Centers for Disease Control

National Institute for Occupational Safety and Health

Final Project Report

Western US Mine Safety and Health Training Program

September 1, 2010 to August 31, 2014

(Cooperative Agreement Number: 1U60OH010017-01 to 04)

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LIST OF ABBREVIATIONS

CSM	COLORADO SCHOOL OF MINES
DOD	DEPARTMENT OF DEFENSE
ERC	EDUCATION AND RESEARCH CENTER
IC	INFORMATION CIRCULAR
LED	LIGHT EMITTING DIODE
MERD	MINE EMERGENCY RESPONSIVENESS DEVELOPMENT
MSA	MINE SAFETY APPLIANCES (COMPANY)
MSHA	MINE SAFETY AND HEALTH ADMINISTRATION
MSHP	MINE SAFETY AND HEALTH PROGRAM
NIOSH	NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
PPE	PERSONAL PROTECTIVE EQUIPMENT
SA	SPECIFIC AIM
SME	SOCIETY OF MINING, METALLURGY AND EXPLORATION
TRAM	TRAINING RESOURCES APPLIED TO MINING
USGS	UNITED STATES GEOLOGICAL SURVEY
WMTC	WESTERN MINING TRAINING CENTER

ABSTRACT

The Western Mine Training Center at the Colorado School of Mines was initiated in September 2010 when it was selected to participate in a three-year cooperative agreement with NIOSH to support the development of training and education programs for workers engaged in mining operations in the Western United States. The overall objective of this agreement was to reduce the number of injuries and illnesses among workers who were involved in mining operations through a focused, relevant, and comprehensive training program that educated mine workers how to identify and protect themselves from risks and hazards in the mining environment and to expand the number of qualified mine safety and health trainers in the U.S. This objective was met by establishing a comprehensive training program that primarily focused on MSHA-required training, professional level training for trainers and mine safety and health professionals, and mine rescue technical rescue training. During the three-year project period and the one-year extension, a total of 336 courses were conducted, which were attended by 4,084 students and resulted in 7,874 training days (calculated by multiplying the number of days for the course by the number of students attending the course). Post course evaluations completed by trainees indicated that these courses were rated as excellent or very good by 82 to 100 percent of the trainees. Several findings indicating the most significant strengths of these courses centered around using highly qualified instructors, using several different instructors to teach each of the courses, including interactive activities, allowing for lots of discussion with instructors and peers. Using computer simulations for mine rescue training was found to be a valuable training tool when learning skills.

SECTION 1

SIGNIFICANT KEY FINDINGS

1. Trainees appreciated having instructors with mining experience and who are technical experts in the topics they are teaching. They also liked having multiple instructors during the courses, either as team teachers or sequentially changing the instructors throughout the day. (SA 1, 2, and 3)
2. Trainees liked the emphasis placed on hazard recognition and accident prevention. One video that appeared to elicit the greatest appreciation for mine safety and health was NIOSH's video, "You Are My Sunshine." (SA 1)
3. Trainees wanted opportunities for discussion with both instructors and other trainees. They wanted to learn not only from the instructors but also from their peers. (SA 1 and 2)
4. Trainees also wanted interactive exercises spaced intermittently throughout the training. Examples of such activities used in our training included polling questions using clickers, small group exercises, touring the Edgar Mine (taking ventilation measurements and scaling), and practical demonstrations. (SA 1)
5. Even though information contained in older videos may still be relevant, trainees did not like watching these videos even if more recently made videos were not available or were of poorer quality in terms of content. (SA 1)
6. According to trainee input, the time requirements and the number of topics that were required to be presented during MSHA-required training may lead to information overload and some topics being limited to a very cursory review. (SA 1)
7. Depending on the specific course attended, trainees also wanted course materials that could serve as a reference, and they also wanted a comprehensive approach to the topic being taught. (SA 2)
8. Trainees overwhelmingly stated that the computer simulation training was useful for learning how to communicate, make decisions, and recognize hazards during an emergency response. (SA 3)
9. Trainees overwhelmingly stated that the computer simulation training was helpful for improving their performance during an emergency response. (SA 3)
10. While quality graphics can improve the learning experience during computer simulation training, it appeared that the quality of graphics was less important when learning skills versus experiencing being in a specific environment. (SA 3)
11. Computer simulation training was a valuable training experience for novice, experienced, and expert mine rescue teams. Although novice teams rated this training higher than experienced and expert teams, at least 80 percent of trainees in each skill level thought the training was useful in learning specific skills. (SA 3)
12. Trainees appreciate being able to learn new rescue skills, and learning skills that lead to safer approaches to rescues for both the victim and the rescuer. (SA 3)
13. Trainees want to train in environments that are realistic in comparison to a real mine emergency. They want to be challenged by exploring in smoke, being required to demonstrate hands-on rescue skills, mitigating real hazards, and working as a team. (SA 3)
14. One issue that is often raised by trainees with the skills training is not having enough time for them to practice the skills. Because the amount of training time is always limited because of limitations in either time, number of instructors, or number of trainees, it is important that team trainers follow-up with practice sessions to aid in skill retention. (SA 3)
15. When conducting training in an actual mine, issues may arise with communication and mechanical systems. Although such conditions may tend to add to the reality of the situation, disruption in services may detract from the learning environment for some trainees. A similar situation may also occur when there are limitations for creating hazards in a mine, such as real fires. (SA 3)

TRANSLATION OF FINDINGS

The above findings are useful to organizations that provide safety and health training and are interested in providing a quality product to their employees/clients. These findings can be applied to any training program whose target audience are adults. The findings from the computer simulation training suggested that the use of simulations when training skills is a valuable learning tool and should be incorporated into training programs whenever possible.

OUTCOMES / IMPACT

The trainees who attend the CSM mine safety and health courses are almost all contractors who work at numerous mine sites throughout the Western United States. It has always been a difficult task to assess the actual impact of our training courses because of a lack of access to injury and illness records. However, we have had some trainees who have provided anecdotal information on how they actually applied knowledge gained from our courses.

In addition to training mine workers, we have also supported three CSM student mine rescue teams (approximately 30 students) with training in both basic and advanced rescue skills relevant to mine emergency responses as well as other types of emergencies occurring at both work and non-work settings. Two of our students were first on scene at a major car accident involving multiple injuries. While waiting for paramedics to arrive, they were able to triage all injured victims and provide first aid to the most severely injured.

Most of the safety and health training and mine rescue training conducted included lessons on first aid, which provided skills sufficient for some of our students to render aid with successful outcomes. One student was with a friend who received stabbing wounds during an attack. With the knowledge he had learned from our classes, the student was able to provide first aid to his friend while waiting for the paramedics to arrive on scene. Another student, who choked on a piece of food, was able to successfully administer the Heimlich maneuver to himself. A mine worker, who also learned how to do the Heimlich maneuver during a New Miner course, was able to successfully perform this maneuver on his young son who was choking on a bottle cap. He told this information to other students in his Annual Refresher course to emphasize the relevance of the training.

