A Review of NIOSH and US Bureau of Mines Research to Improve Miners' Health & Safety Training

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ABSTRACT

This paper reviews NIOSH and US Bureau of Mines research to improve miners' health and safety training. The program began in the late 1970s--after Federal Mine Safety legislation had been passed requiring all mine operators to provide formal safety and health training to miners on a regular basis. These regulations offered unique opportunities for conducting research to improve miners' training. Initial efforts to provide safety and health training were often found lacking in several respects. This paper describes how miners' safety and health training has improved since the 1970s, and identifies areas where further improvements are needed.

INTRODUCTION

This paper presents highlights of a federal government research program to improve miners' safety and health (S&H) training that has existed for more than 30 years. The program began in the US Interior Department's Bureau of Mines in the 1970s. In 1996, the Bureau of Mines was closed, and the mine safety and health research function was transferred to the Centers for Disease Control's National Institute for Occupational Safety and Health (NIOSH). NIOSH continued the Bureau's mine safety training research program, without interruption, to the present. Throughout the remainder of this paper, the mine safety training research carried out by the Bureau of Mines and NIOSH will simply be referred to as ―government research". The information presented in this paper is organized into the following major sections: 1) overview of three decades of mine safety training research; 2) examples of major research accomplishments; 3) future mine safety training research needs; and 4) concluding remarks.

OVERVIEW OF THREE DECADES OF MINE SAFETY TRAINING RESEARCH

The scope of this paper is limited to mine safety training research that has been conducted or funded by the federal government since regulations were passed requiring mine operators to provide such training. The Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173) contained specific language regarding safety training for coal miners (United States Public Laws 91st Congress - First Session 1969). The Federal

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Mine Health and Safety Act of 1977 (Public Law 95-164) expanded these requirements to metal and nonmetal mining, and mandated training for all individuals on mine property who met the definition of ―miner" (United States Public Laws 95th Congress - Second Session 1977). These acts significantly increased the funding available for mine S&H research by the US Bureau of Mines. The government's mine S&H training research program was implemented during the mid 1970s. Like the 1969 Mine Act, it started with a focus on the coal industry. In the 1970's the coal mining industry was establishing or strengthening training programs to meet the new legal requirements. Training research was ―directed toward assisting the mining community in structuring, formalizing, and evaluating training investments" (Pittsburgh Research Center Staff 1981). After 1978, it was directed at the training requirements found in Title 30, Part 48 of the US Code of Federal Regulations (CFR 2009). Some of this initial work was conducted by government researchers, but the majority was completed by non-government contractors. Researchers gathered baseline information about the state of mine training, developed guidelines for conducting and evaluating training, and created instructional materials about basic mining tasks and activities. Details of this work can be found in Informational Circular Report 8858, ―Mine Safety Education and Training Seminar Proceedings" (Pittsburgh Research Center Staff 1981). Along with the development of user-ready training materials, these contract projects covered topics such as 1) assessing the impact of training on accident rates, 2) methods to improve instruction in the classroom and on-the-job, and 3) the development of training simulators. Deficiencies identified during the research of the 1970's pointed the way for future work in areas such as training evaluation and the need for professional development for mine trainers.

At the end of the 1970's and early in the 1980's research on training for non-routine situations was added to the program. The Federal Mine Safety and Health Act of 1977 required mine rescue teams for all underground mines. The government supported training for the team members through a contract to design instructional materials (Pittsburgh Research Center Staff 1981). Training materials were designed for both small and large metal-nonmetal and coal mining operations. These training exercises included problem-solving activities, which became a component of many future training research and development projects.

During the 1980s, government researchers expanded their focus on training to prepare miners for non-routine emergency situations. During this same time period, the employment of new miners significantly declined, lessening the demand to make advances in new miner training about routine mining hazards. In addition, disasters at the Clinchfield Coal Company (1983) and Wilberg (1986) brought the reality of mine disasters to the forefront. Attempts to address the deficiencies identified in post-event analyses of those disasters led to training research and development in the areas of emergency decision-making and use of personal protective equipment—most notably the donning procedure for Self-Contained Self-Rescuers (SCSR). Along with these two disasters, three coal mine fires occurred between 1988 and 1990 which had the potential to have caused major loss of life. Government researchers conducted in-depth interviews with 43 survivors of those events. The information gained through these interviews led to significant advances in knowledge about human behavior during escape from mine fires.

