfully self-escape from a mine emergency:

- **Technical knowledge.** The understanding and proficiency in using escape aids such as lifelines and SCSRs.
- **Mine-specific knowledge.** Knowledge and comprehension of mine-specific details.
- **Escape conceptual knowledge.** The ability to think and adapt to dynamic conditions while making decisions.

Although technical knowledge is included in most new miner safety trainings, mine-specific knowledge and escape conceptual knowledge are not as frequently included or assessed in new miner trainings and at mine sites [Kowalski-Trakofler et al. 2010].

Even though the aforementioned reports are becoming dated, a more recent report compiled by the National Academy of Sciences [NAS 2013] continues to note these same gaps in self-escape training and competency assessment, indicating that self-escape competency assessment is still not being adequately addressed in our nation's current system of training and preparedness. For example, NAS [2013] discussed the importance of maintaining *technical knowledge* by ensuring that everything to support escape is always in the appropriate place and available for immediate use. Another section of their report insisted that mine operators need to work with miners to develop their *mine-specific knowledge* in their statement, "they [operators] need to work with miners to master the ability to recognize and/or respond to warning signals and harness the knowledge of the specific hazards, exits, and resources of their particular mines" (p. 2).

With regard to assessing SEC, the NAS [2013] concluded that, "In training, miners seldom have to demonstrate mastery of a skill, but only have to be in attendance" (p. 116). To ensure that miners can function effectively in an emergency, *escape conceptual knowledge* needs to be

improved, via train-to-mastery scenarios in dynamic conditions that have competency standards. These experts continue to recommend that the industry, the Mine Safety and Health Administration (MSHA), and NIOSH focus on developing and improving methods of evaluating mine workers' self-escape and aided-rescue competencies. In response, more progress needs to be made in addressing the assessment of mine workers' SEC.

Currently, U.S. mine safety regulations require that mine safety trainers assess the effectiveness of their training. Some trainers attempt to evaluate their training by administering a short anonymous quiz or by holding a short question-and-answer session of safety information following their presentations. However, for a variety of reasons, trainers do not typically collect information about an individual's competencies. Therefore, it is often unknown whether mine workers are sufficiently prepared to self-escape. Also, little is known about the effectiveness of self-escape training, or how often mine workers need additional training in order to maintain their mastery of SEC. With the exception of SCSR donning, individual-level evaluations of coal mine workers' SEC are not commonly performed. Reliable and feasible methods are necessary to help mine safety and training professionals assess whether their coal miners possess sufficient competence in self-escape. In response, the present report focuses primarily on the assessment of coal mine workers' SEC.

Objectives

In order to develop a better understanding of current practices relating to the assessment of mine workers' SEC, we interviewed mine safety trainers about their experiences in teaching and assessing SEC. This report was written to convey the types of information that may help those who train and prepare coal mine workers to be able to self-escape during an emergency and includes the following:

- A review and listing of self-escape competencies.
- Key findings about assessment of SEC based on in-depth interviews conducted with coal mine safety trainers.
- Recommendations for **mine safety trainers** to improve self-escape competency assessment during safety training and to maintain SEC after mine safety training.
- Recommendations for **mine operators** to help to instill and maintain SEC after mine safety training.

Mine Worker Self-escape Competencies and Assessment

Self-escape Competencies

National Institute for Occupational Safety and Health (NIOSH) researchers refer to the knowledge, skills, abilities, and other personal attributes mine workers need to have in order to evacuate from their mine quickly and safely as *self-escape competencies* (SEC). Researchers reviewed mine safety training regulations and the available literature on SEC, and solicited input on SEC from many mine safety and training experts to compile a fairly comprehensive list of

SEC [Peters and Kosmoski 2013]. NIOSH’s current list of SEC (see Table 1) was used during the interviews with mine safety trainers discussed in this report.*

Table 1. NIOSH list of coal mine self-escape competencies

Knowing...
<hr/>
1. Mine Emergency Response Plan.
2. Colors of reflective markers for primary and secondary escapeways.
3. The five tactile shapes on a lifeline and what they mean.
4. Alternative methods for navigating your way out of the mine (besides lifeline).
5. What your crew expects you to take care of during an emergency (e.g., miner operator contacts the responsible person).
6. What types of information need to be communicated to the responsible person and to people in other sections.
7. How to communicate nonverbally while using SCSR (both to coworkers underground and to outside persons).
8. How to read and understand a mine map.
9. Where your crew will assemble to prepare for evacuation.
10. Realistic expectations about using SCSRs (e.g., breathing resistance).
11. Realistic expectations about using refuge chambers.
12. Realistic expectations about navigating through smoke.
13. Properties of mine gases (e.g., odor, exposure limits, physical symptoms of overexposure).
14. How the mine ventilation system functions.
15. Types of alarm systems and how to respond to them.
<hr/>
Where to find...
<hr/>
16. Where to find first-aid kits.
17. Where to find escapeway maps.
18. Where to find SCSR caches.
19. Where to find refuge chambers.
20. Where to find tethers and taglines.
21. Where to find gas meters.
22. Where to find phones and radios.
23. Where to find areas of higher elevation in the mine.
24. Where to find all possible exits (shafts, slopes, drifts).
<hr/>
How to use...
<hr/>
25. Communication systems.
26. Gas meters.
27. SCSRs (donning and switching units).
28. Refuge chambers.
29. Lifelines and tethers.
30. Transportation equipment (mantrip, hoist)

*Instructional materials and methods for teaching many SEC identified in Table 1 are available from NIOSH, the National Mine Health and Safety Academy, and various MSHA State Grants recipients [Radomsky et al. 2009]. The list of potential sources of existing training materials on self-escape is provided in Appendix A.

Table 1. NIOSH list of coal mine self-escape competencies (continued)

How to decide...
31. The best evacuation route.
32. When to switch escapeways.
33. When to don SCSRs.
34. When to switch SCSRs.
35. When to use a refuge chamber.
36. Whether to use a refuge chamber as a way station during an escape (conditions and factors to be considered).
37. Whether to split up an escape group, leaving one or more persons behind.
38. Who will lead your escape group.
39. Whether to ride or walk out.
40. Whether to attempt to fight a fire, and when to abandon such efforts.

Before starting to evacuate remember to...
41. Notify the responsible person and people in other sections of the mine who may be affected.
42. Make sure all personnel are accounted for.
43. Plan and discuss your escape strategy.
44. De-energize powered equipment.
45. Gather necessary supplies and equipment (e.g., escapeway maps, radios, gas meter, extra SCSRs, tether, medicines and first-aid kits).

Although this list of SEC, in addition to resources that mine safety trainers can use to provide training on these SEC (Appendix A) is useful, methods that are most appropriate to assess specific SEC and the frequency that these methods should be used is still unknown, prompting knowledge exploration in this specific area.

Interviews about Assessment of SEC with Mine Safety Trainers

When trying to elicit knowledge in a specific area, engaging content experts in issues related to the domain of interest is a common empirical approach. Particularly, using subject matter experts (SMEs) to gain an understanding of a topic area has merit in the areas of training and knowledge preservation [Hoffman et al. 1995]. For example, human factors training and performance for aircraft piloting, radar operation, and air traffic control has been improved by using information provided from highly experienced, expert participants [Chiles 1967; Christensen and Mills 1967].

The interview is the most-used method when researchers want to ask open-ended questions about an expert's knowledge and reasoning [Cullen and Bryman 1988; Weiser and Shertz 1983]. The thorough feedback allows researchers to gain a comprehensive overview of the respective domain, including gaps that may exist in the specific area [Hoffman et al. 1995]. According to these researchers, interviews with SMEs are usually "exhaustive and exhausting" (p. 134).

NIOSH used this preferred empirical approach and interviewed nine mine safety trainers across four states, all considered to be SMEs, to better understand self-escape competency assessment in mine safety trainings. All data were collected after trainers provided consent to participate. Interviews occurred from November 2012 to March 2013. After the third interview, information was already becoming repetitive, indicating saturation of content, indicating that a sample of nine was warranted. The interviews were conducted in a private setting, usually at the safety trainer's place of employment. Each interview lasted approximately two to three hours. Appendix B lists the questions used during the interview. The interview questions were reviewed and approved by the NIOSH Institutional Review Board (IRB).

Trainers who participated had experience conducting a variety of safety trainings including the MSHA Part 48 New Miner Training [30 USC[†] 811, 825], annual refresher training, new task training, and mine rescue training. These trainers had personal training experience that ranged from 4 to 40 years ($M = 17.1$ years; $SD = 10.8$). Trainers' specific jobs are listed below.

- Safety trainers affiliated with training institutions who provided new miner training for those entering the workforce or annual refresher training for mine organizations ($n = 5$).
- Safety trainer within a safety department of a specific mine ($n = 1$).
- Safety trainers for a state or federal agency ($n = 3$).

All trainers had access to a classroom setting and used basic mine safety equipment, such as SCSRs and first-aid supplies, in their training. Several trainers also had access to a simulated mining environment and mining equipment. No one reported conducting new miner training using an actual mine site, although most had experience conducting task training within a mine.

Methods of Assessing Self-escape Competencies

In the 1990s, twelve competency-based qualifications were introduced in Australia under the banner of the "Black Coal Training Package MNC98 Version 2.00" [National Mining Industry Training Advisory Body 2002]. The training package seeks to improve *technical knowledge* to aid a successful self-escape such as knowing basic ventilation plans and the properties of mine gases. Examples of *practiced-based skills* incorporated in this training include communicating effectively, navigating mine plans, and identifying alternative escape routes. The training lists a variety of methods that can be used to establish and assess miners' SEC [Galvin 2008]. The package requires that more than one of the following methods be used to verify competency:

- Written and/or oral assessment of participant's required knowledge.
- Observed, documented, and/or first-hand testimonial evidence of participants: implementation of appropriate requirements, procedures and methods for the safe, effective, and efficient achievement of the required outcomes.
- First-hand testimonial evidence of the participant undertaking and completing escape from hazardous situations unaided.
- Consistently achieving the required outcomes.

[†]United States Code.

In Australia, each miner must obtain a certificate of competency for each job activity they are required to perform. These certificates do not have a lifelong currency; rather, the holders are required to undertake ongoing refresher training and competency assessment to retain their qualification. For a description of Australia's criteria for assessing underground miners' SEC, see Australian Government's *Escape from Hazardous Situation Unaided* [Commonwealth of Australia 2012].

As the interviews with mine safety trainers revealed in the current study, many of the assessment methods mentioned above are currently being used in the United States. Specifically, there are four methods commonly used to assess SEC. Mine safety trainers continued to confirm these same assessment methods in the current NIOSH study. These methods include:

1. Watch each individual perform a task (don SCSR, use gas meter).
2. Use written exams.
3. Orally question a group of students or the class.
4. Watch small groups perform a task under simulated conditions.

Written exams and oral questions are used more often when trying to *assess knowledge*. Oftentimes these types of assessments are more feasible because minimal resources are needed to use these assessment methods. These types of assessment, however, are usually lower in fidelity (i.e. predictable or reliable) because answering questions is not reflective of what mine workers will be required to perform during an actual emergency. For example, a test of knowledge may be able to determine if a mine worker knows the steps involved in donning an SCSR in the order they need to be performed, but it will not adequately assess whether or not that same individual is competent in actually donning an SCSR in an emergency situation.

Watching an individual and/or small groups perform a task is appropriate when trying to *assess decisionmaking* and *practice-based skills* [Leigh et al. 2007]. Although more time-consuming, these assessments tend to have high levels of fidelity because they are often conducted within the actual working environment, use real-world scenarios, and often incorporate interaction with equipment and other people that mine workers would interact with in a real emergency situation. Thus, these types of assessments can enhance *escape-conceptual knowledge*.