We have also directed the focus of mine rescue training towards learning actual rescue skills rather than mine rescue contest rules, resulting in team members being better prepared to respond to all types of emergencies that can occur at mine sites.

CDC estimates that more than 11,000 people die at home every year from injuries received from falls, fires, drownings, or poisonings. Although the mine safety and health training conducted by CSM is directed to workplace hazards, it is also applicable to hazards found in the home and in other settings. For example, our New Miner and Annual Refresher courses include specific instruction on first aid, use of fire extinguishers, slip/trip//fall prevention, and chemical safety. Individuals who apply what they learn for work to other aspects of their life will avoid injuries and be healthier, and will also serve as examples to their family members and friends.

SECTION 2

BACKGROUND

The Western Mine Training Center at the Colorado School of Mines was initiated in September 2010 when it was selected to participate in a three-year cooperative agreement with NIOSH to support the development of training and education programs for workers engaged in mining operations in the Western United States. The overall objective of this agreement was to reduce the number of injuries and illnesses among workers who were involved in mining operations through a focused, relevant, and comprehensive training program that educated mine workers how to identify and protect themselves from risks and hazards in the mining environment and to expand the number of qualified mine safety and health trainers in the U.S. Almost all of the mine workers who attended our courses are contractors working on short-term projects at mine sites and have no internal training programs that could provide this type of training. These companies rely solely on CSM mine safety and health courses.

The scope of this cooperative agreement is limited to mine workers in the Western United States. Although the majority of the trainees are from Colorado, trainees have come from all Western states except for four North Dakota, Louisiana, Nebraska, and Hawaii. Trainees have also come from 12 Eastern states and four foreign countries (Canada, Philippines, Australia, and Peru).

In December 2010, the Mine Safety and Health Program began an organizational transition from Special Programs and Continuing Education to the Mining Department. The rational for this move was improved utilization and synergy of training resources available in both the Mining Engineering Department and the Mine Safety and Health Program. MSHP was then staffed by personnel from the Mine Safety and Health Program (MSHP) and other academic faculty and classified staff in the Mining Department. The staff included one academic, two research, and four administrative faculty; two classified staff; and eleven undergraduate students. The professional staff had a combined 196 years of professional experience, and 109 years of mining experience. All but one staff member were MSHA-approved instructors. Most members of the professional staff had graduate-level degrees and professional certifications.

To further develop and maintain the training program, numerous administrative tasks were conducted during the project period and included the following:

1. Completed several tasks directly associated with the kick-off of this agreement:
    - Participated in a joint meeting with the University of Arizona in October 2010 to discuss collaborative efforts for specific aims 2 and 4.
    - Participated in a joint orientation meeting with NIOSH and the University of Arizona in February 2011.
    - Hosted a site visit from Joel Haight of NIOSH in April 2011.
    - Developed a brochure for the Western Mine Training Center, which highlighted training activities offered by both CSM and the University of Arizona.
2. Transferred the course registration process from Special Programs and Continuing Education (SPACE) to the Mining Department in 2012. Along with the registration process, MSHP also began processing credit card charges. Prior to this change, MSHP was required to pay a fee of $50 per course registration to SPACE. In April 2012 and April 2013, the CSM Comptroller's Office conducted audits of MSHP's process (documenting registrations and handling payments); no issues were identified.
3. Established an advisory board and hosted three meetings in April 2011, May 2012, and Feb 2014. The MSHP advisory board consisted of 12 members and included professionals from the mining industry (coal, gold, molybdenum, and aggregate), labor unions (UMWA and IUOE), MSHA, academia (University of Arizona and Colorado State University) and a professional society (SME). Although not an official member, a representative from NIOSH also attended these meetings.
4. Enhanced marketing efforts to promote interest in MSHP courses. Several different approaches were taken to increase awareness of CSM's training programs, which included:
    - Redesigning the MSHP website. This effort was started during the first year of the cooperative agreement and continued into the second year. Additional courses were added to the material posted, and the registration process, including a downloadable form, was added to the website. Significant effort was also spent on improving the positioning or our website when searches are conducted. Initially, the MSHP website appeared on the fourth or fifth page, but now it appears on the first or second page. Since these changes were made, the number of hits per month increased 31 percent. The new address for this website is: mshp.mines.edu. This work was done primarily by CSM student employees, who received guidance from a consultant.

    - Developing marketing materials. Five tri-fold brochures and four one-page flyers were designed and developed internally by MSHP staff and volunteer support. The brochures provided information on different categories of training courses, such as mine rescue, while the flyers provide information specific to individual courses, such as heavy lifting with air bags.
    - Staffing exhibit booths at conferences and events. The MSHP staffed exhibit booths at several conferences and mine rescue contests. This type of setting provided opportunities to meet directly with individuals, who have an interest in the type of training we offer, and to demonstrate the mine rescue computer simulator. Exhibit booths were staffed at the following events:
        - MSHA Training Resources and Materials Conference held in Beckley, West Virginia on October 12-14, 2010
        - MSHA Training Resources and Materials Conference held in Beckley, West Virginia on October 11-13, 2011
        - Annual Joint Western Regional Mine Safety and Health Conference held in Henderson, Nevada on October 25-26, 2011
        - Winnemucca Mine Rescue Contest held in Winnemucca, Nevada on March 13-15, 2012
        - Elko MinExpo held in Elko, Nevada on June 6-8, 2012
        - Annual Joint Western Regional Mine Safety and Health Conference held in Reno, Nevada on October 22-24, 2012
        - Winnemucca Mine Rescue Contest held in Winnemucca, Nevada on March 12-14, 2013
        - National Metal Mine Rescue Contest, held in Reno, Nevada on July 30 to August 1, 2013
- Since the Edgar Mine was utilized for many of our training courses, and as part of the Mining Department, MSHP staff:
    - Completed weekly inspections and quarterly maintenance of the MineArc refuge chamber per the manufacturer instructions.
    - Occasionally provided staff to conduct tours and fill in for the mine superintendent.
    - Prepared the Edgar Mine prior to training courses.

5. On August 31, 2012, Joel Haight and Launa Mallett of NIOSH conducted a review of our program. We discussed accomplishments during the first and second year of the

cooperative agreement, as well as new directions we were interested in pursuing during the final year of the agreement. We also went to the Edgar Mine to see the built-in refuge chamber that was donated by MineArc. A second NIOSH visit was hosted on February 28, 2013. Lisa Steiner and several members of her team completed a tour of the Edgar Mine, including the built-in refuge chamber that was donated by MineArc. Discussions were held regarding collaborative research projects associated with mine emergencies.