The results from this investigation led to many publications including several sets of training materials and a book (Vaught, Brnich, Mallett, Cole, Wiehagen, Conti, Kowalski, and Litton 2000). These materials have been used extensively, and have served as the basis for changes in mine emergency response training regulations.

In the years between 1992 and 2001, there were no major mine disasters in the United States. The economics of the 1980's and 1990's had created an environment where few new miners entered the industry. Mine employees were primarily experienced workers who planned to stay in their jobs for some time. The training research conducted during the 1990's reflected this relatively stable period. Research was conducted to improve training on both routinely and non-routinely used skills. For example, topics included emergency warning and escape strategies, as well as the hazards of roof falls and the need to stay away from unsupported roof (Peters 1992). Also, work directed at a growing population of contract workers and of workers at small mines was started.

As the year 2000 approached, concern grew regarding the training needs of the future mining workforce. The baby-boomer, experienced workforce began thinking about retirement. Mine trainers saw a population of increasingly older workers caused by the hiring gap in the 1980's and 1990's and began to think about the potential problems associated with bringing in large numbers of new employees within a short period of time. Because the complexity of mining equipment and miners' jobs had increased dramatically over the past 40 years, these new miners would need a substantial amount of training to get them up to speed quickly. Government training researchers started addressing the needs of this new generation of miners in two ways. Questions regarding appropriate training methodologies for them were explored and support for the trainers who would be preparing them was developed. The generation of miners who began their career shortly after the new millennium was expected to be better educated and more technologically savvy than those who had started during the previous hiring boom of the mid 1970's. Many safety professionals believed that these two cohorts of miners would require different approaches to training. The trainers who would be teaching them would need to understand (1) how to use new training delivery technologies, and (2) would need to employ new styles of instruction. Details of the research conducted to help trainers address these changes can be found in three NIOSH Information Circular Reports (Kowalski-Trakofler, Vaught, Mallett, Brnich, Reinke, Steiner, Wiehagen, and Rethi 2004; Peters 2002; Vaught and Mallett 2008).

In 2006 and 2007, mine disasters again caught the attention of the nation. The deaths at Sago, Darby, and Crandall Canyon were seen as a call to action by many. Analyses of these events identified problems that needed, in part, training solutions. In response, training research and development has recently been conducted in the areas of 1) switching between SCSR units, 2) the use of refuge alternatives, 3) communication during emergencies, 4) emergency mine evacuation, and 5) decision-making during mine emergencies. But NIOSH's training researchers are not focused exclusively on improving emergency response training. Significant research and development is also underway to help trainers make the best use of new computer based technologies in the classroom and in other training venues. Computer-based technologies hold much potential for training both new and experienced miners about routine and non-routine workplace hazards (Mallett and Orr 2008).

EXAMPLES OF MAJOR TRAINING RESEARCH ACCOMPLISHMENTS

The government's mine safety training research program can be divided into two major categories: (1) training miners how to respond to mine emergencies, and (2) training miners to recognize and respond to more routinely encountered hazards. This latter focus has been especially important for new miners because, without proper training, they will not understand the types of hazards that are inherent to their new work environment. Because miners do not routinely utilize the knowledge, skills and abilities they would need to respond to mine emergencies, there are some important differences in the training strategies that must be used in order to maintain their emergency response competencies at an acceptable level. The next two sections present examples of the research performed to improve miners' training on each of these two important areas of mine safety.