Previous literature indicates that the specific competency to be measured will often determine assessment methods [Leigh et al. 2007]. The SEC list in Table 1 illustrates that assessments often measure competencies concerning knowledge, decisionmaking, or integration of practice-based skills and tasks. Therefore, a combination of assessment methods is likely necessary to ensure the highest levels of competence. Mine safety trainers were probed about the four assessment methods mentioned above during the interviews, including what methods they prefer, how feasible assessment methods are used during safety training, and barriers to using assessment and specific assessment methods during safety training. Their responses are discussed next.

Key Findings about Assessment Based on Interviews with Mine Safety Trainers

For a more detailed review of mine safety trainers' feedback, gaps, and recommendations, refer to the tables and in-depth description of the results in Appendix C. This section focuses on three areas regarding self-escape competencies (SEC) assessment: Methods and frequency of competency assessment; feasibility of competency assessment methods; and barriers to completing assessments.

Methods and Frequency of Self-escape Competencies Assessment

As Tables C1–C5 (Appendix C) indicate, most trainers had experience providing training on various SEC. However, because there are several ways in which competencies can be assessed it was important to learn what assessment methods are commonly used and for what SEC by mine safety trainers. Trainers were asked to indicate the specific assessments used for each self-escape competency listed. The following list was given to those trainers who participated:

- Watch each individual perform a task.
- Provide written exams.
- Orally question a group of students or the class.
- Watch groups perform a task under simulated conditions.
- Use other methods.
- I have not evaluated this competency.

The summary and presentation of Tables C6–C8 in Appendix C report the results of assessment methods used by trainers and how often these methods were used. Researchers also wanted trainers' expert opinions about the best way to assess individual mine workers' competencies (even if they did not have the resources to perform the type of assessment). Full results and Tables C9–C11 report the results of methods preferred by trainers to assess individuals.

Different methods were chosen for individual and group level assessments depending on the competency area (e.g., knowing how to do something or how to use something) being assessed. These results indicate that there are several ways to assess an individuals' ability to self-escape, each offering different strengths and weaknesses, as referenced in the review of literature.

Assessing Knowledge

When assessing whether or not someone *knows something*, or has *proficient knowledge*, trainers more often reported orally questioning groups or administering a written exam to evaluate competence. In general, trainers explained that when they want to assess whether a student knows something, they will administer some sort of written exam or quiz and then follow up the exam with an oral question-and-answer session that involves the entire class. They felt this combination of individual and group level assessment helped them determine whether students grasped a certain topic.

Assessing Decisionmaking

When assessing *how to make a decision* during a particular emergency, a majority of trainers indicated that written and oral questioning of each miner are methods they commonly use to assess mine workers' competence. Trainers seldom reported "watching" an individual or group progress through a decisionmaking process. Those trainers who did indicate engaging in such an assessment often had the ability to use a simulated mine in which they could create a mock emergency and watch individuals decide whether or not to fight a fire or watch a group engage in a discussion about whether or not they should take refuge.

Assessing Practice-based Skills

When assessing whether or not someone *knows how to use or do something*, trainers more often reported watching the individual or group perform that specific task to evaluate competence. However, as Table C7 shows, besides watching individuals don and switch SCSRs, which all trainers reported doing, there was not much consistency in the methods trainers reported using to assess whether an individual is competent in using tools to aid self-escape.

To illustrate, every trainer asserted that donning an SCSR is a task for which each individual needs to demonstrate their proficiency in operating; this would warrant individual-level assessment via watching a demonstration. Although watching small groups is sufficient for activities that would be performed in groups during an emergency, such as tethering and walking out in smoke, it was not the preferred method for evaluating individual competence. Rather, trainers advocated for individual-level assessments, when possible. One trainer summarized this assertion when he said:

Individual demonstrations, in most cases, are better than group demonstrations, apart from escape routes, refuge chambers, and tethering, which are group decisions. The latter decisions (escape routes, taking refuge, tethering) are made by groups and are best evaluated by observing a group. But more often than not, trainers should evaluate on an individual basis. If mine workers are in a group, one can sit back and do nothing, and absorb nothing.

Trainers were able to document a combination of assessment methods if they felt that more than one would be best at assessing a competency. Although there was not much consistency from trainer to trainer, most indicated that a combination of methods (e.g., watching and orally questioning an individual) was best for assessing individual competence. Trainers felt the combination of assessment methods was particularly useful when using written exams, especially when a literacy barrier exists. They felt that providing a written exam needed to be followed up by oral questioning or demonstration. These results continue to indicate the importance of using different assessment methods, based on the competency being evaluated.

Feasibility of and Barriers to Completing Assessment

Although individual competency assessment methods and some group-level assessment methods may be more desirable than others in determining proficiency, these methods are not always practical. Trainers were asked about the feasibility of using common assessment methods to evaluate the miners they typically train. The mean scores for the feasibility of assessment methods for each training scenario provided to the nine trainers are presented in Table C12 (Appendix C). In general, trainers felt that all of the assessment methods were feasible but some

required more time and resources. Although trainers' feedback about feasibility of methods was dependent on a particular procedure that they were thinking of, they usually noted challenges related to time, access to resources, the absence of mine-specific details and training, and remediation efforts.

Feasibility of Assessing Practice-based Skills

Trainers continued to assert that extra time and resources are barriers that prevent them from being able to better evaluate practice-based skills. For example, one trainer said in reference to demonstrating a procedure in a classroom setting, "If you have 25–30 people in a class, you still need 25–30 SCSRs because you would have the logistics of putting them back together if you did not have enough SCSRs for every individual. So, even if we have done it (have each miner demonstrate a procedure), it's still time consuming and takes a lot of resources." These issues are further discussed below.

Time

Time was the major reason cited for not being able to more adequately address a task and ensure every individual mine worker is competent. A shared response here was, "Time is the biggest thing. Preparation time and time to spend on subjects (competencies)." Time was discussed in several different capacities. Trainers referenced that there is not enough time during the actual training to conduct frequent repetitions of a task, such as donning an SCSR. Also, the time that a mine has to give up to provide training to mine workers was discussed. One trainer said, "The small mines are running on minimum people, so they can't spare the people to get away and do this type of training." For example, one trainer said, "How do you purchase everything you need AND how do you pull a number of people out to provide training and replenish resources? Shifts are always changing, which affects scheduling and time available."

Access to Resources

As the previous quote illustrated, time was also referenced in combination with resource capacity. One trainer noted, "It's always some sort of time/resource constraint. Whether it's the cost of sending miners to a simulated mine to do scenario-based kinds of things or something else. There's limited days in the year and limited instructors." Concerning resources, trainers continually discussed access to the necessary tools and equipment being a problem. Besides general supply needs, however, money was referenced as the biggest resource that safety training appears to be lacking. In addition, several trainers noted a cut in training funding in recent years, making the future need for training equipment even greater. One trainer noted that most training is only meeting and not exceeding current compliance requirements and that greater repetition in training is needed. However, he referenced money as the primary reason why training is not given more frequently.

Trainers consistently indicated that, although these SEC are discussed in trainings, miners do not have the opportunity to actually perform tasks. For instance, in reference to firefighting one trainer said, "How to put out a fire and save their mine. We tell them but they don't actually do it. Many people have never touched a fire extinguisher." Similarly, when referring to communication systems, another trainer indicated, "We tell them about it, but we don't have them demonstrate. But we need to make sure they know how to use communication devices and SCSRs, communicate amongst themselves and outside, what key information you need to communicate, like providing your location." However, as trainers often referenced, this type of

training and assessment of practice-based skills is difficult to do when you are training a group and have no means to quantify the success of each individual. In addition, individual assessment can be particularly difficult for trainings that occur at smaller mines. Mine workers are the most limited resource at times, and as a result, there may be resistance to removing workers from underground to participate in an individual evaluation of skill sets.

Feasibility of Assessing Knowledge and Decisionmaking

In terms of assessing both knowledge and ability to make decisions, taking written tests or having a mine worker show a safety trainer something on a map were the only two assessment methods that were discussed as being very easy to complete in a new miner training. Written tests were noted as the easiest assessment technique. However, several trainers referenced literacy as an issue that needs to be addressed whenever anything written is provided at safety training. As far as orally questioning miners to see if they understand a concept or having them make a decision, such as how to best evacuate a mine using a map, trainers still noted that it takes time, but is much more feasible. Because these two assessment methods are the most feasible, they were administered most often to assess competence in the areas of knowledge and decisionmaking. However, trainers often said that assessing these types of competencies is difficult because both the trainers and future mine workers are not familiar with and therefore cannot discuss the specific details and layout of their mine. Similarly, mine workers should be informed of how long it may realistically take to respond during an emergency for specific escape and/or rescue procedures. Understanding how long a particular procedure may take could affect mine workers' decisionmaking process regarding whether to get out of the mine immediately or use a refuge chamber as a last resort.

Mine-specific Details Needed

Several trainers felt that there was not enough discussion during and after safety training about the importance of mine workers understanding the layout of their specific mine, knowing the little nuances of it, and knowing every possible way to escape. One trainer asserted the importance of mine layout when he said, "If you're in smoke you can fall because you don't know the number of steps on the stairs. Many don't talk about the particular escapeways and cache locations of a mine, they just do what is mandated by law." Another trainer asserted, "We're training too much on lifelines, because they might be destroyed in an explosion. Or a beltline might be destroyed. They need to know their escape routes out." A similar comment was made with regard to training on barricading. The trainer said this topic needs more attention in current training:

You may not be able to get to a refuge chamber. We [mine workers and mine safety trainers] need to continue to know about barricading and temporary barricading, setting up curtains, etc. We talk a lot about these things [refuge chambers] but guys don't know what to do with them. What if the chamber doesn't work? Can I set up an area with 13 people with enough air? Mechanical objects fail; we have to have survival skills if things don't work and we want to live.

These results indicate that emphasis on self-learning mine-specific details is important at each mine and should be discussed by trainers and mine operators upon completion of training. This aspect leads to the final barrier that emerged, remediation.

Remediation Needed

Trainers discussed their thoughts on remediation and followup assessments. Generally, they often noted that followup assessments do not occur at all. In these instances they said that knowledge and decisionmaking ability degrade quickly, even if students practiced and were successfully evaluated during training. The common deficits trainers discussed in which students need additional practice are listed below:

- Don and switch SCSRs (both in and out of a simulated environment).
- General decisionmaking during simulated escape exercises.
- Communication with their group about escape routes.
- Reading a mine map.
- Tethering.
- Types of gases and their appropriate ranges.

Miners' ability to don and switch their SCSRs, especially in a simulated smoke environment, was discussed as the primary skill in which miners experience difficulty during training. As one trainer said, "Skills for SCSR donning degrade rapidly. And, all of the different types of SCSRs that are on the market that we use just compound the problem." Generally, trainers noted that miners often are clumsy with their SCSRs, don't go through the steps correctly, and in a simulated emergency may don their SCSR incorrectly or not at all.

It is worth noting that because several of the trainers were trainers that were not directly affiliated with a particular mine, they do not keep documentation of any individual evaluation or assessment results. Rather, they indicated that each individual mining organization should keep documentation about a mine worker's skill sets because trainers do not typically have the time or resources to keep files for every worker. In addition, trainers do not retrain the same mine workers every year, whereas mine operators keep records of other task trainings or remediation efforts completed by their employees. Developing and implementing more consistent assessment and documentation methods is a challenge likely to involve several iterations over time because tools should be broad enough to have utility at a range of mine sites and be useful when training both the novice and veteran coal miner.

The NAS [2013] asserted that efforts on the part of mine operators and other industry stakeholders to empower self-escape in a mine emergency are needed. These results indicate that mine safety experts agree that significant improvements are needed in *several* aspects of our current systems of preparing and equipping mine workers to safely evacuate from mine emergencies. Our current recommendations specifically address mine safety trainers and mine operators.

Recommendations for Mine Safety Trainers to Enhance Training and Assessment of Self-escape Competencies

The results revealed a need to improve training and assessment methods among the mine training community. We acknowledge that a variety of barriers exist that impede trainers' ability to make continuous quality improvements. However, we provide four practical and feasible recommendations for mine safety trainers in an effort to help aid future training and assessment.