6. One of our instructors and one of our student employees attended a Level 2 training offered by DXP. They are now both qualified to train on using and maintaining the BG4 breathing apparatus.
7. MSHP continued to seek partnerships with other organizations involved with rescue training. Since the MSHP mine rescue training focused on advanced technical rescue skills, partnerships were with local fire departments that could assist with this training. MSHP established partnerships with Black Hawk, Golden, and Denver Fire Departments. MSHP also established a partnership with the Mine Technology and Training Center, located in Ruff Creek, PA to collaborate on conducting IG 7a skills contests. An effort was initiated to form a partnership with the National Mining Association related to supporting training efforts for implementing the Core Safety Management System.
   - Hired three new faculty members as professional instructors.
8. Requested a change in the principal administrator for this agreement. Gary Baughman, who retired in December 2010, was replaced with Kadri Dagdelen, the head of the Mining Department.
9. Arranged an agreement with Qinetiq for a 3-month trial period for their mining simulation software. During this trial period, students will utilize the simulation software to improve their knowledge of mine rescue procedures mining tasks. Due to delays in processing the agreement between Qinetiq and CSM Purchasing Department, the trial period was delay until 2015.
10. Obtained additional equipment for training:
    - A new cascade system for filling BG4 oxygen bottles was purchased and will be installed in the School House at the Edgar Mine.
    - A supplied air system and tripod were purchased for use during confined space training. Some additional rope rescue gear was also obtained, including helmets, gloves and ropes. This equipment was purchased with Brookwood-Sago grant funds.

- A high volume stainless steel dryer was purchased from Georgia Steel for drying respirator face pieces and BG4 parts. The price of this dryer was significantly discounted by Georgia Steel.
- Three MX-4 multi-gas meters were purchased from Industrial Scientific for use in the Edgar Mine. The price of the meters was significantly discounted by Industrial Scientific.
- A Savox hard line communications system for mine rescue/confined space rescues was purchased by the Colorado School of Mines with technology fees. The manufacturer offered a significant discount towards the purchase price.
- Four Motorola HT 750 radios with a charger were purchased for mine rescue contests from Frontier Radio Communications.

11. In addition to the above purchased equipment, we were very fortunate to receive donations from numerous vendors. The equipment obtained through donations was absolutely critical to being able to offer the advanced mine rescue skills training. The following is a list of donations received:
    - Two refuge chambers were donated, one from MineARC Systems North America, LLC valued at $60,000 and one from Jack Kennedy Metal Products & Buildings Inc. valued at $100,000. The MineARC chamber was designed for twenty miners and has been placed off the Army drift in the Edgar Mine, about 200 feet outby the exhaust fan. The Kennedy chamber, which is a skid-mounted chamber, was designed for 4 miners and is located in the Boudin Drift. MSHP staff were instrumental in securing these donations and directing/supporting the installation of the MineARC refuge chamber.
    - The Black Hawk Fire Department donated 25 complete sets of bunker gear that are used for firefighting training. Each set included a jacket, pants, helmet, protective head/neck gear, gloves and boots. The estimated value of this donation was $25,000.
    - Dräger donated five new Sentinel BG4s breathing apparatus and accessories, valued at $60,000, to the student mine rescue teams.
    - DXP donated a set of six refurbished BG4s valued at $48,000.
    - Industry donations were obtained to purchase a trailer for storing/transporting mine rescue equipment and gear. The student mine rescue teams utilize the trailer for transporting their equipment to mine rescue contests, and between campus and the Edgar Mine. This trailer would also available for use by local emergency response

organizations should they need to use the BG4 breathing apparatuses for a rescue response.

- Technical rescue equipment needed to conduct basic technical rope rescues, heavy lifts using air bags, and installing ground support using rescue struts was donated by Paratech.
- Northern Lights donated 20 LED cap lights and two charging stations.
- Denver Fire Department donated three self-contained breathing apparatuses with one spare bottle.
- The Henderson Mine donated a Masterline oxygen booster pump used for filling BG4 cylinders.
- MSA donated PPE valued at $500.

SPECIFIC AIMS

The CSM cooperative agreement included the following specific aims:

1. The implementation of a safety and health training program intended to satisfy MSHA requirements as specified under 30 CFR Part 48 for New Miner and Refresher Training in both surface and underground operations, with a particular focus towards meeting the needs of underserved groups such as suppliers, contractors, and equipment manufacturers. This aim was designed in collaboration with the State of Colorado Division of Reclamation, Mining and Safety and the University of Arizona (UA) to supplement and enhance current training activities sponsored through the MSHA State Grants program. This aim also includes the pooling of resources with the State of Colorado to conduct training applicable for MSHA trainer certification, as well as general mining related first aid training.
2. The development of a broad-based Professional Training Curriculum that seeks to augment and improve the technical abilities, working knowledge, and effectiveness of safety and health professionals/trainers in their capacity to train workers at their individual operations. This project aim is facilitated through several specific program components including: (1) a Train-the-Trainer workshop which will offer courses by acknowledged experts on a variety of technical subjects, ranging from engineering controls to exposure assessment & hazard recognition, and on instructor coaching, training methodologies, and adult education; (2) a Safety Specialist Course that focuses on enhancing the knowledge and capabilities of experienced miners who have recently transferred into or have assumed positions where

they possess responsibilities for safety and health training and/or compliance; (3) offering Joint Industry Training that brings together management and labor to engage in productive dialog regarding safety and health issues pertinent to their operations; and (4) increasing the availability of professional training opportunities through course offerings at locations throughout the western United States. To leverage capabilities, this aim will be performed in collaboration with several academic programs at UA, including the Colleges of Engineering, Public Health, and Education.

3. Provide mine rescue and emergency response training that focuses on improving the capabilities of the incident command center structure in order to enhance greater effectiveness in decision-making and communication. In addition to classroom instruction, this training utilizes a number of different computer simulations that can be adapted to reflect specific types of mines and hazards. This aim will complement the existing mine rescue training being performed at the CSM Edgar Experimental Mine and will be implemented in collaboration with UA's surface mine rescue training program.
4. The development of a user-friendly website that serves as an electronic repository of training materials and information found in the public domain. This aim intends to improve the distribution of quality training materials to end-users, promote an overall increase in training capacity and effectiveness, and reduce the unnecessary duplication of training materials which often occurs due to the lack of accessibility.
5. Develop innovative and interactive training materials that utilize effective pedagogies to address need areas identified within the industry and that cater to the cross-sectional diversity of the industry's workforce, including disadvantaged learners

In February 2011, NIOSH requested that the original Specific Aim 4 (Developing a web-based library of safety and health training materials.) be omitted, and the scope of Specific Aim 5 be reduced, where these efforts and resources would then be focused on facilitating the remaining specific aims. To improve our overall training program, CSM used the resources from the original Specific Aim 4 to evaluate the CSM training program as stated above. The University of Arizona, which was also selected to participate in a separate cooperative agreement with NIOSH, and CSM agreed to collaborate on tasks associated with Specific Aims 2 and 4.