Improving Miners' Ability to Respond to Mine Emergencies

Unlike skills such as the ability to recognize and avoid hazards, which are employed in the workplace every day, there is another set of skills miners need that they may seldom (if ever) employ in the course of their career. These skills come into play if they should get caught up in problems involving fires, explosions, or other catastrophic events. In such situations they need to be able to gather information, analyze risks, communicate with each other, and make informed judgments and decisions. If they can do that, their actions may prevent or limit some of the worst consequences of the problem they are facing (Cole, Berger, Vaught, Haley, Lacefield, Wasielewski, and Mallett 1988). If they are lacking these non-routine skills, however, manageable problems may quickly get out of hand. University of Kentucky (UK) researchers, working on a Bureau of Mines contract, identified two critical non-routine skill domains that needed to be addressed through training and assessment: 1) self rescue, which requires task training to proficiency on devices needed to cope with the situation, particularly SCSRs; and 2) escape, which requires, among other things, training in the area of judgment and decision making.

Self-contained self-rescuers

The SCSR studies began in the summer of 1985 when UK project staff interviewed 50 mine safety experts about SCSR usage. The key finding from these interviews was the fact that most underground coal miners never actually put the apparatus on. Instead, procedures for donning the unit were covered in annual refresher classes and were typically explained by a trainer who stood before the class and demonstrated the steps involved (Cole et al. 1988).

SCSR donning is a motor task, and the only effective way to teach a motor task is to have the trainee learn by doing (Schmidt 1988). The researchers decided to develop one universal hands-on donning task. They used a procedure in which the miner would kneel, loop the neck strap, activate the oxygen, insert the mouthpiece, put on the nose clips, put on the goggles, complete tying the straps, replace his or her cap, and be ready to travel

(Vaught, Brnich, Wiehagen, Cole, and Kellner 1993). The ―3+3” donning method had some compelling features other than just the fact that it would be easy to teach and learn. First, it could be applied to all apparatuses so that instruction would be the same for each one. Second, because of this, every donning performance regardless of the unit being used could be evaluated the same way. Third, due to the donning procedure's simplicity, it should be possible to develop a simple evaluation instrument. A ―connect the dots” evaluation form was developed. This device could show sequencing errors and actions done incorrectly so that the evaluator could see, in graphic detail, how each person had performed.

A second feature of motor tasks is that people forget over time (Hagman and Rose 1983; Johnson 1981). To explore this aspect of motor tasks a team of government researchers worked with a coal mine in the west. They trained the mine's workforce to the point that each miner was able to perform a perfect donning sequence on the day he or she was trained. Then these trained miners were divided into two groups (a control group and an experimental group) from which samples would be taken during the ensuing year. These samples were drawn without replacement every three months. The control group received no additional training during the year. At nine months no one sampled from this group was able to don his or her SCSR proficiently. The experimental group had SCSR practice and evaluation added as part of their escapeway travel (every 45 days) and fire drills (every 90 days). At the end of the year 65 percent of those sampled from the experimental group were still able to perform a perfect sequence. While this study was only one in a series, it is the one that cut to the heart of the matter: workers need to be well trained initially and then given the opportunity to practice regularly. Additionally, it could be argued that the best place to do this is in the workplace.

In 1993 the research team published recommendations from lessons they had learned from their studies: 1) only one procedure should be taught; 2) training should be hands-on, with evaluation and feedback; 3) training ought to be conducted in-mine to minimize the interruption of production; 4) hands-on practice should be scheduled as part of fire drills and other emergency preparedness routines; 5) training models with easily cleaned and replaceable mouthpieces ought to be used; 6) distributed mental rehearsals could be provided between hands-on practice sessions; and 7) trainers should sample their workforce periodically and do spot evaluations in order to keep track of proficiency levels, with remediation given as needed (Vaught et al. 1993). Many of these recommendations have now been put into practice in the industry (US Department of Labor 2006).

Judgment and decision making

Having established judgment and decision making as a critical non-routine skill, the UK project team turned their attention to how it could best be taught and assessed. They sat in on many annual refresher classes in several states as observers, and sometimes as participants (Cole, Wasielewski, Lineberry, Wala, Mallett, Heley, Lacefield, and Berger 1988). They found that it was when there was an opportunity to discuss and resolve actual or realistic problems, often presented in story form (such as one trainer's account of a multiple fatality which had happened in Virginia) that they paid the most attention.