Incorporate or Enhance Simulated Training Activities

Based on responses from trainers, all mine safety trainings should include simulated training activities or hypothetical scenarios whenever applicable to teach and assess SEC. Incorporating more hands-on activities and spending more time probing what students learned is important to increase the effectiveness of trainings. Additional research both inside and outside of the mining industry also recommends realistic, scenario-based activities within simulated environments to help cultivate effective decisionmaking skills during an emergency or stressful situation [e.g. NIOSH 2013; Beilock 2010; McKinney and Davis 2003].

For example, the NAS [2013] recommended the increased use of simulated mine environments to conduct trainings with realistic expectations for mine workers. Scenario-based activities within simulated conditions rely on controlled exercises in which students are presented with cues that are similar to those found in the actual mine environment and then given feedback based on their responses [Cannon-Bowers et al. 1998]. The notion of scenario-based training is consistent with the need to provide novice decisionmakers with a variety of tasks as a means to augment their experience and accelerate their skill development [Cannon-Bowers and Bell 1997]. Specifically, Miller [1990] presented a pyramid of understanding that individuals should ascend from in order to demonstrate proficiency of a competency:

- Level 1: **Knowledge.** Knowing facts and procedures.
- Level 2: **Knowing How.** Competence in using knowledge to formulate a response.
- Level 3: **Showing How.** Being able to demonstrate while observed.
- Level 4: **Does.** Being able to respond independently as a practitioner.

These levels support that trainings should facilitate an individual's ability to acquire and demonstrate a skill rather than just possess knowledge [Rolfe et al. 1998]. For instance, even if someone knows how to read a mine map, the ability to make quick decisions about an escapeway in a stressful environment is quite different. Trainers in the current study agreed, emphasizing the importance of mine workers practicing and learning in a hands-on activity, simulated mining environment, or in a real mine.

Trainers in the current study contended that, due to lack of time and resources, they often have to watch small groups perform a task instead of only evaluating one individual at a time. However, one positive aspect of these group-based tasks is that they allow individuals to become familiar with their respective members' knowledge, skills, attitudes, and task-relevant attributes [Cannon-Bowers and Salas 1998]. Using group-based training or teamwork is applicable for some portions of mine safety trainings because miners more often respond as a group during an emergency escape [NIOSH 2000; USBM 1994]. Also, because leaders that are not always the foreman or shift leader often emerge during emergencies, it is important to practice assigning tasks and making group decisions before being faced with a real emergency [USBM 1994].

As the results illustrated, trainers in the current study seldom reported "watching" an individual or group go through a decisionmaking process. Those trainers who did indicate engaging in such an assessment often had the ability to use a simulated mine in which they could stage an emergency and watch a group engage in a discussion about whether or not they should take refuge, etc. Regardless of the resources available, however, trainers referenced the logistics

for conducting trainings in a real or simulated mine as a barrier for most safety trainers. For this reason, collaboration with mining organizations to coordinate mock emergencies on a consistent basis is critical.

In addition, even if access to a simulated mine environment is not possible, trainers can still format activities in classrooms that require demonstration of skills. For example, one trainer said that he sets up a lifeline in the hallway outside the classroom and has students maneuver the path of the lifeline and assert what each signal means. Therefore, options are available for trainers with more limited resources.

Assessment Tools for Simulated Activities

Trainers in the current study expressed a need for safety trainings to have standardized tools for assessing miners' competencies. Several organizations have had similar difficulties trying to operationally assess competence. For example, the U.S. military noted that it is difficult to design tests that are suitable for everyone and suggested that any operational testing system contain multiple assessments that require trainees to make a variety of decisions during simulated scenarios or activities [Knapp and Campbell 2006].

As the results in the current study exhibit, mine safety trainers more often assess individuals and groups using observation than other methods of assessment. However, trainers in this study did not reference any assessment tool for consistently evaluating and documenting competence while watching students. Rather, a collective comment was "you know it when you see it." However, how can we be sure that trainers are seeing the same thing and, further, documenting what they saw to followup with students? Other fields, such as internal medicine, also face similar challenges of assessing clinical skills through direct observation. In response, they have made efforts to develop robust work-based assessment tools in which checklists, behaviorally anchored rating scales (BARS), and behavioral observation scales [Muchinsky 1990] have helped improve the rater reliability evaluations of individual performance.

For example, Rosen et al. [2008] recommend using critical events within a scenario to create behavioral checklists to assess competence. The authors advocated for ordering these events in time, and trainers can score each behavioral response dichotomously (i.e., yes or no). They indicated these checklists are advantageous for two reasons. First, because events are listed in order, trainers can focus their attention on specific tasks that occur during a scenario, making it easier to pay attention. Second, trainers only score the "presence or absence of specific behaviors and do not make judgments about the quality of the behavior, increasing the reliability of ratings" [p. 1196]. These checklists can be used to determine general proficiency and as a method to provide feedback to students.

A similar checklist exists for assessing SCSR donning competency [USBM 1993]. The NIOSH research team incorporated the 3+3 donning method into a training package for mine safety trainers to help facilitate hands-on learning. The SCSR donning performance checklist (Figure D1, Appendix D) allows for a yes-or-no response, so trainers can simply indicate what a student did and did not do during the donning of their SCSR. Such evaluation checklists can prompt important points for trainers to discuss with each student. In addition, each student can receive a copy of their 3+3 checklist to serve as a reminder for the correct donning procedure.

If trainers use scenario-based activities such as taking refuge, wayfinding, or reading a mine map, these behavioral checklists may be useful as a quick method to document competence. If behavioral checklists exist for more skills, trainers may be able to quantitatively assess each individual during trainings with more ease. Subsequently, if a cumulative sheet for each mine worker documented scores for each activity, this recording could be provided to the mine. This information could subsequently allow mine management to have documentation that, although an individual could demonstrate donning an SCSR, he/she may have had trouble ventilating a mine. Any deficiencies noted could be further developed on the job.

Finally, the creation of behavioral, dichotomous checklists may be a helpful aid for mine safety trainers who are not as familiar with newer mining equipment and technology. For example, a behavioral checklist for using refuge chambers may be useful because this technology is newer and some mine safety trainers may not have real experience with this equipment, particularly if the trainer has not been underground for several years.

Assess the Most Critical Self-escape Competencies

As Table 1 illustrates, NIOSH identified 45 competencies that mine workers should know to aid self-escape during an emergency. Because there is often only 8 to 32 hours to cover this information, depending on the type of training, tasks should be prioritized and, at the least, mine workers may be able to participate in hands-on activities for the most crucial SEC. We asked trainers from the current study to identify subject areas in which mine workers are in the greatest need of better training. Although not a detailed task analysis, the NAS [2013] also suggested eight subject areas in which miners are in the greatest need of better training. The subject areas identified by the NAS and by the nine mine safety trainers in this study are similar (see Table 2), providing a strong starting point for prioritizing the SEC in which mine workers need more simulated practice before beginning a career as an underground coal miner.

Table 2. Self-escape competencies for which mine workers need better training

National Academy of Science recommendations [NAS 2013]	Mine Safety Trainers' recommendations
SCSR donning and switching	SCSR donning and switching
SCSR expectations	SCSR expectations
Simulated smoke	Shapes of lifeline signals
The effects of carbon monoxide	Firefighting skills
The concept of ventilation leakage	How ventilation works in a mine
Wayfinding	General escapeway training, escape routes from mines, and reading a mine map
Effective warnings	Communication systems
Problem-solving and decisionmaking	Barricading and refuge shelters

However, if hands-on tasks conducted within a classroom or simulated environment are not appropriately evaluated and discussed, trainees may not fully reflect and learn from their experiences. This area is addressed next.

Include Individual Assessment and Debriefings when Possible

Behavioral checklists, such as the SCSR Donning Sequence Evaluation Sheet (Figure D1, Appendix D), is one way to begin some type of evaluation of mine workers' SEC. However, general debriefing with trainees about their role(s) during mining activities is crucial to help implant learning experiences. Even though there is a trend toward assessments during group work, especially in simulated activities, it is crucial that each individual participates in each training activity [Gredler 1992]. A common fault in using group activities or simulations is that a trainer primarily examines the group and overlooks the experiences of each individual [Vernon 1990]. Gillespie [1973] indicated that simulated exercises are not self-teaching. Rather, trainers need to debrief the exercise(s) so students can reflect on their decisions and subsequent actions in a similar situation in the future. He suggested that a structured form of debriefing, in the form of a standard set of questions, questionnaires, discussions, etc. are useful. Several of the training packages listed in Appendix A contain probing questions that trainers can adapt when debriefing a simulated activity. However, as mine safety trainings continue to evolve and become more hands-on, new training materials and debriefing scripts may be needed to help guide trainers through a discussion.

Even though time is usually limited during trainings, instead of shortening the evaluation and debriefing, Hofstede and Pedersen [1999] asserted that it is better to shorten the simulation activity so that individuals are given the opportunity to reflect on their experiences. For example, in a meta-analysis of 31 studies, Tannenbaum and Cerasoli [2013] found that the use of debriefs, or followup discussions, in trainings resulted in an average of 25% performance improvement in both individual participants (26%) and teams (25%). They also found that the average debrief lasted approximately 18 minutes, illustrating that including this type of intervention into a training would not require much time but yield better performance among participants.

In addition, debriefing activities should consist of empowering dialogue that target mine workers to help and support each other in self-escape skill development. As we have discussed, assessing individual competency is difficult for one trainer, and fellow coworkers should be encouraged to help. One trainer noted that in most cases, it is expected that a peer will help another peer in need, although it is not made explicit. Instead of making assumptions, trainers need to enhance the concept of group learning and teamwork during debriefings.

However, even if mine safety trainings start incorporating more simulated activities with regular assessment, results from this study also indicate that consistent trainings and assessment in skill proficiency needs to occur. Remediation efforts need to be conducted more frequently because, as several trainers noted, the mining environment, which includes the other mine workers you work with, is constantly changing [Kowalski-Trakofler et al. 2008]. In addition, because the mine environment is constantly changing, safety trainers need to remain vigilant of the ways mine processes are changing with time and newer technology. This knowledge maintenance for trainers is the final recommendation to improve mine safety training and assessment.

Maintain Personal Knowledge of Mine Processes

It was common for trainers to say that many certified trainers across the nation have not been underground in several years and that the mining environment has drastically changed. These trainers said that it is easy to lose touch and not know what's going on in mines. As one trainer acknowledged, "I become more obsolete every day," because the mine conditions and protocols change daily. In response, they felt that trainers who were more knowledgeable about current mining conditions and issues may be better prepared to train new miners. It does not take much for a trainer familiar with the mining industry to get up-to-date, as some trainers exclaimed, "We may only be inside the mine an hour or two but we can pick up a lot of information quickly."

All mines are different, which makes the trainers' job of staying up-to-date even more difficult. For instance, one trainer noted that the colors used to designate escapeways can vary across mines because the use of color in escapeways is not standard across mines, which makes it difficult for a trainer to teach and assess this competency. Further compounding this barrier, however, is a time constraint. Trainers noted that the time allotment to prepare for training and to stay current on mining topics is difficult. One trainer exclaimed that the effort to continually provide new topics that are tailored to the specific mine and to that mine's training preferences is challenging. Other trainers had similar feedback, remarking that safety trainers do not know as much as they should about the present mining environment and that better methods are needed in order for trainers to obtain and maintain their certification. Therefore, it is important for safety trainers to keep abreast of new mining processes and technology and, if possible, review the mine layout for a specific organization before an annual refresher training. Knowing a little bit of information about the specific mine may help guide more informed dialogue with mine workers throughout the training.