METHODOLOGY

During the three-year project period and the one-year extension, a total of 327 training courses and professional presentations were conducted by CSM. Many of these courses supported MSHA training requirements as defined in 30 CFR Part 48 (new miner training for surface and underground mines, and annual refresher training). CSM MSHP conducted 336 courses that were attended by 4,084 students and resulted in 7,874 training days (calculated by multiplying the number of days for the course by the number of students attending the course). Specific course statistics are provided in Table 1.

Other professional training courses offered included mine rescue and underground search and rescue training utilizing several different training methods, including computer simulations, field exercises and underground mine exercises. The main focus of these courses was to help facilitate the development of advanced skill-sets and expertise that are necessary when responding to mine emergencies involving conditions that are dynamic and life threatening. These technical rescue skills are also very applicable when responding to typical industrial accidents that result in serious injuries and fatalities at underground and surface mines and also mills. When applicable to the training exercise, an incident command was staffed that concentrated on developing more effective decision-making and communication during mine emergencies. Important advanced rescue skills were also taught that included the use of air bags for heavy lifts, technical rope rescues when victims are located on different levels than rescuers, confined space entry and rescue, ground support using aluminum struts, and firefighting techniques. Other skill-sets taught included the extraction of multiple victims from a refuge chamber and constructing ventilation controls in large drifts.

During this project CSM continued to offer and conduct mine rescue training using computer simulations. Throughout the project period, the simulation software was upgraded to improve the underground environment and to add interactive tasks completed by the team members.

The professional training activities included courses specifically developed and tailored for the mining industry and were unique in terms of content and how they were taught (continuing adult education courses). As a consequence, they differed from other courses taught by other training organizations. The Safety Specialist Course was designed for experienced miners entering the safety and health field, who needed to acquire basic knowledge relevant to tasks typically conducted by safety specialists. Other professional courses conducted included an Introduction to Mine Safety and Health, Leading Culture Change, and MSHA Instructor courses.

Several presentations were also conducted at professional conferences held in the United States. The presentations were on hazard recognition, confined spaces, exposures to hazardous noise, brain-based safety (using recent knowledge of how the brain functions to improve safety management), and advanced mine rescue training. A total of 16 interactive hazard recognition activities were completed. These activities are based on fatalities and near misses occurring at mine sites and encourage trainees to identify potential fatal hazards, the likely root cause and other causal factors of the fatality, and several preventive measures. The interactive nature of these training activities allows for discussion and for trainees to relate the conditions leading to the fatalities to their mines and jobs. These activities are posted on the Colorado School of Mines (CSM) Mine Safety and Health Program (MSHP) website (mshp.mines.edu) as downloadable files, and are available to the public.

All of the courses and presentations offered by CSM were presented by Mine Safety and Health Program (MSHP) employees and two academic faculty members, except for five courses and one presentation, which were taught by two contract instructors. Two MSHP employees also supported nine State of Colorado MERDs conducted at the Edgar Mine.

Other activities were completed that enhanced the training experience and included:

1. CSM MSHP developed an online annual refresher course so that individuals who are not physically able to attend classroom training can still meet MSHA's annual training requirements. This mode of training is particularly relevant to individuals who are working outside of the US or at remote operations. This course received approval from MSHA.
2. Since the mine rescue computer simulator uses the Edgar Mine in the simulations, a "crawl-walk-run" approach for mine rescue training was developed. After completing a training session on the simulator, mine rescue teams complete at least two rescue exercises in the Edgar Mine, with one of the exercises being very similar to the exercise completed with the computer simulator exercise, while the second exercise is much different and is located in a different area of the mine. This approach allowed teams to be first introduced to mine rescue without the physical stress present. The first exercise then added this aspect to the training along with other issues typically associated with an underground environment. The

Table 1. Summary course data for the time period September 1, 2011 to August 31, 2014

Course	Number of Courses	Days per Course	Number of Students	Number of Training Days
MSHA-Required Training				
New Miner (Surface)	23	3	348	1044
New Miner (UG)	27	4	225	900
New Miner (UG for Experienced Surface Miner)	19	2	52	104
New Miner (Surface) (CSM Students)	2	4	57	228
New Miner (UG) (CSM Students)	4	5	130	650
Task Training (UG)(CSM Students)	4	5	111	555
Annual Refresher	51	1	723	723
Annual Refresher - Online	1	1	5	5
First Aid	2	0.5	36	18
Confined Spaces Presentation for Henderson Mine Annual Refresher	13	.13	714	93
Mine Rescue Training				
Computer Simulations	26	0.5-1.0	215	181.5
Edgar Mine Exercises	9	1.0-2.0	75	97
Heavy Lift with Airbags	12	0.5-1.0	103	58.25
Technical Rope Rescue	7	1.0 to 1.5	118	98
Confined Space Entry/Rescue	3	1.0	53	53
Ground Control	3	0.5-1.0	31	18
Fire Brigade Training	12	0.5-2.0	113	142
Abandoned Mine Training	2	0.25 to 0.5	39	13
CSM Student MR Teams	81	(Varies)	24-35	768
2nd Collegiate MERD	1	2.5	41	103
Army Training				
Expanded New Miner UG & Mine Rescue	4	61	62	961
Mine Rescue		2	4	8
Mine Rescue		2	2	4
Mine Rescue		4	2	8
Specialized Training				
MSHA Instructor	5	3	27	81
Safety Specialist	3	4 to 5	20	97
Leading Culture Change	1	2	4	8
Intro to Mine Safety & Health	1	5	22	110
Conference Presentations	11	.04 to .13	469	70.2
TOTAL	**327**		**3,831**	**7,198.95**
State of Colorado Mine Rescue Training Supported by CSM MSHP				
MERDs / Contests	9	1-3	253	675
GRAND TOTAL	**336**		**4,084**	**7,873.95**

second exercise provided an opportunity to transfer what was learned during the first two exercises to a new exercise conducted in a different part of the Mine.

3. Several new courses were offered that focused on improving technical rescue and firefighting skills. These courses included Heavy Lifting using Air Bags, Technical Rope Rescues, and Fire Brigade Training. Our undergraduate student workers also developed and conducted an Abandoned Mine Safety course for local fire departments.
4. To facilitate the training exercises held at the Edgar Mine, an ultra-light mine rescue cart was designed and constructed for transporting a stretcher, first aid bag, and equipment during rescue responses. The CSM student mine rescue teams tested the prototype and provided feedback on improving the design.

At the completion of each training course, trainees were asked to complete an evaluation form. They were asked to rate various aspects of the course and to provide information on what they perceived as significant strengths and weaknesses of the course. They were also asked if the training will be useful to their job and if they will use the information received to train others. A summary of evaluation results received are provided for each type of course given. (NOTE: The evaluation data presented in this report were collected during the project period, with only a few exceptions. The Air Bag Heavy Lift, UG Mine Rescue, and Firefighting summaries also included data obtained from two courses conducted in September 2014.)