This was not too surprising because problem solving is an integral part of living, and problems often are posed in story form. The use of storytelling (or narrative) has been explored in the literature and shown to be the primary way in which people make sense out of things that occur in their daily lives (Clandinin and Connelly 2000; Cole 1997; Czarniawska 1997; Cullen and Fein 2005).

A good simulation presents an interesting and believable story that includes the teaching points the developers want to get across. In developing a simulation the researchers began with a problem, often taken from accident reports or from interview accounts by people who had been on the scene of a mine emergency. They would then turn the problem into a story that unfolded over time and had predicaments that the person working the problem would be required to deal with. As the story went along, there would be decision points that presented the trainee with an array of choice alternatives. Alternatives at each decision point in an exercise would consist of good choices and poor choices, but all of them plausible. For several reasons, one being their low cost and ease of use in miner training, the project team decided to develop paper and pencil simulations.

Once a simulation had been developed an instructor's guide and student workbook with an answer sheet were prepared. The workbook presented the story's decision points one page at a time. At each decision point in the story the trainee would make one or more selections among the choice alternatives on the answer sheet. The choices were printed in invisible ink, which he or she made visible with a special developing pen. Once developed, there was a response to each choice that gave feedback as to whether the choice was a good or poor one, and explained the reasons why. In this way the person working through the story received immediate corrective feedback where needed, and positive reinforcement when earned. The simulation, a form of programmed learning, proved to be an effective teaching device. In addition, however, the developed choices were a visible record of how the trainee performed at each choice point. So, it was also an embedded test (Cole 1994). The data from these tests could be examined to indicate where people were having problems and where remediation would be advisable. In addition, a trainer could get an idea of how effective his or her instruction was in any particular area. Therefore, in addition to being an effective instruction method, the simulations were inconspicuous measures that could be used for many positive purposes.

In all, there were 65 latent image simulations constructed by the UK staff, dealing with a variety of problems. They were field tested with a national sample of roughly 4,000 miners and found to be effective and reliable teaching and assessment instruments. There have been more than 400,000 copies of the answer sheets distributed in the US and abroad (Cole, Wiehagen, Vaught, and Mills 2001). And, simulations based on stories are still being developed – now by researchers at the NIOSH Office of Mine Safety and Health Research. Many of the interactive mine safety training simulations developed by government researchers have been converted to electronic delivery format by the Mine Safety & Health Administration, see http://www.msha.gov/interactivetraining.htm).

MERITS: A training simulation for emergency command center personnel

Near the conclusion of the UK contract work, government researchers began to focus their attention on training to improve the abilities of command center personnel to make good decisions at the outset of potentially disastrous situations. A computer-based training simulation titled ―Mine Emergency Response Interactive Training Simulation” (MERITS) was developed and tested (Mallett 2002). MERITS is an extension of previous work that compiled a knowledge base relevant to mine disaster management via interviews, analysis of literature, reviews of past events, and observations of mock mine disasters. The MERITS simulation is used to train emergency command center personnel to effectively manage an underground mine fire. Modeled after training simulations developed for other industries (e.g. nuclear, chemical, etc.), MERITS simulates underground and surface events related to the disaster. It exposes the user to events that typically occur during a mine emergency, such as lack of information and miscommunication. It also presents trainees with issues that must be addressed, such as briefing news media and victims' families, ordering supplies, interfacing with government enforcement agencies, and housing mine rescue teams. MERITS allows individuals who are typically present in a command center to practice information gathering, situation assessment, decision-making, and coordination skills without risk to personnel or property. The outcome of the scenario is determined by the users' decisions and their emergency response plans. Field tests have been conducted with several groups of mining officials. Evaluations conducted at the completion of the simulation suggest that MERITS is a very beneficial experience for those who may someday need to manage the response to mine emergency.