Recommendations for Mine Operators to Enhance and Maintain Self-escape Competencies at Mine Sites

The results also revealed a critical role for mine operators to help further instill and maintain competencies in mine workers after safety training. We acknowledge that mine operators and mine sites have limited resources and busy production schedules that impair their ability to hold continuous training. However, we provide three practical and feasible recommendations for mine operators in an effort to help instill and maintain the SEC that mine workers acquire at mine safety training.

Include Remediation and Followup after Safety Training

In addition to a lack of task redundancy at new miner trainings, results from this study also indicate that little remediation is done after a mine worker becomes certified and begins a career underground. For example, several trainers said that even if a miner can demonstrate proficiency in SCSR donning, this competency is short-lived and not reassessed often enough. However, a mine operator may generally assume that a mine worker who has completed a new miner or annual refresher training may be prepared for an emergency. Followup training within a mine workers' particular environment is necessary after completion of new miner training. Particularly, mine operators could inquire with mine safety trainers to determine if a specific

student or students had problems demonstrating proficiency in a task so they could continue to work with employees, if necessary to further instill specific SEC. Even having a general discussion with their workforce immediately after training about what new skills mine workers learned, or relearned, could help instill the SEC recently acquired.

Provide Orientation on Mine-specific Details to New Mine Workers

In addition to general debriefing of training, followup training may help new miners learn the nuances of their specific mine. Although individual mine workers should take personal responsibility to ask questions about the mine upon starting a new job, mine operators should also continue to emphasize the importance of learning about the mine and notifying new miners what questions to ask management and coworkers. The likelihood of the same team that worked together during a training simulation to work together to manage a real emergency in the future is low [Borodzicz and van Haperen 2002]. Therefore, followup exercises would allow new miners to become more comfortable communicating and making decisions with their coworkers to better manage emergencies.

As part of a NIOSH research project to improve the assessment of coal miners' self-escape competencies (SEC), NIOSH researchers developed and tested a method for assessing mine workers' knowledge of lifeline signals. Appendix E discusses the particulars of this assessment. Similar to the recommendations from trainers, the assessment involved the use of a real mining environment, hands-on activities, individual-level assessment using a paper-and-pencil evaluation, and remediation following the initial training. This description serves as an exemplar approach from which we hope mine operators can glean and adopt information to improve the consistent application of mine-specific activities and assessment methods.

Organize Mock Emergencies for New Employees

The most desired "wish" discussed by trainers was that of requiring each and every mine worker to go through a simulated self-escape training or go through a mock emergency drill in their own mine on a consistent basis. Trainers indicated that miners need to see what a mine looks like in full smoke. In addition, by organizing annual simulated trainings or mock drills, trainers explained that miners could be trained on all possible contingencies like a fire, roof fall, or something else that may block their primary escape route. Trainers said this experience is invaluable because it builds self-efficacy and speed in making emergency response decisions. As one trainer stated, "Any coal miner that's hired has to take a class built on skill level. They need everything from the books, to practice, to the simulators. They need to have the opportunity to have failures without consequences. Every mine should have a training center at their facility so you can have remediation and practice with people early on." Because mine safety trainers may not have access to mines to facilitate such activities, it is recommended that mine operators organize mock emergency drills on a regular basis to help mine workers maintain their SEC. In addition, incorporating regular mock emergency drills would satisfy a NAS [2013] recommendation that advised the implementation of annual self-escape scenario exercises at every underground mine.

Conclusions

This report discussed the importance of training and assessing mine workers' self-escape competencies (SEC) and identified the gaps in training that still exist regarding rigorous assessment of these SEC. Specifically, the results from interviews with mine safety trainers indicate that more simulated activities need to be done with new mine workers, that more evaluation tools are needed to aid the assessment of these activities, and that students should be thoroughly debriefed following simulation training exercises. Also, the frequency of assessment and of remediation efforts needs to increase after training, at the specific mine site, to help employees further master SEC. An example of such post-training followup is provided in Appendix E of this document.

Improving methods of assessing miners' SEC may not only better prepare workers for self-escape, but it may also help identify gaps in current training protocols and support the need for additional training resources. For example, by developing and using some type of assessment protocol (e.g., behavioral checklists), it may be easier to make strong justifications for improving teaching methods and resources. Tracking individuals' proficiency assessments during mine training and comparing results between different training facilities may provide information about the specific resources that aid in the development of SEC. Specifically, such a comparison may provide hard data in support of simulated environments for mine safety trainings. As mentioned in the Australian report on competency assessment, there are valid ways to assess competencies other than written testing. Several forms of assessment should be explored and subsequently validated in the United States to improve mine workers' self-escape competencies.

This report presented a variety of information concerning SEC. Although not a representative sample, the results continue to show the importance of placing a consistent focus on assessment of SEC during current mine safety trainings. With the continued development of hands-on training activities and assessment methods, the mining industry can continue to improve upon existing training methods and further enhance mine workers' abilities to self-escape. Finally, good communication and coordination between outside trainers and the mine operator is vital to ensuring that everything is covered in an effective manner. As the NAS [2013] indicated, collaboration between several key organizations and individuals is necessary to improve and maintain mine workers' abilities to self-escape. This report targeted mine operators and mine safety trainers as a source to begin improving the quality and quantity of methods used to train and assess self-escape competencies.

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Appendix A: Resources for Teaching Coal Mine Self-escape Competencies

Certain types of information on self-escape are unique to every mine, and should be obtained from the mine's safety department. However, many useful resources have been developed for teaching coal mine self-escape competencies that are applicable to almost any coal mine. Links to training materials and guidance documents available from NIOSH, Penn State University, and MSHA are provided below. These resources are organized into the following categories:

- I. What to do Before Starting to Evacuate
- II. Using Emergency Equipment
- III. Communication
- IV. Decisionmaking
- V. Other Issues

I. What to do Before Starting to Evacuate

(Communicate, assemble, plan escape, gather items)

- Smoke on the Section (currently being updated)
- Low Coal Fire (currently being updated)
- Travel Through Smoke (currently being updated)
- Belt Fire Exercise (currently being updated)
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #20: Procedures When the Alarm Sounds) http://www.emc.psu.edu/minerstownhall_training/bsg2.html

II. Using Emergency Equipment

Types of alarm systems and how you should respond to them. *Consult Mine Safety Dept.*

- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #19: Fire Detection Systems) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

How to use mine communication equipment in emergencies

- Radio 101: Operating Two-Way Radios Every Day and in Emergencies <http://www.cdc.gov/niosh/mining/works/cover-sheet522.html>
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #15: Zones and Communication) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

How to operate a refuge chamber. (These materials are intended to *supplement* the chamber manufacturer's manuals and instructional materials—not to replace them.)

- How to Operate a Refuge Chamber: A Quick Start Guide <http://www.cdc.gov/niosh/mining/works/coversheet1695.html>
- Recommendations for Refuge Chamber Operations Training <http://www.cdc.gov/niosh/mining/works/coversheet271.html>

How to use a gas meter. *Consult manufacturer.*

How to use tethers

- Escape and Evacuation: A Miners' Education and Training Toolbox (Toolbox Talk #17, Tethers: Why and How) http://www.eme.psu.edu/minerstownhall_training/bsg2.html

How to use SCSRs

- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #6, SCSRs: What You Should Know; Talk #11: SCSR Switching) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf
- MSHA [2006]. Self-Contained Self-Rescuers: A Comprehensive Guide to the Inspection, Care and Use of. This DVD is available from the National Mine Health and Safety Academy for \$10. Email: MSHADistributionCenter@dol.gov or see MSHA Catalog of Training Products for the Mining Industry 2011, DVD #013. <http://www.msha.gov/TRAINING/prodintr.htm>

III. Communication

What to remember to say and find out during an emergency

- The Emergency Communication Triangle <http://www.cdc.gov/niosh/mining/works/coversheet838.html>
- Escape and Evacuation: A Miners' Education and Training Toolbox (Toolbox Talk #4 How You Communicate a Mine Emergency Matters) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #16 Responsible Person) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

IV. Decisionmaking

Whether to go to a refuge chamber or continue trying to escape

- When Do You Take Refuge? Decisionmaking During Mine Emergency Escape <http://www.cdc.gov/niosh/mining/works/coversheet1556.html>
- Man Mountain's Refuge <http://www.cdc.gov/niosh/mining/works/coversheet1679.html>
- Harry's Hard Choices <http://www.cdc.gov/niosh/mining/works/coversheet1838.html>

- Escape and Evacuation: A Miners' Education and Training Toolbox (Toolbox Talk #5 What Would You Rather Do – Escape or Seek Refuge?) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

Whether to leave someone behind during an escape

- Escape from a Mine Fire – Decision Making Exercise. (currently being updated)
- Escape from a Mine Fire – video. See MSHA Catalog of Training Products for the Mining Industry 2011, DVD #013. <http://www.msha.gov/TRAINING/prodintr.htm>
- Harry's Hard Choices <http://www.cdc.gov/niosh/mining/works/coversheet1838.html>

Deciding who leads the escape group

- Behavioral and Organizational Dimensions of Underground Mine Fires (see Chapter 9: Leadership in Escape) <http://www.cdc.gov/niosh/mining/works/coversheet45.html>
- Lead the Way (video). Available from Virginia Division of Mines Marshall.moore@dmme.virginia.gov

Deciding which escapeway to use and when to switch escapeways

- Low Coal Fire (currently being updated)
- Belt Fire Exercise (currently being updated)
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk # 13: Primary and Secondary Escapeways) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

Deciding whether to walk or ride out

- Travel Through Smoke (currently being updated)

Deciding whether to fight a fire

- Belt Fire Exercise (currently being updated)

V. Other Issues

Mine emergency response plan. *Consult Mine Safety Department for your mine's specific plan.*

- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #8 Know Your Emergency Response Plan) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

Wayfinding

- Mines must have systems in place for helping people find their way out, such as escapeway markers, and lifelines. Some mines use different colored markers to show people whether they are going inby or outby, and whether they are in the primary or secondary escapeway. In addition, every mine has various other features that can help people determine which way they need to go to get out, e.g., following along various

structures such as the conveyor belt, water lines or high voltage power cables; or remembering to keep stoppings on your left.

- Mine Lifelines. Flash cards can be used to help miners learn and review the meaning of the 5 tactile shapes on a lifeline. They can be printed from this website <http://www.cdc.gov/niosh/mining/works/coversheet1826.html>
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #7: What are the Purposes of Lifelines?) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf
- Behavioral and Organizational Dimensions of Underground Mine Fires (see Chapter 8: Wayfinding and Escape Behavior) <http://www.cdc.gov/niosh/mining/works/coversheet45.html>
- Underground Coal Mine Map Reading Training <http://www.cdc.gov/niosh/mining/works/coversheet1825.html>
- Escape & Evacuation: A Miners' Education and Training Toolbox (Talk #9: Knowledge of Escapeway Map Saves Time and Lives) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

Emergency escape duties/roles

- If people in a mining crew have been designated to perform various duties during an emergency, this needs to be communicated well and reviewed often (also who the backup persons are).
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #12: Responsibilities of Each Miner during a Fire or Fire Drill) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf
- Escape and Evacuation: A Miners' Education and Training Toolbox (Talk #16: Responsible Person) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf

How to communicate nonverbally while wearing an SCSR

- Nonverbal Communication for Mine Emergencies <http://www.cdc.gov/niosh/mining/works/coversheet461.html>

How to recognize and respond to symptoms of traumatic incident stress during escape

- Man Mountain's Refuge <http://www.cdc.gov/niosh/mining/works/coversheet1679.html>
- Traumatic Incident Stress: Information for Emergency Response Workers <http://www.cdc.gov/niosh/mining/works/coversheet643.html>

Developing realistic expectations about:

- **Using mine refuge chambers:** Refuge Chamber Expectations Training <http://www.cdc.gov/niosh/mining/works/coversheet455.html>