The information in Table 1 has been broken into more detailed information for each course/activity by specific aim. For Specific Aim 1, CSM conducted 146 courses/presentations; trained 2,042 mine workers, 298 CSM undergraduate students, and 140 military personnel; and completed 4,320 training days. The number of courses conducted are listed below.

1. Conducted 23 MSHA Part 48 New Miner Courses for Surface Mines
2. Conducted 27 MSHA Part 48 New Miner Courses for UG Mines
3. Conducted 19 MSHA Part 48 UG New Miner for Experienced Surface Miners Courses
4. Conducted 48 MSHA Part 48 Annual Refresher Courses
5. Conducted 1 MSHA Part 48 Online Annual Refresher Course
6. Conducted 2 MSHA Part 48 New Miner Courses (Surface Mines) for college students
7. Conducted 4 MSHA Part 48 New Miner Courses (UG Mines) for college students
8. Conducted 4 Underground Task Training Courses for college students
9. Conducted 13 presentations on “Confined Spaces” for the Henderson Mine annual refresher training

10. Conducted 4 Expanded New Miner and 3 Annual Refresher Courses for the Army

During the project period, 542 mining, safety and health, and occupational health professionals attended courses and presentations given by the CSM MSHP professional staff for Specific Aim 2. Courses and presentations given for this specific aim are described below.

1. A course on Safety Management and Loss Control was taught for the first time during the fall semester of 2010. While the course was specifically oriented towards risk and safety management practices utilized in the resource industries, it attracted both undergraduate and graduate students from a variety of engineering disciplines. A total of 9 students completed the course, spanning 45 hours of instruction and laboratory exercises. A variation of this course was taught again in Fall 2013 and Fall 2014.
2. The Mine Safety Specialist Course was conducted in April 2012 and December 2013.
3. Since 2010, members of the CSM MSHP have provided lectures on an annual basis at the Colorado State University (CSU) for graduate students majoring in industrial hygiene on Mine Safety and Health Programs and industry best practices. These service activities have also included the organization of numerous tours of the Edgar Mine, as well as commercial mining operations in Colorado for graduate students and faculty from health sciences programs at the Colorado State University, University of Colorado, and the Mountain & Plains ERC.
4. Conducted a five-day course, Introduction to Mine Safety and Health, for a Chinese delegation of 23 professionals (government safety professionals with mining oversight responsibilities) on October 15-19, 2012 in Chicago.
5. On December 12-13, 2012, an upper management course, “Leading Culture Change” was offered by one of our contract instructors with extensive experience and education in applying functional brain-based knowledge to improving safety and health programs through culture change.
6. A new course “Mine Safety and Health Management” was developed and offered for upper division undergraduate and graduate students by the CSM Mining Engineering Department in Fall 2013. This course was added to the CSM bulletin and will be offered every fall semester.
7. Developed three new courses: Job Safety Analysis and Hazard Analysis, Root Cause Analysis, and 30 CFR. This last course was developed in response to inquiries from

trainers/S&H professionals experienced with OSHA regulations, who wanted to provide services to the mining industry.

8. Updated courses and course materials: Since our courses were typically given by no less than four instructors, the training presentations were developed using many different formats. In order to be consistent, a new format was designed and most presentations were reformatted. Some presentations with outdated injury & fatality data were updated with more recent statistics when such data were available. Evaluation forms were also updated and new ones were created for new courses. A training manual was also developed for the 30 CFR Part 48 New Miner training courses. Instead of just providing copies of presentations, a set of reference materials for each topic presented during the course was assembled. Presentations were periodically updated to reflect current injury statistics, fatality information and new training materials. Some presentations were also modified to include polling using the set of clickers/polling devices donated by Turning Technologies. The pre and post-tests completed for the New Miner courses were also revised so they could be administered using the clickers.
9. During the 2010 and 2011 TRAM Conferences held in Beckley, West Virginia, training presentations were given and an exhibit booth was manned for two days. The presentations were each 1-hour long and both dealt with using computer simulations for mine rescue training. Approximately 50 people attended the presentations and another 100 people visited the booth to see demonstrations of the mine rescue computer simulations.
10. A one-hour presentation (Ergonomics Processes: Implementation Guide and Tools) was given at the IV International Seminar on Occupational Health in Mining Operations on October 27, 2010 in Lima, Peru. Approximately 150 occupational health and safety and health professionals attended this presentation.
11. A presentation was given at the 2011 SME Annual Meeting on March 1, 2011 titled ‘Small Hardrock Mining: Current Challenges & Opportunities”. Given in the Small Mine Safety Session sponsored by the Coal & Energy Division, the presentation addressed safety and health issues in small metal/nonmetal operations. Approximately 60 people attended this presentation.
12. A 90-minute presentation on U.S. Mine Safety and Health trends and standards was given to undergraduate and graduate students at the China University of Mining & Technology on March 15, 2011 in Beijing, China. In attendance were approximately 100 students. Following the talk, a meeting took place with faculty members from the Mine Safety program to discuss potential collaborations and faculty internships between universities.

13. In collaboration with the University of Arizona, five training presentations were offered at the Annual Joint Western Regional Mine Safety and Health Conference that was held in Henderson, Nevada on October 25-26, 2011. The presentations were 1-hour in length. CSM's presentations were as follows:
    - Utilizing MSHA Fatality Reports/Fatalgrams for Training
    - Mine Rescue Training Using Computer Simulations

    CSM also shared a booth with the University of Arizona, which allowed CSM to demonstrate the mine rescue computer simulator, as well as to discuss training courses with interested parties. The number of attendees at this conference was 446, and the number of attendees at each presentation was about 25. CSM staff estimated that approximately 200 conference attendees were contacted at the booth.
14. As a collaborative effort, CSM and the University of Arizona offered nine presentations at the 8th Annual Mine Safety and Health Conference, which was held October 22-24, 2012 in Reno, Nevada. CSM conducted five one-hour presentations. About 150 people attended these five presentations, and another 100 visited our booth. The titles of these presentations were:
    - Training Tools for Hazard Recognition and Accident Prevention
    - Confined Space Entry Procedures for Mines and NFPA Confined Space Rescue for Mine Rescue Teams
    - Using Cognitive-Behavioral Safety to Strengthen Organizational Culture
    - Occupational Hearing Loss – Prevention, Recognition and Training
    - Enhanced Mine Rescue Training – Practice Makes Perfect
15. Janet Torma-Krajewski and Jerry Powers participated in a poster presentation/discussion at the International Council of Metals Mining Safety and Health Conference held on November 14, 2012. The focus of the presentation was the CSM mine rescue computer simulation training. The primary attendees at this conference were senior level management and safety and health professionals from multinational mining companies.
16. Christine Geier and Erin Keogh, two undergraduate students, who were members of CSM's Student Mine Rescue Teams, gave a presentation on February 26, 2013 at the Annual SME conference in Denver titled "Colorado School of Mines: Mine Rescue Training using Computer Simulations". Approximately 50 people attended this presentation. They also published an article titled: Colorado School of Mines Mine Rescue Simulator in Mining Engineering, 66 (2): 53-58, 2014. A copy of the article is provided in the Appendix.