Improving Miners’ Ability to Respond to Routine Hazards
It is vital that miners be able to recognize and respond to common workplace hazards. Examples of two lines of research studies to improve miners’ training in this domain are provided: 1) visual hazard recognition, and 2) story telling videos.

Visual hazard recognition studies
The ability to perceive hazards is, perhaps, more difficult to achieve in underground mining than in other types of work areas because the work environment is confined, dark, and constantly changing due to the mining process. Workers must be alert and continuously cognizant of their surroundings. The information needed to recognize hazards is often available in the form of visual cues found throughout the workplace. Government researchers have conducted a series of studies on the effectiveness of novel approaches to improving miners’ abilities to *visually* recognize mining hazards. Two examples of these studies are described below.

Stereoscopic images. In order to realistically portray certain types of hazardous conditions in the workplace, it is very desirable to add cues that convey information about depth and/or distance. For example, cracks that indicate the potential for a structural failure are often almost impossible to perceive in conventional slides and photographs. However, stereoscopic (3-D) slides have been found to be quite effective at illustrating such features. Two research studies have found that 3-D images are superior to 2-D for the purpose of training underground miners to recognize various geological conditions that are known precursors of mine roof failure (Barrett, Wiehagen, and Peters 1988; Blignaut 1979).

Although there appears to be no data on the question, stereoscopic photography may also be effective at portraying a variety of other potentially hazardous conditions in the workplace, such as the danger of falling from elevated work areas. During the 1980s and 90s government researchers created several training modules that involve using sets of 3-D slides to portray hazards at a variety of mining operations including underground coal and limestone mines, and surface aggregates mines. These training packages include 3-D slides, a student problem booklet and an instructor's guide (see ―View-Master Reel" Training Exercises at ttp://www.cdc.gov/niosh/mining/products/#Training%20Packages).

Degraded images. Government researchers have conducted studies on the effectiveness of using degraded versus highlighted illustrations of hazards commonly found in underground mines. Highlighted examples of hazards are easy to detect. They are clear, close-up, unobstructed views. In contrast, degraded pictures of hazards are more difficult to detect. They are partially hidden, poorly illuminated, or were photographed from an eccentric angle, or through hazy or dusty conditions. During the 1970s, experiments were conducted on the use of degraded images to train military aircraft personnel to correctly identify ground targets (Cockrell 1979). Researchers found that, in contrast to those trained with highlighted examples, those who were trained with degraded examples performed significantly better on a subsequent target recognition test.

Underground miners work in an environment where the hazards they need to be able to detect are often degraded—they are difficult to see because they are partially hidden, poorly illuminated, and covered with dust. Government researchers decided to conduct an experiment similar to Cockrell's to determine whether degraded images are better than highlighted images for the purpose of teaching miners to recognize mining hazards (Kowalski-Trakofler and Barrett 2003). The researchers took three sets of pictures of hazards found in underground coal mines. One set showed highlighted views of 35 hazardous conditions. These slides were used to train one group of miners. A second set of slides showed degraded views of the same types of hazardous conditions. These slides were used to train a second group of miners. Participants in both groups viewed each slide for five seconds. Then, the instructor reviewed the slides and discussed the hazards depicted in each scene. After the training phase, participants in both groups were asked to view a third set of slides. This last set of slides illustrated 36 hazards of the same type that were shown during the earlier training phase. Participants viewed each slide for five seconds and then reported any hazards to the experimenter. The dependent measure in this experiment was the number of hazards the participant correctly reported. It was found that participants trained with degraded images were able to identify a significantly higher number of hazards than those who had been trained with the highlighted set of hazards. Based on these findings, a ―Degraded image hazard recognition" training program was created. The training module includes degraded image slides, a student problem booklet and an instructor's guide.

Story Telling Videos

A second example of government research to improve training on routine hazards involves using narrative accounts of accidents based on interviews with miners. During the past 20 years, researchers videotaped several miners as they told about various types of mining accidents, e.g., roof collapses, fires, electric arc flashes, etc. These stories are told in a very compelling fashion. They are a valuable tool for imparting historical information about mine safety to the next generation of miners. As previously mentioned, storytelling (or narrative) has been explored in the literature and shown to be the primary way in which people make sense out of their world. Along with each video, the training module includes an instructor's guide. These guides contain: questions the instructor could use to encourage group discussions about key training points, a picture or diagram of the accident scene, and additional background information about the safety topics covered in the video (see videos at http://www.cdc.gov/niosh/mining/products/#Videos).