- **Using SCSRs: I Can't Get Enough Air! Proper Self-contained Self-rescuer Usage** <http://www.cdc.gov/niosh/mining/works/coversheet343.html>
Expectations Training for Miners Using Self-Contained Self-Rescuers in Escapes from Underground Coal Mines <http://www.cdc.gov/niosh/mining/works/coversheet985.html>
- **Navigating through smoke:** Several mine training facilities offer simulated smoke evacuation training using a maze in a trailer or a building or mine passageways filled with smoke: MSHA's National Mine Health and Safety Academy (Beaver, WV), the Colorado School of Mines Edgar Mine Rescue Training Center (Idaho Springs, CO), Southern West Virginia Community and Technical College (Logan, WV), the Mining Technology and Training Center (Prosperity, PA), West Virginia University's Mining Extension and Outreach Program (Morgantown, WV), Rend Lake Community College (Ina, IL), Kentucky Coal Academy at Madisonville Community College (Madisonville, KY), Alabama Mine Training Consortium at Bevill State Community College, (Sumiton, AL), and Western Energy Training Center at College of Eastern Utah (Helper, UT).
Behavioral and Organizational Dimensions of Underground Mine Fires (see Chapter 7: Smoke as an escape and behavioral environment and Chapter 8: Wayfinding and escape behavior) <http://www.cdc.gov/niosh/mining/works/coversheet45.html>
- **Mine Gases:** Miners should know the odors and properties of gases (e.g., specific gravity of carbon monoxide, CO), exposure limits, physical symptoms of overexposure, and consequences of failing to isolate lungs.
Escape and Evacuation: A Miners' Education and Training Toolbox (Toolbox Talk #1: Know the Dangers of Coal Mine Atmospheres) http://exponentevents.com/minerstownhall/escapeandevacuation_handbook.pdf
Escape from Farmington No. 9 <http://www.cdc.gov/niosh/mining/works/coversheet1628.html>
Smoke on the Section (Currently being updated)
- **How the mine ventilation system functions and the hazards of system failures:**
Consult your mine's ventilation plan.

MSHA [2011]. Catalog of Training Products for the Mining Industry. <http://www.msha.gov/TRAINING/prodintr.htm>.

NIOSH Mine Safety Training. Most mine safety training materials developed by NIOSH can be found at <http://www.cdc.gov/niosh/mining/works/productlist.html> or <http://www2a.cdc.gov/nioshtic-2/publications/pubresults.asp>.

Appendix B: Interview Guide for Mine Trainers Regarding Self-escape Competencies

1. Introduction

Hello, my name is _____. I work for the National Institute for Occupational Safety and Health (NIOSH). NIOSH is doing a research study to gather information on what coal mine safety trainers think about how to train miners to be able to self-escape during mine emergencies. Because you have much experience providing safety training to coal miners, I would like to interview you. The interview may take about 2 hours. Your participation is completely voluntary. You don't need to answer any questions that you don't want to answer. Your responses to interview questions will be treated in a confidential manner. I do not record the names of the people I interview. The information you provide will be analyzed and reported along with the information provided by other mine trainers. In any public release of results, no data will be disclosed that could be used to identify specific individuals. Only NIOSH staff who are involved in collecting or preparing the information for analysis will have access to your answers.

If you do not object to being interviewed, I need you to review and sign this consent form. *[Give form to trainer and explain.]*

Do you have any questions before I begin the interview?

2. Trainer's Background

I'd like to start by asking a few questions about you and your experience as a mine safety trainer.

2.1 What types of jobs have you performed that are related to underground coal mining?

2.2 How many years have you provided safety training for underground coal miners?

2.3 How long has it been since you last conducted coal miner safety training as mandated by 30 CFR Part 48? [# of weeks]

2.4 Which types of mandated coal miner safety training have you taught? [new miner, annual refresher, new task]

2.5 Have you trained mine rescue teams?

2.6 Have there been any incidents at a mine where you have worked that required underground miners to initiate emergency response procedures? *[If NO, skip to Section 3.]*

2.7 *[If YES]* I'd like you to think about the most recent incident. Please describe what happened. [Probes: How long ago did this happen? Did miners don their SCSRs? Did they evacuate from the mine?]

2.8 Thinking about the most recent incident, what aspects of self-escape training should be changed in order to improve how miners would respond to similar incidents in the future?

3. Self-escape Competencies

Self-escape competencies are the knowledge, skills, and abilities coal miners need to possess to get out of the mine quickly and safely during mine emergencies. We have attempted to compile a list of these competencies.

3.1 I would like you to review this list of self-escape competencies and circle the number beside each topic on which you have provided formal training.

[Hand list to the interviewee and wait for them to review and circle competencies.]

3.2 Are there any other self-escape competencies that you think miners should be trained on that we do not have on our list? *[If NO, skip to 3.4.]*

3.3 Please tell me what those competencies are.

3.4 I'd like you to think about the instructional methods you have used to teach self-escape competencies over the years. Have you found any methods that seem to work especially well? *[If NO, go to section 4.]*

Please describe the method(s).

4. Competency Assessment

The next section of this interview concerns the *assessment* of self-escape competencies.

There are several ways to evaluate a miner's self-escape competencies. Here is a list of potential assessment methods.

[Hand the following list to the trainer.]

Assessment Methods Response Options

1. Watch each individual perform a task (don't SCSR, use gas meter).
2. Use written exams.
3. Orally question a group of students or the class.
4. Watch small groups perform a task under simulated conditions.
5. Use other methods.
6. I have not evaluated this competency.

[Hand list to trainer.]

4.1 Please review this list of competencies, and write the number of the assessment technique or methods you use in the blank beside each competency. If you have not had any experience assessing a competency, please write the number "6" in the blank.

For each competency the trainer has assessed at the individual level (options 1 or 2), ask: “How do you decide whether an individual miner is sufficiently competent at [XYZ]?”

For each competency the trainer has assessed using “5 Use other methods,” ask: “Please describe how you assessed [XYZ].”

4.2 Do you keep documentation on your assessments of miners’ self-escape competencies?
[If NO, go to 4.4.]

4.3 How do you use that information?

[Probe: Is the information used to ensure that miners who need additional training will get it?]

4.4 Some assessments involve observing or questioning groups of students, and other assessments are done at the individual level. There are various ways to assess an individual’s competency. It could be done by watching each miner demonstrate a procedure (e.g., donning SCSR), giving miners a written exam, or asking each miner to explain something or answer a question without relying on help from others. The best way might vary depending on the type of self-escape competency.

We would like your opinions about the best way to assess an individual miner’s competencies.

Here is a list of potential assessment methods.

[Hand the following list to the trainer.]

Individual Assessment Technique Response Options

1. Watch each individual perform a task (don SCSR, use gas meter).
2. Use written exam.
3. Orally question each individual.
4. Watch small groups of individuals perform a task under simulated conditions.
5. Other methods (please describe).

Using these options, please write the number of the assessment technique that represents the best way to determine if an individual miner is proficient at that competency in the blank beside each competency listed.

[Hand list to trainer.]

In other words, if you used this competency assessment technique, you would be confident in making judgments about whether or not an individual miner’s understanding and/or capabilities are sufficient. You may list more than one assessment technique if you think a combination of methods should be used.

[NOTE: If the issue comes up, say “Please assume most miners are capable of taking written tests.”]

[Review the trainer’s responses and ask them to describe anything they listed as “5 Use other methods.”]

Feasibility of Assessment Methods

Although a competency assessment technique might be excellent in terms of discriminating between miners who are proficient and those who are not, there are various reasons why it might not be practical or feasible to use that technique. Using the 4 response options on this card, I would like you to rate how feasible it would be to use each assessment technique to assess the miners you typically train. In rating feasibility, please consider the amount of time and resources needed to use the technique.

Response Card

1. It would be very easy to do.
2. It is feasible but would require a little more time, effort, resources.
3. It is feasible but would require substantially more time, effort, resources.
4. It is not at all feasible.

How feasible would it be to...

4.5 Have each miner demonstrate a procedure in a classroom setting. _____
[Probe: What are the strengths and limitations of this technique?]

4.6 Have each miner demonstrate a procedure in the mine. _____
[Probe: What are the strengths and limitations of this technique?]

4.7 Have each miner respond to a written test or quiz. _____
[Probe: What are the strengths and limitations of this technique?]

4.8 Orally question each miner to see if he/she understands a concept. _____
[Probe: What are the strengths and limitations of this technique?]

4.9 Describe a potential emergency situation and ask each miner questions to see if he/she knows what to do to self-escape. _____
[Probe: What are the strengths and limitations of this technique?]

4.10 Have each miner respond to a computer-based training simulation to see if he/she would know how to respond to various emergency scenarios. _____
[Probe: What are the strengths and limitations of this technique?]

4.11 Have each miner show you on a map the best way to evacuate the mine from various locations. _____
[Probe: What are the strengths and limitations of this technique?]

4.12 Some miners may not be fully capable of self-escape, and would have trouble getting out of the mine on their own in an emergency. What are the primary reasons some miners might have difficulty getting out of the mine on their own?

Please use the options on this response card to answer the following 3 questions.

Proportion of Miners – Response Options

1. Less than 10%
2. Less than 25%
3. Between 25%–50 %
4. More than half

4.13 Of the coal miners you are familiar with, what proportion would have difficulty getting out of the mine on their own?

- 1 2 3 4 (circle one)

4.14 Some miners may actually have the knowledge and capabilities required to self-escape, but they would have difficulty demonstrating their proficiencies on a written test. Of the coal miners you are familiar with, what proportion fall into that category?

- 1 2 3 4 (circle one)

4.15 Of those miners who would have difficulty demonstrating their proficiencies on a written test, what proportion would perform better on a behavioral assessment?

- 1 2 3 4 (circle one)

5. Remediation

5.1 People learn new things at different rates. Some miners may need more instruction or practice than others to become proficient at self-escape. Have you ever suspected that a miner needed additional training or practice on a self-escape competency? *[If NO, skip to section 6.]*

5.2 I'd like you to think about the most recent instance. What was the training topic(s)?

5.3 What made you suspect that this person needed more training?

5.4 Did you provide them with additional help? How?

6. Concluding Questions

6.1 Which 2 or 3 self-escape competencies are miners in greatest need of better training on?

6.2 What are the biggest obstacles to improving this type of training?

6.3 Which 2 or 3 self-escape competencies could trainers do a better job of assessing?

6.4 What are the biggest obstacles to assessing these competencies?

6.5 Besides mine trainers, should anyone else be involved in assessing miners' self-escape competencies?

[Probes: Who? How could they help?]

6.6 What are the biggest gaps or limitations in our nation's current system of coal mine self-escape training?

6.7 If you had a limitless amount of authority and resources at your disposal, what would you do to improve the self-escape competencies of our nation's coal miners?

6.8 These are all the questions I have. But before we close, is there anything else you would like to add about self-escape competencies.

Thank you very much for participating in this study.

Appendix C: Complete Results from Interviews with Mine Safety Trainers about SEC Training and Assessment

The main document noted the critical feedback, perceived gaps, and recommendations received throughout the interviews in terms of training and assessment of mine workers' self-escape competencies (SEC). This Appendix contains the complete results of the interviews and a more in-depth discussion of those results.

Self-escape Competencies that Trainers Addressed in Mine Safety Training

Trainers responded to a variety of questions related to skill-building competencies. First, trainers were asked to respond to whether or not they provided formal training on "knowing" a specific SEC. For example, if trainers provided formal training on knowing the five tactile shapes on a lifeline and what they mean, he/she circled that competency to indicate that they did provide formal training on knowing this competency.

As Table C1 indicates, the only two SEC on which every trainer provided knowledge-based training were: (1) realistic expectations about using SCSRs (e.g., breathing resistance) and (2) how to communicate nonverbally while using an SCSR. However, a majority of trainers also provided formal training on knowing how to navigate through smoke, properties of mine gases, mine ventilation, reading a mine map, and communication systems. The SEC on which the least number of trainers ($n=5$) reported providing formal training was what your crew expects you to take care of during an emergency. Several trainers noted that this competency is mine specific and difficult to provide formal training on during a new miner training, in particular.