17. Jerry Powers gave a one-hour presentation titled “Safety Best Practices in Mining - Applications for Tunnel Construction” at the Art and Science of Safe Tunneling Conference sponsored by the University of Washington, held in Seattle on May 30, 2013. The number of people attending this presentation was approximately 120.
18. Nicole Henderson, a mining engineering undergraduate student and the captain of the women’s mine rescue team, presented: “Colorado School of Mines Mine Rescue Program” at the 2013 International Mine Rescue Conference in Niagara Falls, New York.
19. The following article was submitted to SME as a preprint for the 2014 Annual Meeting and for publication in Mining Engineering: Henderson N, Mischo H, and Brune JF [2014]: The Role of Student Mine Rescue Training in Today’s Mining Engineering Curriculum: A Case Study Establishing a Student Mine Rescue Team at the University of Freiberg, Germany.
20. CSM provided a speaker for a key note address on brain-based safety/safety culture during the 9th Mine Safety and Health Conference, held in Las Vegas, NV, October 2013. The presentation was given by Dr. Melanie Kinser, who is a contract instructor for the CSM Mine Safety and Health Program.
21. CSM WMTC staff also assisted NIOSH with the translation to Spanish of IC 9407 (Ergonomics and Risk Factor Awareness Training for Miners) and IC 9509 (Ergonomics Processes: Implementation Guide and Tools for the Mining Industry) to Spanish.
22. Participated as a member in the 2013 annual meeting of the Colorado State University Industrial Hygiene Program Advisory Board.
23. In 2012/2013, several faculty members from the CSM Western Mining Training Center took on leadership roles in several significant SME safety initiatives, including:
    - 2012 and 2013 SME/CIM Safety Management & System Reliability Conference: Meeting and Program Chairs and the Organizational Program Committee (While the 2012 conference in Minnesota was deemed a success, the 2013 conference in Toronto was cancelled due to insufficient sponsorship and poor industry response in Canada.)
    - 2012, 2013 and 2014 SME Safety & Health Committee, Committee Chair, Subcommittee Chairs, and Committee Members
    - Development of a Safety & Health Short course for 2013 SME Annual Meeting
24. Several members from the CSM Western Mining Training program have and are participating in the Safety and Health Committee of the American Exploration and Mining Association (formally known as the Northwest Mining Association).

25. Several members of the MSHP program have participated in the NORA Mining Sector Committee annually since the formation of the group in 2010.
26. Conducted meetings with government officials from Columbia, Mongolia, China, Afghanistan, Turkey, and Poland during 2012/2013 to discuss potential collaborations in establishing educational and training programs in occupational mine safety and health applicable to both academic and industry settings.
27. Provided educational instruction on safety risk management to professional groups of mining engineers and geologists from the Afghan Ministry of Mines and the Afghan Geologic Survey as part of a capacity building project sponsored by the USGS and DOD Economic Task Force (February 2013 and September 2014).

During the project period, 888 rescuers, including 71 students and 70 military personnel, participated in mine rescue training for Specific Aim 3. Courses conducted and activities completed for this specific aim are described below:

1. 26 mine rescue teams (coal, metal/nonmetal and student teams) were trained using computer simulations.
2. 9 metal mine rescue teams completed exploration exercises in the Edgar Mine.
3. 12 US Army Underground Search and Rescue teams completed underground search and rescue training in June 2011-2014.
4. 11 mine rescue teams completed courses on using air bags to perform heavy lifts
5. 7 mine rescue teams completed courses on performing technical rope rescues
6. 12 mine rescue/fire brigade teams completed courses on fighting fires
7. An abandoned mine training course for local responders was developed. The need for this course occurred when a local teenager became trapped in an abandoned mine and the local responders were not familiar with the hazards associated with facilitating a rescue from an abandoned mine. This course, which includes a classroom session, as well as an underground exercise at the Edgar Mine, was developed by Clancy Harman and Chris Enright, two CSM undergraduate students, who then conducted the course in September 2012 for the Golden Fire Department. Since taking this course, the Golden Fire Department responded to another call where they had to rescue college students trapped in a cave. The CSM Student Mine Rescue Team also responded to both calls in an advisory capacity to the Golden Fire Department.

8. The simulation software was upgraded to include more interactive features. Team members can now resolve hazards, such as putting out fires or resetting timbers, maintain an inventory of supplies, check BG4 oxygen levels, and measure oxygen and hazardous gas levels. Smoke levels and lighting appropriate to an underground mine were added as features of the underground mine model. Team members can also tie off when entering smoke and visibility is reduced, date/initial intersections and post any other information deemed necessary during an exploration. A second level was also added to the Edgar Mine model along with the ability of the team members to move between the two levels. Significant progress was made in upgrading the simulation software to include ventilation features. Initially this effort involved integration of MFIRE with the simulation software on a very basic level; however, the MFIRE software proved to be very cumbersome to use during an actual training session. Consequently, it was decided to develop a very basic ventilation program that could be used with the simulation software. The ventilation software has been developed and tested in a portion of the mine model, but has not yet been fully integrated with the entire model. A coal mine model was also developed for simulated coal mine emergency exercises. (Support for this task was provided from carryover funding from the previous NIOSH cooperative agreement and several MSHA Brookwood-Sago Grants (2010-2014)).
9. During this project, new technical rescue courses were developed, which included:
    - Heavy lifting using air bags
    - Confined space entry and rescue
    - Technical rope rescues
    - Ground support using aluminum struts
    - Firefighting for fire brigades and mine rescue teams
10. Hosted a demonstration of the NIOSH mine rescue simulator on September 17-18, 2013 for the student mine rescue teams. NIOSH also obtained user input from the students for the simulator and the BG4 training module.
11. An ultra-light stretcher cart was designed and developed to support the mine rescue exercises at the Edgar Mine. This cart replaced two other stretcher carts that had significant design flaws that made them very difficult to use in actual mine environments. The new cart is constructed of aircraft grade aluminum, has two large wheels, and is equipped with racks for two fire extinguishers and a BG4. Photos are provided in the Appendix.
12. Starting in July 2011, the Mine Safety and Health Program provided support and technical guidance to the CSM Student Mine Rescue Teams. During the project period, the three

student teams completed 81 training sessions and participated in 8 mine rescue contests. The team members completed 768 training days. The students secured donations of approximately $100,000 (cash/equipment). The three CSM Student Mine Rescue Teams, also accomplished the following:

- Planned, organized, and conducted the 2013 Collegiate MERD prior to the SME Conference. Five student mine rescue teams (41 students) participated in this event, including three CSM student teams, one team from the Missouri University of Science and Technology, and one team from the University of British Columbia. The University of Arizona sent a partial team to observe the MERD and two mining professors from Freiberg University of Mining and Technology in Germany were also present at the training exercise. Both groups were interested in establishing student mine rescue teams at their respective Universities and wanted to gather information from this event. This event was refereed by MSHA and Henderson Mine personnel, and five industry professionals served as team mentors. The MERD was financed by donations from industry partners.
- Updated the Student Mine Rescue website to provide information about the CSM teams and to provide useful information and training materials to other student teams and academic institutions (http://organizations.mines.edu/minerescue/).
- CSM Student MRTs participated in two regional mine rescue contests in 2012, 2013 and 2014. For these years, two teams attended the contest held in Winnemucca, Nevada, and one team participated in the contest held in Wilmington, Illinois. In 2014, one team also participated in the Colorado Mine Rescue Contest held in Golden, CO and the National Mine Rescue Contest held in Lexington, KY. The CSM teams earned 1st place overall at Wilmington (2013) and 3rd place overall (Novice category) at Nationals (2014).

Implementation of this Specific Aim 4 (*Conduct a comprehensive evaluation of the CSM training program that will determine its effectiveness in terms of promoting the reduction of injuries to mining personnel)* was initiated during the second year of the cooperative agreement. Activities completed include:

1. Development of an evaluation plan
2. Review of current evaluation instruments and development of supplemental evaluation instruments for the New Miner and Annual Refresher Training
3. Collection of evaluation data for 3 New Miner and 3 Annual Refresher courses

4. Development of evaluation instruments for conference presentations
5. Collection of evaluation data for two conference presentations
6. Analysis of the evaluation data
7. Preparation of reports with recommendations for improvements

For Specific Aim 4, two types of training materials were developed. These are described below:

1. Sixteen interactive hazard recognition activities were developed for recent mining fatalities using information made available by MSHA (fatalgrams and investigation reports). The initial five activities were tested during training classes prior to being finalized. During the testing, the trainees were able to identify several potential fatal hazards, the likely root cause and other causal factors of the fatality, and several preventive measures. The interactive nature of this training activity allowed for discussion, including input from one trainee who was very knowledgeable about operating the equipment involved in the fatality. His information was helpful in improving the final presentation. The remaining 11 activities were developed using the same format. All of the activities were placed on the MSHP website as downloadable files.
2. A searchable database of MSHA fatality investigation reports and fatalgrams was developed. It was decided to provide the data in an Excel spreadsheet, which can be sorted at multiple levels to extract specific fatality reports. A guide for searching this spreadsheet was also written to assist users, who are not familiar with Excel. Both the guide and spreadsheet are accessible on the MSHP website. Although this task is considered complete, the database has been updated periodically as new fatality reports are released from MSHA.

RESULTS AND DISCUSSION

SPECIFIC AIM 1 - MSHA REQUIRED TRAINING

.Post course evaluations completed by trainees indicated that these courses were rated as excellent or very good by 89 percent of the trainees. The most significant strengths of these courses included the highly qualified instructors, opportunities for discussion, and the emphasis placed on hazard recognition and accident prevention. For the New Miner Underground course, an additional strength of the program was the experience of training at an actual underground mine.

MSHA Part 48 New Miner Training

Overall, the ***New Miner Surface*** training courses were rated as excellent or very good by 91 percent of the trainees. The opportunities for discussion and to interact with the instructors or other trainees were rated as excellent or very good by 88 to 94 percent of the trainees. The most significant strengths of this course included the experience and knowledge of the instructors, the emphasis placed on hazard recognition and accident prevention, and it was all very easy to understand. Significant weaknesses included comments indicating that there should be more interactive presentations, some of the videos were outdated, and there was not enough time for all the subjects covered during the training. Ninety-nine percent of trainees thought the course would be useful in their job. Forty-three percent said they would use what they learned to train others. Additional information from the evaluations is provided in Table 2.

Overall, the ***New Miner Underground*** training courses were rated as excellent or very good by 85 percent of the trainees. Opportunities for discussion and to interact with the instructors or other trainees were rated as excellent or very good by 85 to 93 percent of the trainees. The most significant strengths of this course included the experience of being in an actual mine, the knowledge of the instructors, and the excellent instruction. The most significant weaknesses were that there was not enough time spent at the Edgar Mine, and the outdated facilities at the Edgar. Ninety-eight percent of trainees thought the course would be useful in their job. Forty percent said they would use what they learned to train others. Additional information from the evaluations is provided in Table 3.

Table 2. Combined evaluation results for all New Miner Surface courses.

New Miner Surface*	Excellent	Very Good	Good	Fair	Poor
Content	110	111	33	5	1
Pace	78	104	58	19	1
Level	92	105	53	7	0
Visual Aids	110	97	43	8	2
Course Material	96	109	45	9	0
Opportunity for Discussion	170	72	12	5	1
Opportunity to Interact with Instructors	184	74	12	5	0
Opportunity to Interact with Participants	149	80	24	6	0
Overall Evaluation	112	117	23	0	0

*The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 3. Combined evaluation results for all New Miner Underground courses.

New Miner Underground*	Excellent	Very Good	Good	Fair	Poor
Content	79	63	28	2	0
Pace	67	61	35	9	1
Level	69	67	32	5	0
Visual Aids	85	62	21	5	0
Course Material	74	62	30	5	0
Opportunity for Discussion	96	67	16	4	0
Opportunity to Interact with Instructors	109	52	11	1	0
Opportunity to Interact with Participants	98	49	24	2	0
Overall Evaluation	75	71	22	3	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Overall, the ***New Miner Underground for Experienced Surface Miners*** training courses were rated as excellent or very good by 81 percent of the trainees. Opportunities for discussion and to interact with the instructors or other trainees were rated as excellent or very good by 94 percent of the trainees. The most significant strengths of this course included the experience of being in an actual mine, conducting ventilation measurements, the knowledge of the instructors, and the excellent instruction. The most significant weaknesses were some of the videos were outdated, and the course was heavily focused on hard rock mining. Eighty-eight percent of trainees thought the course would be useful in their job. Thirty-eight percent said they would use what they learned to train others. Additional information from the evaluations is provided in Table 4.

Table 4. Combined evaluation results for New Miner Underground for Experienced Surface Miners courses conducted during the last two years of the project period.