FUTURE MINE TRAINING RESEARCH NEEDS

Although many types of improvements to miners' safety training are still needed, it appears particularly important for future research to focus on two objectives: 1) utilizing methods that improve realism and increase trainee engagement (participation or involvement), and 2) developing methods for evaluating miners' competencies.

Research on Improvements to Training Methods

Research on the effectiveness of occupational safety training methods suggests that such training is more effective when the training methods are highly realistic and engaging (Burke, Sarpy, Smith-Crowe, Chan-Serafin, Salvador, and Islam 2006; Cohen 2004; Robson, Stephenson, Schulte, Chan, Bielecky, Wang, Heidotting, Irvin, Eggerth, Peters, Clarke, Cullen, Boldt, Rotunda, and Grubb 2009). To facilitate the transfer of training to the job, it is important that practice drills and simulations be as realistic as possible. Training should reflect actual conditions on the job as closely as possible. Such training builds miners' confidence and enables them to respond appropriately to emergency situations and hazardous conditions. Great strides have been made in improving the realism of miners' safety training over the past 40 years, but there is definitely room for further improvements.

Research also strongly suggests that higher levels of engagement in occupational H&S training are positively associated with knowledge acquisition and reduction in accidents, injuries and illnesses. Low engagement H&S training typically employs oral, written or multimedia presentations of information by an expert source, but requires little or no active participation by the learner, other than attentiveness. During low engagement learning sessions, miners often do not have an active cognitive or behavioral role that can be clearly documented. With high engagement training methods, the trainee has a much more active role in the learning process. The trainee engages in significant cognitive and behavioral interaction with the material, and has many opportunities to ask questions of experts/instructors and engage in focused discussion with other trainees. High engagement training methods frequently provide trainees with opportunities to discover new cognitive strategies related to problem-solving and decision-making. Participants are often involved in hands-on practice of the behaviors to be learned. Examples can range from table-top exercises conducted in a classroom setting, to mine emergency escape and rescue training within a real or simulated mine. According to Burke (2006), behavioral modeling training is also an effective way to increase engagement in S&H training. Behavioral modeling involves trainee observation of a role model, followed by trainee modeling or practice, and feedback designed to modify behavior.

Several additional computer simulations, such as MERITS, need to be created to provide mine managers and responsible persons with the opportunity to practice handling a wide variety of mine emergency situations. The more experience people gain through participating in such role playing simulations, the better prepared they will be to handle real-world events. Virtual reality technologies also appear to hold much potential for improving the realism and engagement of miners' safety training (Mallett et al. 2008).

Research on Competency Evaluation Methods

For the most part, US mine H&S training regulations simply require miners to attend training classes for a prescribed number of hours. Other than donning their SCSR properly, regulations do not require that miners demonstrate their mastery of specific H&S competencies. Definitions and standards concerning what constitutes –successful" completion of mandated mine H&S training need to be developed, along with detailed and valid instruments, checklists and procedures for measuring individual miners' competencies. The Mine Safety Technology and Training Commission recently cited the lack of suitable methods for evaluating competencies as a particularly important deficiency in the area of miners' emergency response training (Mine Safety Technology and Training Commission 2006).

CONCLUDING REMARKS

Collectively, our nation's miners sit through millions of hours of mandated S&H training each year, and mining companies spend millions of dollars to provide this training. Unless effective training materials and methods are used, miners are unlikely to learn what they need to know to actually help them reduce their risk of suffering occupational injury and illness. Many miners sit through the same training lectures and films year after year in order to fulfill the requirements of the law. In these situations, their "training" ends up being a very unfortunate waste of time and resources, i.e., a wasted opportunity. On the other hand, when training is done well, it is extremely valuable and worthwhile to both the miners and their employer.