Next, trainers were asked to indicate whether they provided formal training on where to find particular items that can assist with self-escape during an emergency. For example, if a trainer indicated that they provide formal training on where to find refuge chambers, they circled that competency on the list provided. The response distribution for each SEC is presented in Table C2. Trainers indicated that often where to find something is mine-specific, so they could not provide accurate formal training on, for example, where to find phones and radios, because they may be placed in different locations within each mine. Although there was not one SEC on which every trainer noted they provided formal training, where to find SCSR caches, tethers, and refuges received the highest frequency of responses ($n=8$).

In addition, trainers were asked if they provided formal training on "how to use" something during an emergency that requires self-escape. For example, trainers were asked if they provided formal training on how to use gas meters during an emergency. Trainers continued to circle each SEC on which they provided formal training. These results are displayed below in Table C3. All of the trainers indicated that they provide formal training on how to don and switch an SCSR. Most trainers also provided specific training on how to use gas meters and lifelines during an emergency.

Similarly, trainers were also asked whether or not they provide formal training on the specifics of decisionmaking during a mine emergency. For example, trainers were asked if they provided formal training on how to decide whether or not to use a refuge chamber. Trainers continued to circle those SEC on which they did provide formal training. These results are displayed in Table C4. A continued focus and effort on SCSRs was reported, with every trainer

noting that they discuss how to decide when to don and switch an SCSR. In general, trainers discussed these topic areas. How to decide when to switch escapeways, who will lead the escape group, and using a refuge as a way station were included in the least number of trainers’ formal training programs ($n=6$).

Finally, trainers were asked whether or not they provide formal training on what to do before evacuating an emergency situation. If trainers indicated that they provide training on making sure to de-energize powered equipment before exiting the mine, they circled that competency. As you can see in the results in Table C5, a majority of trainers indicated that these discussions are included in their training.

Table C1. “Knowing” SEC on which trainers provided formal training (N=9)

Provide formal training on “Knowing” what to do during an emergency that requires self-escape	Number of “Yes” Responses (n)
Mine Emergency Response Plan	6
Colors of reflective markers for primary and secondary escapeways	7
The five tactile shapes on a lifeline and what they mean	8
Alternative methods for navigating your way out of the mine (besides lifeline)	8
What your crew expects you to take care of during an emergency	5
What types of information need to be communicated to the responsible person and to people in other sections	8
How to communicate nonverbally while using SCSR (both to coworkers underground and to outside persons)	9
How to read and understand a mine map	8
Where your crew will assemble to prepare for evacuation	7
Realistic expectations about using SCSRs	9
Realistic expectations about using refuge chambers	7
Realistic expectations about navigating through smoke	8
Properties of mine gases	8
How the mine ventilation system functions	8
Types of alarm systems and how to respond to them	6

Table C2. “Where to Find” SEC on which trainers provided formal training (N=9)

Provide formal training on “Where to Find” something during an emergency that requires self-escape	Number of “Yes” Responses (<i>n</i>)
First-aid kit	7
Escapeway maps	7
SCSR caches	8
Refuge chambers	8
Tethers and taglines	8
Gas meters	7
Phones and radios	7
Areas of higher elevation in the mine	5
All possible exits (shafts, slopes, drifts)	7

Table C3. “How to Use” SEC on which trainers provided formal training (N=9)

Provide formal training on “How to Use” something during an emergency that requires self-escape	Number of “Yes” Responses (<i>n</i>)
Communication systems	7
Gas meters	8
SCSRs (donning and switching units)	9
Refuge chambers	7
Lifelines and tethers	8
Transportation equipment (mantrip, hoist)	6

Table C4. “How to Decide” SEC on which trainers provided formal training (N=9)

Provide formal training on “How to Decide” during an emergency that requires self-escape	Number of “Yes” Responses (<i>n</i>)
The best evacuation route	7
When to switch escapeways	6
When to don SCSRs	9
When to switch SCSRs	9
When to use a refuge chamber	8
Whether to use a refuge chamber as a way station during an escape (conditions and factors to be considered)	6
Whether to split up an escape group, leaving one or more persons behind	7
Who will lead your escape group	6
Whether to ride or walk out	8
Whether to attempt to fight a fire, and when to abandon such efforts	8

Table C5. “Before Evacuating” SEC on which trainers provided formal training (N=9)

Provide formal training on “What to do Before Evacuating” during an emergency	Number of “Yes” Responses (<i>n</i>)
Notify the responsible person and people in other sections of the mine who may be affected.	8
Make sure all personnel are accounted for.	8
Plan and discuss your escape strategy.	7
De-energize powered equipment.	7
Gather necessary supplies and equipment.	7

In general most trainers had experience providing training on various SEC. Upon completing the checklists, trainers were asked if there were any SEC on which they thought mine workers should be trained that were missing from the checklists. The majority of trainers indicated that the cumulative list was comprehensive and that they had nothing to add. However, a couple of the trainers mentioned that some competencies could be enhanced and some added in training, based on their training experience and observations. They suggested enhancing or adding the following topics:

- Firefighting methods (e.g., using an extinguisher to put out a fire).
- Realistic first-aid training (e.g., have bleeding suits to teach combat trauma).
- Correct manner of barricading if a refuge chamber is not nearby.
- Calibration of the air composition in a refuge chamber and adjusting the oxygen concentration level.
- Instructions on the use of capsules in the case of an emergency rescue through a borehole.
- Knowledge of water, seals, and how areas of higher elevation could change the escape route during an inundation.
- Instructions on the use of a multigas detector as an escape tool.

Some of the SEC that trainers listed above were described more generally on the checklists provided, but trainers asserted that more in-depth training was needed in certain areas. For instance, although we listed “where to find a first-aid kit,” as a training competency, there was no competency listed about how to use this first-aid equipment, particularly in an emergency situation. As one trainer noted, MSHA does not have first-aid training requirements for miners, with the exception of those involved in mine rescue teams. So, perhaps adding a competency about realistic expectations regarding the application of first-aid methods may be appropriate.

Self-escape Competencies that Trainers Assessed in Mine Safety Training

This section of the interview explored assessment methods used by mine safety trainers. We wanted to learn what assessment methods are commonly used by mine safety trainers. Trainers were given a list of potential assessment methods:

- Watch each individual perform a task.
- Provide written exams.
- Orally question a group of students or the class.
- Watch groups perform a task under simulated conditions.
- Use other methods.
- I have not evaluated this competency.

Tables C6–C8 display separate results for the individual level (i.e., watching each individual perform a task or taking a written exam) and the group level (i.e., orally questioning a group of students or watching groups perform a task under simulated conditions). The totals for individuals and groups also include other methods that trainers noted that they use to evaluate SEC. A couple of trainers indicated that they evaluate an individual by asking him/her to show them the task. For example, one trainer explained that instead of just watching a mine worker try to read a mine map, he asks each worker to go through the map step by step, and explain how to escape from a particular location. Or, some trainers noted watching an individual perform a task under simulated conditions, rather than the group as a whole. This situation was often specific to donning SCSRs. In general, however, other methods of assessment were seldom offered throughout the interviews.

Table C6 indicates the number of trainers who reported assessing whether or not a mine worker knows a specific SEC. In general, trainers explained that when they want to assess whether a student knows something, they will administer some sort of written exam or quiz and then follow up the exam with an oral question-and-answer session that involves the entire class. They felt this combination of individual and group level assessment helped them determine whether students grasped a certain topic.

Next, trainers were asked how they assess whether or not mine workers know how to use something that can enable self-escape during an emergency. Table C7 reports the frequency of trainers who indicated the different ways that they assess whether individuals know how to use something during an emergency that requires self-escape. As the table shows, besides watching individuals don and switch SCSRs, which all trainers reported doing, there was not much consistency in the methods trainers reported using to assess whether an individual is competent in using SEC tools.

Table C8 also reports on assessment methods used by trainers to evaluate mine workers' self-escape competence. Researchers inquired whether trainers assess mine workers' ability to make decisions during an emergency that requires self-escape. Trainers primarily indicated written and oral questioning as methods they commonly use to assess mine workers' competence in knowing what to do during a mining emergency. Trainers seldom reported "watching" an individual or group progress through a decisionmaking process. Those trainers who did indicate engaging in such an assessment often had the ability to use a simulated mine in which they could simulate an emergency and watch individuals decide whether or not to fight a fire or watch a group engage in a discussion about whether or not they should take refuge.

Observation of the Individual

In general, we were more focused on the ways that trainers assessed competence at the individual level. Therefore, we probed the ways in which trainers conducted their individual-level assessments and any other methods they used. Trainers were asked, "How do you decide whether an individual miner is sufficiently competent at [SEC]?" Normally, trainers indicated that they can assess competency through general observation of the individual. A common response to this question was, "Just by watching them, you can tell if someone is struggling." One trainer used donning an SCSR as an example when he explained that, after a student finishes donning the unit, he can assess whether or not the student correctly followed the steps during the procedure.

Written Exams

Of the trainers who used written exams, a majority reported having trainees do a self-check of their test answers but not collecting the results. Similarly, when trainers were queried about whether they kept documentation on any individual-level assessments of miners' SEC, trainers commonly replied, "I don't keep tests they perform. I administer the test and then review it. They keep it or trash it; we don't file it." However, a couple of trainers noted doing pre-tests and post-tests if the content is newer or conducted as a part of an MSHA regulation. As one trainer said, "If it's something they're signing off on (e.g., certified to use gas meters), it goes with that documentation in their file."

Table C6. Frequency of “Knowing” SEC individual and group level assessment (N=9)

Assessment of whether miner “Knows What to do” in an emergency that requires self-escape	“Yes” (n) to Watch Individual	“Yes” (n) to Provide Written Exams	“Yes” (n) to an Individual-level Assessment	“Yes” (n) to Orally Question Group	“Yes” (n) to Watch Group	“Yes” (n) to a Group-level Assessment
The 5 tactile shapes on a lifeline and what they mean	3	5	7	7	4	7
Alternative methods for navigating your way out of the mine (besides lifeline)	2	5	6	7	3	7
What types of information need to be communicated to the responsible person and to people in other sections	1	5	5	7	2	7
How to communicate nonverbally while using SCSR (both to coworkers underground and to outside persons)	4	2	6	5	2	5
How to read/understand a mine map	1	5	5	6	1	6
How to navigate through smoke	4	1	6	3	4	6
Properties of mine gases	2	8	8	6	2	6
How the mine ventilation system functions	1	6	7	4	1	4
What supplies and equipment to take during an escape	1	3	4	5	3	6

Table C7. Frequency of “How to Use” SEC individual and group level assessment (N=9)

Assessment of whether miners know “How to Use” something during an emergency that requires self-escape	“Yes” (n) to Watch Individual	“Yes” (n) to Provide Written Exams	“Yes” (n) to an Individual-level Assessment	“Yes” (n) to Orally Question Group	“Yes” (n) to Watch Group	“Yes” (n) to a Group-level Assessment
Communication systems	4	1	5	4	3	4
Gas meters	6	3	6	4	1	4
SCSRs (donning and switching units)	9	5	9	3	5	6
Refuge chambers	3	3	5	3	4	5
Lifelines and tethers	4	3	6	5	2	6
Transportation equipment	2	3	5	4	1	4

Table C8. Frequency of “How to Decide” SEC individual and group level assessment (N=9)

Assessment of whether miners “ How to Decide” during an emergency that requires self-escape	“Yes” (n) to Watch Individual	“Yes” (n) to Provide Written Exams	“Yes” (n) to an Individual-level Assessment	“Yes” (n) to Orally Question Group	“Yes” (n) to Watch Group	“Yes” (n) to a Group-level Assessment
The best evacuation route	1	2	5	7	2	7
When to don SCSRs	1	5	7	7	3	8
When to use a refuge chamber	1	3	5	5	3	7
Whether to ride or walk out	1	2	2	5	1	6
Whether to attempt to fight a fire, and when to abandon such efforts	2	3	5	6	2	6

The Selected Best Methods for Individual Assessment

The frequency for each assessment technique is displayed in Tables C9–C11, grouped by SEC type (i.e., knowing, how to use, and how to decide).