With help from academic institutions, mining companies, MSHA, and other providers of miners' training, government researchers have produced over 90 training modules on a wide variety of mine S&H topics. However, the primary emphasis of the government's training research program is not upon the production of training materials per se, but rather upon finding better *processes and methods* of training. Most of these training modules were developed in the course of research studies to determine the feasibility and effectiveness of using innovative new methods of presenting occupational S&H information to miners. Although the technologies available for developing and delivering miner training continue to evolve and improve, the basic principles behind the types of training that government researchers strive to produce remain constant.

Several major improvements have taken place in the way mine S&H training is conceptualized and practiced since the federal mine training regulations were instituted almost 40 years ago. The government's training research program is but one of several important forces that are responsible for bringing about the following improvements to miners' training:

1) Greater emphasis upon learning that requires collaboration and active problem solving.

2) Greater integration of miners' practical knowledge and experience with the mandatory S&H information they are required to receive annually.

3) Greater realism in training scenarios and greater fidelity of visual illustrations.

4) Greater use of training materials that are thoroughly authenticated and field tested. All materials should be authenticated with subject matter experts and thoroughly field tested with multiple groups of miners before releasing them to mine trainers.

The goal of the government's mine training research program has been--and will continue to be--providing assistance to the mining industry with appropriate use of new theories, methods, and technologies as they take their training programs into the future.

REFERENCES

Barrett, E, W Wiehagen, and R Peters. 1988. Application of Stereoscopic (3-D) Slides to Roof and Rib Hazard Recognition Training. U.S. Department of the Interior, Bureau of Mines, Information Circular Report 9210.

Blignaut, C. 1979. The perception of hazard: The contribution of signal detection to hazard perception. *Ergonomics* 22:1177-1183.

Burke, M, S Sarpy, K Smith-Crowe, S Chan-Serafin, R Salvador, and G Islam. 2006. Relative effectiveness of worker safety and health training methods. *American Journal of Public Health* 96:315-324.

CFR. 2009. Code of Federal Regulations. Washington DC: U.S. Government Printing Office, Office of the Federal Register.

Clandinin, D, and F Connelly. 2000. *Narrative Inquiry: Experience and Story in Qualitative Research*. San Francisco: Jossey Bass.

Cockrell, J. 1979. Effective Training for Target Identification Under Degraded Conditions. U.S. Army Research Institute for the Behavioral and Social Sciences.

Cohen, A. 2004. Report from the 1999 National Conference on Workplace Safety & Health Training: Putting the Pieces Together & Planning for the Challenges Ahead. Cincinnati, Ohio: U.S. Department of Health and Human Services, CDC, NIOSH Publication No. 2004-132.

Cole, H. 1994. Embedded performance measures as teaching and assessment devices. *Occupational Medicine: State of the Art Reviews* 9 (2):261-281.

———. 1997. Stories to live by: A narrative approach to health behavior research and injury prevention. In *Handbook of Health Behavior IV: Relevance for Professionals and Issues for the Future*, edited by Edited by D.S. Gochman. New York, NY: Plenum Press.

Cole, H, P Berger, C Vaught, J Haley, W Lacefield, R Wasielewski, and L Mallett. 1988. *Measuring Mine Health and Safety Skills*. Pittsburgh, PA: US Department of Interior, Bureau of Mines, Contract Technical Report No. 2.

Cole, H, R Wasielewski, GT Lineberry, A Wala, L Mallett, J Heley, W Lacefield, and P Berger. 1988. Miner and trainer responses to simulated mine emergency problems. Paper read at Proceedings: Mine Safety Education and Training Seminar, Information Circular Report 9185, at Pittsburgh, PA.

Cole, H, W Wiehagen, C Vaught, and B Mills. 2001. Use of Simulation Exercises for Safety Training in the U.S. Mining Industry. U.S. Department of Health and Human Services, CDC, Information Circular Report 9459, NIOSH Publication 2001-141.