Table C9. Perception of best methods to assess individuals’ competencies of “Knowing” something (N=9)

Best individual assessment for “Knowing” something to self-escape	Watch Individual	Written Exams	Orally Question Individual	Watch Small Groups
The 5 tactile shapes on a lifeline and what they mean	4	7	4	1
Alternative methods for navigating your way out of the mine (besides lifeline)	3	2	5	1
What types of information need to be communicated to the responsible person and to people in other sections	5	5	6	2
How to communicate nonverbally while using SCSR	5	2	5	2
How to read and understand a mine map	5	5	2	1
How to navigate through smoke	6	2	1	4
Properties of mine gases	4	6	7	0
How the mine ventilation system functions	4	4	6	1
What supplies and equipment to take during an escape	0	6	3	1

Table C10. Perception of best methods to assess individuals' competencies of "How to Use" something (N=9)

Best individual assessment for "How to Use" something to self-escape	Watch Individual	Written Exams	Orally Question Individual	Watch Small Groups
Communication systems	7	2	3	0
Gas meters	7	3	2	0
SCSRs (donning and switching units)	8	2	2	2
Refuge chambers	5	2	3	3
Lifelines and tethers	6	2	3	3
Transportation equipment (mantrip, hoist)	0	2	3	1

Table C11. Perception of best methods to assess individuals' competencies of "How to Decide" something (N=9)

Best individual assessment for "How to Decide" something to self-escape	Watch Individual	Written Exams	Orally Question Individual	Watch Small Groups
The best evacuation route	0	3	5	2
When to don SCSRs	0	5	6	2
When to use a refuge chamber	0	3	5	2
Whether to ride or walk out	0	4	8	2
Whether to attempt to fight a fire, and when to abandon such efforts	3	5	8	3

Summary of Best Assessment Methods to Evaluate Miners' Self-escape Competencies

Although the results for the individual assessment methods, particularly for watching an individual perform a task, administering a written exam, or orally questioning an individual, are similar, different methods were warranted "best" depending on the different competency areas. For example, in general, when assessing whether or not an individual miner has proficient knowledge, trainers noted that a written exam or orally questioning each mine worker are the best methods to evaluate competence. However, when assessing whether or not a mine worker knows how to use something, trainers more often felt that watching the individual perform the task was most beneficial in evaluating competence. Finally, when assessing how to make a decision during a particular emergency, a majority of trainers deemed orally questioning each miner as the best way to evaluate their competency. In general, trainers noted that, although

watching small groups is sufficient for activities that would be performed in groups during an emergency, such as tethering and walking out in smoke, it was not the preferred method for evaluating individual competence.

Trainers were able to document a combination of assessment methods if they felt that more than one would be best at assessing a competency. Although there was not much consistency from trainer to trainer, most indicated that a combination of methods (e.g., watching and orally questioning an individual) was best for assessing individual competence. Trainers felt that the combination of assessment methods was particularly useful when using written exams, especially when a literacy barrier exists. They felt that providing a written exam needed to be followed up by oral questioning or demonstration. These results continue to indicate the importance of using different assessment methods, based on the competency being evaluated.

Feasibility of Assessment Methods

Trainers advocated for individual level assessments, when possible. One trainer summarized this assertion when he said,

Individual demonstrations, in most cases, are better than group demonstrations, apart from escape routes, refuge chambers, and tethering, which are group decisions. The latter decisions (escape routes, taking refuge, tethering) are made by groups and are best evaluated by observing a group. But more often than not, trainers should evaluate on an individual basis. If mine workers are in a group, one can sit back and do nothing, and absorb nothing.

Although individual competency assessment methods and some group-level assessment methods may be more desirable than others in determining proficiency, these methods are not always practical. Therefore, we probed trainers about the feasibility of using common assessment methods to evaluate the miners they typically train. When responding to each prompt, trainers were asked to consider the amount of time and resources needed to use each technique. Trainers were given a response card with the following feasibility options:

1. It would be very easy to do.
2. It is feasible but would require a little more time, effort, resources.
3. It is feasible but would require substantially more time, effort, resources.
4. It is not feasible at all.

The mean scores for the feasibility of assessment methods for each training scenario provided to the nine trainers are presented in Table C12. These mean scores are based on the average of each trainer's selection of one of the four feasibility options above for each assessment technique provided.

Table C12. Trainers’ perceived feasibility of assessment methods (N=9)

Assessment technique	Mean
Have each miner demonstrate a procedure in a classroom setting.	2.2
Have each miner demonstrate a procedure in a mine.	2.7
Have each miner respond to a written test or quiz.	1.1
Orally question each miner to see if he/she understands a concept.	2.3
Describe a potential emergency and ask each miner questions to see if he/she knows what to do to self-escape.	2.1
Have each miner respond to a computer-based training simulation to see if he/she would know how to respond to various emergency scenarios.	2.4
Have each miner show you on a map the best way to evacuate the mine from various locations.	1.7

As the feasibility list we provided to trainers shows (numbered 1–4 above Table C12), a lower number indicates that the assessment method is more feasible. Although we are not able to provide statistically significant means, these data points in Table C12 reveal that trainers felt most of these assessment methods were feasible, but required more time and resources. Taking written tests or having a mine worker show a safety trainer something on a map were the only two assessment methods that were discussed as being very easy to complete in a new miner training.

Simultaneously, trainers were asked to discuss the strengths and limitations of each method. Although trainers’ feedback was dependent on a particular procedure that they were thinking of, they usually noted time, resources, and logistics as major limitations. A universal response was, “Anytime you focus more on the individual it bumps up the time and resources needed.” For example, one trainer said in reference to demonstrating a procedure in a classroom setting, “If you have 25–30 people in a class, you still need 25–30 SCSRs because you would have the logistics of putting them back together if you did not (have enough SCSRs for every individual). So, even if we have done it (have each miner demonstrate a procedure), it’s still time-consuming and takes a lot of resources.”

However, despite the barriers to implementing assessment for scenarios in which trainers were thinking of how to use something (e.g., an SCSR, gas meters, etc.), trainers were quick to say that using higher fidelity methods to evaluate skills, such as in an individual demonstration in a classroom or in a simulated environment, is the best way to validate proficiency, as evident in Table C10, referenced earlier.

As far as orally questioning miners to see if he/she understands a concept or having them show the trainer how to complete a task, such as how to best evacuate a mine using a map, trainers still noted that it takes time, but is much more feasible. Similarly, written tests were noted as an easy assessment technique, allowing trainers to measure where each individual stands in terms of knowledge. However, several trainers referenced literacy as an issue that needs to be addressed whenever anything written is provided at safety training.

In terms of computer-based training simulations, many trainers noted that these activities can be exciting for younger students, but it does not always work well with older, more experienced mine workers who are not as comfortable using computers. Even if trainers did not specifically reference age as a barrier to this assessment, they referenced general technology competence. Trainers noted that some miners may not even own a computer or know how to turn on a computer. In addition, having enough computers for every mine worker is challenging and not always feasible. Overall, because of resource allocation and time limitations, most trainers did not indicate that any one technique was easy *and* feasible.

Using e-trainings or other computerized programs may help enhance the time allotted for hands-on activities and assessment. Besides using interactive programs to help adhere to training time constraints, trainers may be able to keep better records of training assessments while also maintaining the interest levels of younger generation mine workers.

Mine Workers' Ability to Demonstrate Self-escape Proficiency

Another section of the interview probed trainers to think about the proportion of mine workers they train, and evaluate miners' proficiency in different assessment situations. Trainers were provided with three questions and asked to respond with one of four options. Table C13 shows the results for each of these questions.

Table C13. Trainers' perceived proficiency of mine workers' skills (N=9)

Situation	(n) Who Said < 10%	(n) Who Said < 25%	(n) Who Said 25%–50%	(n) Who Said >50%
Of the coal miners you are familiar with, what proportion would have difficulty getting out of the mine on their own?	5	1	1	2
Some miners may actually have the knowledge and capabilities required to self-escape, but they would have difficulty demonstrating their proficiencies on a written test. Of the coal miners you are familiar with, what proportion would fall into this category?	2	3	3	1
Of the miners who would have difficulty demonstrating their proficiencies on a written test, what proportion would perform better on a behavior assessment?	0	0	1	8

These responses suggest that miners may be better able to demonstrate their proficiencies in a behavioral assessment rather than a written assessment. This observation has implications for further integrating higher-fidelity behavioral assessments, rather than written assessments, into new miner safety training. If this occurs, it is possible that the response to the first prompt, miners being able to escape on their own, would increase.

To delve deeper into this issue of miners’ ability to get out of the mine on their own, we asked trainers to list primary reasons why some mine workers might have difficulty escaping from an emergency. Trainers were not provided any prompts or examples of why some miners may not be able to escape on their own. However, the responses from the trainers were all similar. The distribution of results was shown in Table C14.

Table C14. Reasons why a mine worker cannot self-escape during an emergency

Reason why a mine worker cannot self-escape	<i>n</i>
Has physical limitations (e.g., fitness, stamina)	8
Does not know the escapeways	7
Has fear and anxiety	6
Does not pay attention during ride into the mine	5
Assumes others will lead him/her out	4
Cannot read a mine map	3
Feels complacent with mine environment and job	3

Remediation

Another section of the interview discussed the issue of remediation. We acknowledged during the interview that people learn things at different rates, meaning some mine workers may need more instruction or practice than others to become proficient at self-escape. Then, we asked trainers if they ever suspected that a miner in attendance at one of their training’s needed additional practice on a specific self-escape competency. A majority of trainers answered yes, prompting us to probe and ask them to provide the competency area(s). The common deficits trainers discussed are listed below:

- Don and switch SCSRs (both in and out of a simulated environment).
- General decisionmaking during simulated escape exercises.
- Communication with their group about escape routes.
- Reading a mine map.
- Tethering.
- Types of gases and their appropriate ranges.

Miners’ ability to don and switch their SCSRs, especially in a simulated smoke environment, was discussed as the primary skill in which miners experience difficulty during training. As one trainer said, “Skills for SCSR donning degrade rapidly. And, all of the different types of SCSRs that are on the market that we use just compound the problem.” Generally, trainers noted that miners often are clumsy with their SCSRs, don’t go through the steps correctly, and in a simulated emergency may don too soon or not at all.

Similar to what they said at the beginning of the interview about SEC assessment, trainers noted that they often know when individuals need more training in a particular area because they can observe the miner(s) struggling. Particularly for those trainers who had access to a simulated mine, they could observe miners while they were demonstrating a task. Observing skill deficit is easier in a simulated emergency, and as one trainer exclaimed, “Just because they can tell you how to do it, it doesn’t mean they would be able to do it, in smoke, in the escapeway.”

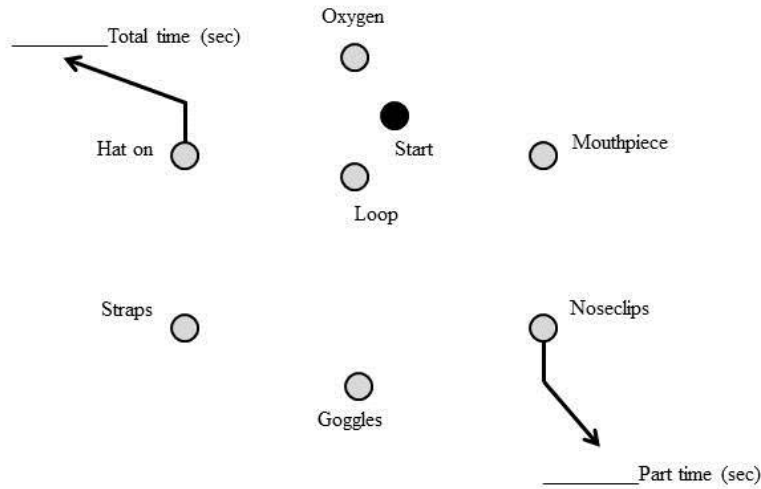
Generally, trainers indicated that they spend extra time with a person and/or group who may be struggling by offering individual instruction and then walking them through the task again. Or, some trainers set up a new scenario for a group to act out to help enhance confident decisionmaking. Regardless of the type of feedback provided, several trainers noted that they must communicate in a nonthreatening way to miners, which includes an open but noncritical discussion of what the miners did right or wrong and why.