Cullen, E, and A Fein. 2005. Tell Me a Story: Why Stories are Essential to Effective Safety Training. U.S. Department of Health and Human Services, CDC, Report of Investigation 9664, NIOSH Publication No. 2005-152.

Czarniawska, B. 1997. *Narrating the Organization: Dramas of Institutional Identity*. Chicago, IL: University of Chicago Press.

Hagman, J, and A Rose. 1983. Retention of military tasks: A review. *Human Factors* 25 (2):199-213.

Johnson, S. 1981. Effect of training device on retention and transfer of a procedural task. *Human Factors* 23 (3):257-272.

Kowalski-Trakofler, K, and E Barrett. 2003. The concept of degraded images applied to hazard recognition training in mining for reduction of lost-time injuries. *Journal of Safety Research* 34:515-525.

Kowalski-Trakofler, K, C Vaught, L Mallett, M Brnich, D Reinke, L Steiner, W Wiehagen, and L Rethi. 2004. Safety and Health Training for an Evolving Workforce: An Overview From the Mining Industry. U.S. Department of Health and Human Services, CDC, Information Circular Report 9474, NIOSH Publication 2004-155.

Mallett, L. 2002. NIOSH Releases New Computer-Based Training Exercise Called MERITS. U.S. Department of Health and Human Services, CDC, NIOSH Technology News No. 496.

Mallett, L, and T Orr. 2008. Working in the Classroom - A Vision of Miner Training in the 21st Century. In *The International Future Mining Conference & Exhibition*. Sydney, Australia.

Mine Safety Technology and Training Commission. 2006. Improving Mine Safety Technology and Training: Establishing U.S. Global Leadership. National Mining Association.

Peters, RH. 1992. Miners' Views About Why People Go Under Unsupported Roof and How To Stop Them. U.S. Department of the Interior, Bureau of Mines, Information Circular Report 9300.

———. 2002. Strategies For Improving Miners' Training. U.S. Department of Health and Human Services, CDC, Information Circular Report 9463, NIOSH Publication 2002-156.

Pittsburgh Research Center Staff. 1981. Mine Safety Education and Training Seminar Proceedings. Pittsburgh, PA: Department of Interior, U.S. Bureau of Mines, Information Circular Report 8858.

Robson, L, C Stephenson, P Schulte, S Chan, A Bielecky, A Wang, T Heidotting, E Irvin, D Eggerth, R Peters, J Clarke, K Cullen, L Boldt, C Rotunda, and P Grubb. 2009. Systematic review of the effectiveness of training & education programs for the protection of workers. Toronto Canada and Cincinnati Ohio: Institute for Work & Health and National Institute for Occupational Safety and Health.

Schmidt, R. 1988. *Motor Control and Learning: A Behavioral Emphasis*. Champaign, IL: Human Kinetics Publishers.

United States Public Laws 91st Congress - First Session. 1969. Federal Coal Mine Health and Safety Act, Public Law 91-173. Washington D.C.: U.S. Government Printing Office.

United States Public Laws 95th Congress - Second Session. 1977. Federal Mine Safety & Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164. Washington D.C.: US Government Printing Office.

US Department of Labor. 2006. *Mine emergency evacuation: Final rule*. Federal Register, US Government Printing Office.

Vaught, C, M Brnich, L Mallett, H Cole, W Wiehagen, R Conti, K Kowalski, and C Litton. 2000. Behavioral and Organizational Dimensions of Underground Mine Fires. U.S. Department of Health and Human Services, CDC, Information Circular Report 9450, NIOSH Publication 2000-126.

Vaught, C, M Brnich, W Wiehagen, H Cole, and H Kellner. 1993. *An Overview of Research on Self-Contained Self-Rescuer Training*. Pittsburgh, PA: US Department of the Interior, Bureau of Mines, Bulletin 695.

Vaught, C, and L Mallett. 2008. Guidelines for the Development of a New Miner Training Curriculum. U.S. Department of Health and Human Services, CDC, Information Circular Report 9499, NIOSH Publication 2008-105.