In reference to followup assessments, it is worth noting that because several of the trainers were trainers that were not directly affiliated with a particular mine, they are not the ones who have to keep documentation. Rather, they indicated that each individual mining organization should keep documentation about a mine worker’s skill sets. One trainer explained, “It’s difficult for us as a third party because they’re not our employee. So we provide a list of names to the mine for them to follow up with after the training.” Such followup is very important. Mining companies need to actively solicit input from trainers about which knowledge, skills, and abilities (KSAs) each miner has mastered and the ones on which he/she needs additional instruction or practice. The transmittal of these details from mine safety trainers to the mine workers’ employer is necessary in continuing to develop mine workers’ SEC throughout their careers as underground coal miners.

Appendix D: SCSR Donning Sequence Evaluation Sheet

Evaluation for _____ Date _____
Mine _____ Trial # _____
Type of unit _____

1. Connect the dots in the diagram below to show the steps the trainee took in donning the SCSR. If a step was started but not finished, dip the line toward the step. Do not touch the dot if the step was not completed or was done incorrectly.



2. After the task is completed, please list any errors that need to be corrected and then review these errors with the trainee.

Figure D1. SCSR donning sequence evaluation sheet.

Appendix E: Description of Methods and Remediation Efforts Used by NIOSH to Assess a Self-escape Competency

In 2009, a federal regulation [30 CFR[†] 75.380] was passed requiring coal mine operators to install escape lifelines. They are literally lines installed along mine passageways that miners can grab onto and follow out of the mine during an emergency. Five types of tactile signals must be installed on the lifeline to provide an additional navigational tool to help miners escape in the event of an emergency. Lifelines can be especially helpful when miners must escape on foot in conditions of very low visibility (i.e., due to smoke or the absence of light). The tactile signals (Figures E1 and E2) include:

- Directional cones to indicate the direction miners need to go to exit the mine.
- A coil to indicate a refuge chamber.
- Two sets of double cones (diamonds) to indicate an SCSR cache.
- Two directional cones in a row to indicate a branch line.
- A ball to indicate a personnel door (i.e., man door).



Figure E1. Lifeline Signals sticker.

Despite the implementation of the new lifeline safety feature, mine workers may not always remember what the signals mean, especially in an emergency situation. It is important that mine workers are able to identify the signals reliably because it could save them a significant amount of time while trying to escape.

[†] Code of Federal Regulations. See CFR in references.

Description of Field Test

In 2010, a team of NIOSH researchers assessed the ability of 345 coal mine workers who worked at a large western coal mine to correctly identify the five lifeline tactile signals. They participated in both a written and a hands-on behavioral assessment of their knowledge. During their regularly scheduled safety training classes (during the months prior to the NIOSH field tests), the mine’s training staff had explained to all miners the purpose and placement of lifelines and the meaning of the five tactile signals.

Behavioral Assessment

Immediately following their annual underground smoke expectations training, the miners ($n=345$) were asked to walk a 100-foot length of lifeline in theatrical smoke and to identify each lifeline tactile signal they came across. This lifeline was set up to ensure that each participating mine worker would have to identify all five signals. To make the test realistic, multiple instances of some signals were used (i.e., there had to be a branch line indicator for each of two branch lines—one for an SCSR cache and one for a refuge chamber). There were a total of eight signals on the line, including three directional cones, two branch line signals, one personnel door signal, one SCSR cache signal, and one refuge chamber signal. A NIOSH researcher walked with each miner and recorded whether the individual identified each of the eight signals correctly or incorrectly. As the miner came to each signal along the lifeline, he/she was asked to specify what it indicated. For example, the miner might say “refuge chamber” when he/she felt the coil on the line, which would be correct. Table E1 presents the distribution of scores. Of the 345 coal miners, 78% had a perfect score (8 out of 8 correct).

Table E1. Behavioral assessment scores breakdown

Score	<i>n</i> out of 345	Percentage of miners (%)
8	269	78
7	22	6.4
6	27	7.8
5	12	3.5
4	12	3.5
3	3	0.9
2 and below	0	0

Written Matching Tests

Immediately following the completion of their behavioral test, each miner was also asked to complete a matching exercise (Figure E2). Each miner was asked to review a one-page map that showed all five lifeline signals and to match the number for each signal with the correct label for that signal in a provided word bank (see Figure E2). Of the 345 miners, 89.3% had a perfect score (5 out of 5). The average score was 4.76. The distribution of scores on this matching test is shown in Table E2.

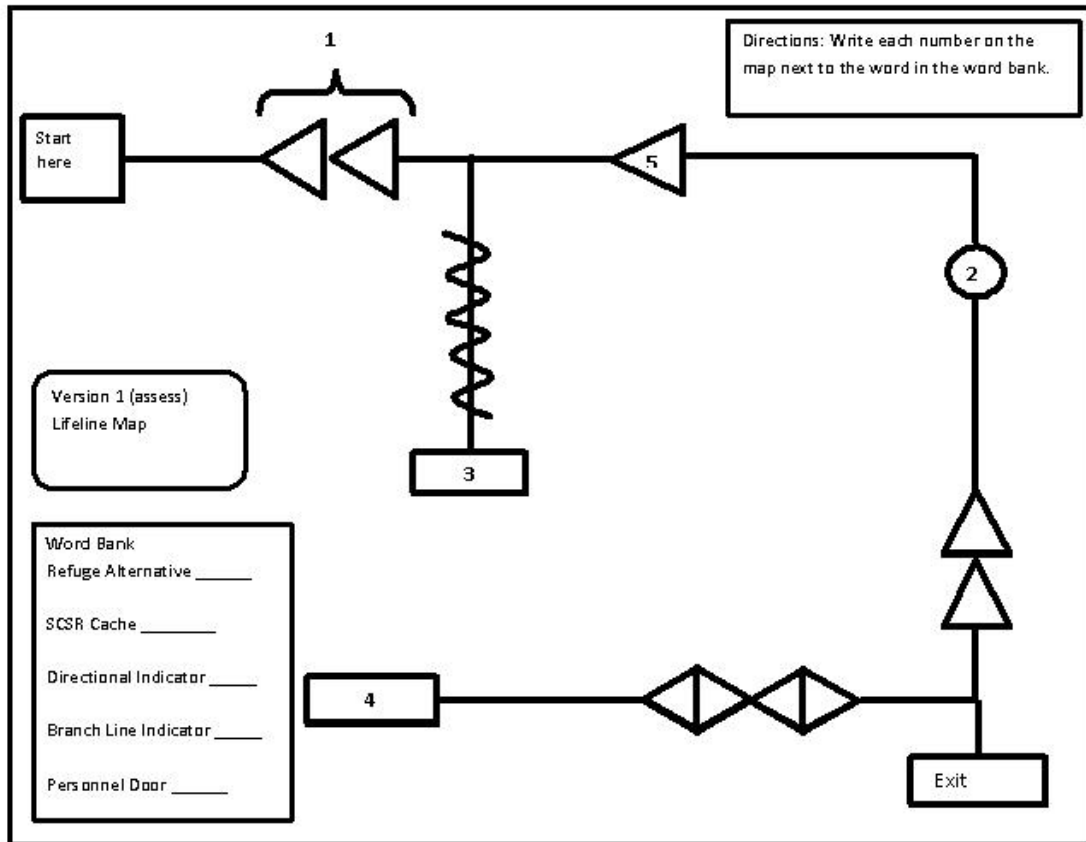


Figure E2. Map used for the written matching test.

Table E2. Scores on written matching test

Score	<i>n</i> out of 345 with score	Percentage with test score (%)
5	308	89.3
4	5	1.4
3	21	6.1
2	7	2.0
1	4	1.2
0	0	0

Mean score = 4.76

Frequent Mistakes and Misconceptions

In the written matching test, out of the five signals, the branch line, refuge chamber, and SCSR cache signals were the most frequently misidentified. The signals for branch line (two cones) and SCSR cache (two sets of double cones) may be confused with each other because both signals are made up of a combination of multiple cones. The signals for SCSR cache (double diamond) and refuge alternative (coil) may be confused with each other because they are the two signals that denote what might be at the end of a branch line.

Researchers also received some verbal feedback from mine workers that revealed a few misconceptions. For example, some miners incorrectly called the branch line signals “change of direction” indicators and interpreted to NIOSH researchers that the signal meant that the lifeline was changing directions. Also, some miners knew the correct meaning of the signal, but felt that it was necessary to follow every branch line while escaping on the lifeline.

Recommendations for Lifeline Tactile Signal Training

Based on the results of this SEC assessment, several recommendations emerged from the study for trainers involved in helping mine workers improve their recognition of lifeline tactile signals:

1. Incorporate frequent lifeline tactile signal refresher training sessions using simple flashcards. Refresher sessions can be conducted during preshift safety and informational meetings above ground or below ground at the start of a shift or during a meal break. Refresher sessions can be conducted in large groups or one-on-one. Reviewing the lifeline tactile signals using the flashcards will take only a few minutes. Templates for making flashcards are available from NIOSH [2011].
2. Emphasize the differences between signals that are commonly confused. The signals for branch line (two directional cones) and SCSR cache (double diamond) are often confused because both signals involve a combination of multiple cones. The signals for SCSR cache (two sets of double cones) and refuge alternative (coil) are commonly confused

because both signals appear on branch lines. One miner stated that he remembers the signal for SCSR cache by remembering that SCSR has four letters and the signal is made up of four cones. Trainers can ask miners to suggest other methods that they use to remember what the signals mean.

3. Correct miners' misperceptions about branch lines. Some miners incorrectly called the branch line signals "change of direction" indicators and interpreted to NIOSH researchers that the signal meant that the lifeline was changing directions. Inform miners that the double cone signal does not indicate a change in direction of the main lifeline, but instead, indicates a branch line leading to either an SCSR cache or a refuge chamber.
4. Remind miners that branch lines do not lead out of the mine; instead, they lead to an SCSR cache or refuge alternative. Miners should only follow a branch line during escape if they need to use or reach whatever the branch line leads to. Some miners knew the correct meaning of the signal, but incorrectly felt that it was necessary to follow every branch line while escaping on the lifeline.
5. Use stickers and posters as a useful memory jogger (see example in Figure E1). Some coal companies are giving their mine workers reflective stickers that show the shapes of the five lifeline signals. This helps to reinforce what mine workers are taught during their new miner and annual refresher safety training sessions.
6. Trainers should consider making up a short length of lifeline with the tactile signals attached, and use it during training sessions to provide mine workers with hands-on practice in identifying the meaning of the signals.
7. The results of the assessment suggest that it is advisable to use both hands-on and written methods for assessing the recognition of lifeline tactile signals. Combining the two approaches appears to be more effective than using only a written test. For various reasons (e.g., test-taking anxiety or low literacy), some people have trouble performing well on written tests even though they may be capable of performing appropriately during an emergency.

These recommendations are similar to the gaps that emerged during discussions with mine safety trainers. Eventually, all SEC should be assessed frequently, and multiple methods should be used to evaluate competence. In addition, remediation and frequent assessment efforts can be improved via stronger communication between mine safety trainers and mining organizations.



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