New Miner UG for Experienced Surface Miners*	Excellent	Very Good	Good	Fair	Poor
Content	12	2	1	1	0
Pace	9	4	2	1	0
Level	9	5	1	0	0
Visual Aids	7	7	2	0	0
Course Material	9	5	2	0	0
Opportunity for Discussion	12	3	1	0	0
Opportunity to Interact with Instructors	12	3	1	0	0
Opportunity to Interact with Participants	11	4	1	0	0
Overall Evaluation	11	2	2	14	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

MSHA Part 48 Annual Refresher Training

The ***Annual Refresher*** training courses were rated as excellent or very good by 86 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 72 to 86 percent of the trainees. The most significant strengths of this course included the experience and knowledge of the instructors, the variety of instructors, and the comprehensiveness of the material presented. Significant weaknesses included that there was not enough time to cover all topics and the use of some outdated audiovisual materials. One trainee, when asked to identify weaknesses of the training, stated: "*This is by far the most useful MSHA training I have ever had, no suggestions for improvement, well done*!" Ninety-nine percent of the trainees thought the course would be useful in their job. Forty-six percent said they would use what they learned to train others. Additional information from the evaluations is provided in Table 5.

Table 5. Combined evaluation results for all MSHA Annual Refresher courses.

Annual Refresher*	Excellent	Very Good	Good	Fair	Poor
Content	216	269	74	5	0
Pace	172	239	128	27	0
Level	192	240	117	13	1
Visual Aids	222	210	114	22	3
Course Material	204	237	101	14	0
Opportunity for Discussion	265	234	74	16	2
Opportunity to Interact with Instructors	283	206	67	11	0
Opportunity to Interact with Participants	212	193	121	36	4
Overall Evaluation	207	274	71	8	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

SPECIFIC AIM 2 - SAFETY & HEALTH PROFESSIONAL/TRAINER TRAINING

MSHA Instructor Course

Overall, the ***MSHA Instructor*** training courses were rated as excellent or very good by 96 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 100 percent of the trainees. The most significant strengths of this course included the experience and knowledge of the instructors and the materials (outlines and lesson plans) received to assist with developing their training courses. The significant weakness was not enough time given to prepare their presentation. One hundred percent of the trainees thought the course would be useful in their job, easy to understand, and useful in learning how to communicate to students. Additional information from the evaluations is provided in Table 6.

Mine Safety Specialist Course

Overall, the ***Mine Safety Specialist*** training courses were rated as excellent or very good by 81 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 100 percent of the trainees. The

Table 6. Combined evaluation results for all MSHA Instructor courses.

MSHA Instructor*	Excellent	Very Good	Good	Fair	Poor
Content	18	8	1	0	0
Pace	17	8	2	0	0
Level	21	5	1	0	0
Visual Aids	15	10	2	0	0
Course Material	19	7	1	0	0
Opportunity for Discussion	24	3	0	0	0
Opportunity to Interact with Instructors	24	3	0	0	0
Opportunity to Interact with Participants	24	3	0	0	0
Overall Evaluation	22	4	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question..

most significant strengths of this course included the experience and knowledge of the instructors, and the material presented was comprehensive. According to one trainee: *"The course material was excellent but the knowledge of the instructors surpassed the content."* Significant weaknesses included that there was not enough time for field exercises, and there was not enough time to cover all of the material. One hundred percent of the trainees thought the course would be useful in their job, and 88 percent stated that they would use what they learned to train others. Additional information from the evaluations is provided in Table 7.

Table 7. Combined evaluation results for all Mine Safety Specialist courses.

Mine Safety Specialist*	Excellent	Very Good	Good	Fair	Poor
Content	7	6	4	0	0
Pace	5	5	7	0	0
Level	6	6	4	1	0
Visual Aids	7	3	5	2	0
Course Material	8	5	4	0	0
Opportunity for Discussion	16	0	1	0	0
Opportunity to Interact with Instructors	16	0	1	0	0
Opportunity to Interact with Participants	15	1	1	0	0
Overall Evaluation	8	5	3	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Leading Culture Change

Overall, the ***Leading Culture Change*** course was rated as excellent or very good by 75 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 75 percent of the trainees. The most significant strength of this course was the interaction and discussion among participants and the instructor. All of the participants agreed or strongly agreed that the instructor provided clear instructions, engaged participants, asked meaningful questions, and linked the discussion to the content of the course. All of participants indicated the training was useful to their jobs, and 75 percent of the trainees indicated that they would use the training they received to train others. Additional information from the evaluations is provided in Table 8.

Table 8. Combined evaluation results for the Leading Culture Change course.

Leading Culture Change*	Excellent	Very Good	Good	Fair	Poor
Content	1	2	1	0	0
Pace	1	0	3	0	0
Level	1	2	1	0	0
Visual Aids	1	1	0	2	0
Course Material	1	1	1	1	0
Opportunity for Discussion	3	0	1	0	0
Opportunity to Interact with Instructors	3	0	1	0	0
Opportunity to Interact with Participants	3	0	1	0	0
Overall Evaluation	1	2	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

SPECIFIC AIM 3 - MINE RESCUE TRAINING

Mine Rescue Computer Simulation Training

Evaluation results received from all trainees participating in the computer simulation mine rescue training indicated that 97 percent thought the training was useful to their job and 96 percent thought it would be helpful for improving performance during mine rescue exercises. Almost all of the trainees thought the computer simulation training was useful for learning how to communicate, make decisions, and recognize hazards during a mine emergency. To demonstrate the versatility of this system, evaluation results were compared among software versions and different experience levels of the rescue teams. From these comparisons it was learned that novice teams gave a slightly higher overall evaluation of the training than experienced teams and that this simulation system was a viable training method for both novice and experienced mine rescue teams. Ninety percent of novice team members rated the overall training as excellent or very good, while 81 percent of experienced team members gave similar ratings. The overall evaluation also increased when comparing the results between version 1 and 2 of the simulation software. Seventy-five percent of the trainees using version 1 rated the training as excellent or very good, while 97 percent of the trainees using version 2 gave similar ratings. The primary differences between the two versions were the enhanced environmental conditions simulating underground conditions (smoke and lighting) and interactive decision points. This study was published in Mining Engineering and is provided as an attachment in the Appendix.

Twelve coal, thirteen metal/nonmetal, and four student mine rescue teams, as well as twelve US Army teams, completed the ***Computer Simulation Training*** during the project period. Eighty-four percent of the trainees rated the overall training experience as excellent or very good. The most significant strengths of this training included being able to stop the simulation to discuss procedures, teamwork, interaction with instructors, and realism of the situation. The most significant weakness was a software issue that occurred during two of the training sessions, which was subsequently rectified and hasn't occurred since. Additional information from the evaluations is provided in Table 9. Students from Missouri University of Science and Technology are shown using the computer simulator in Figure 1.

Table 9. Combined evaluation results for all Computer Simulation courses.

Computer Simulation*	Excellent	Very Good	Good	Fair	Poor
Content	87	115	36	6	0
Pace	76	92	57	14	3
Level	70	109	49	5	1
Visual Aids	68	75	60	22	10
Course Materials	17	29	28	3	
Opportunity for Discussion	144	75	24	2	0
Opportunity to Interact with Instructors	163	62	19	1	0
Opportunity to Interact with Participants	142	74	20	3	1
Overall Evaluation	99	106	34	4	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

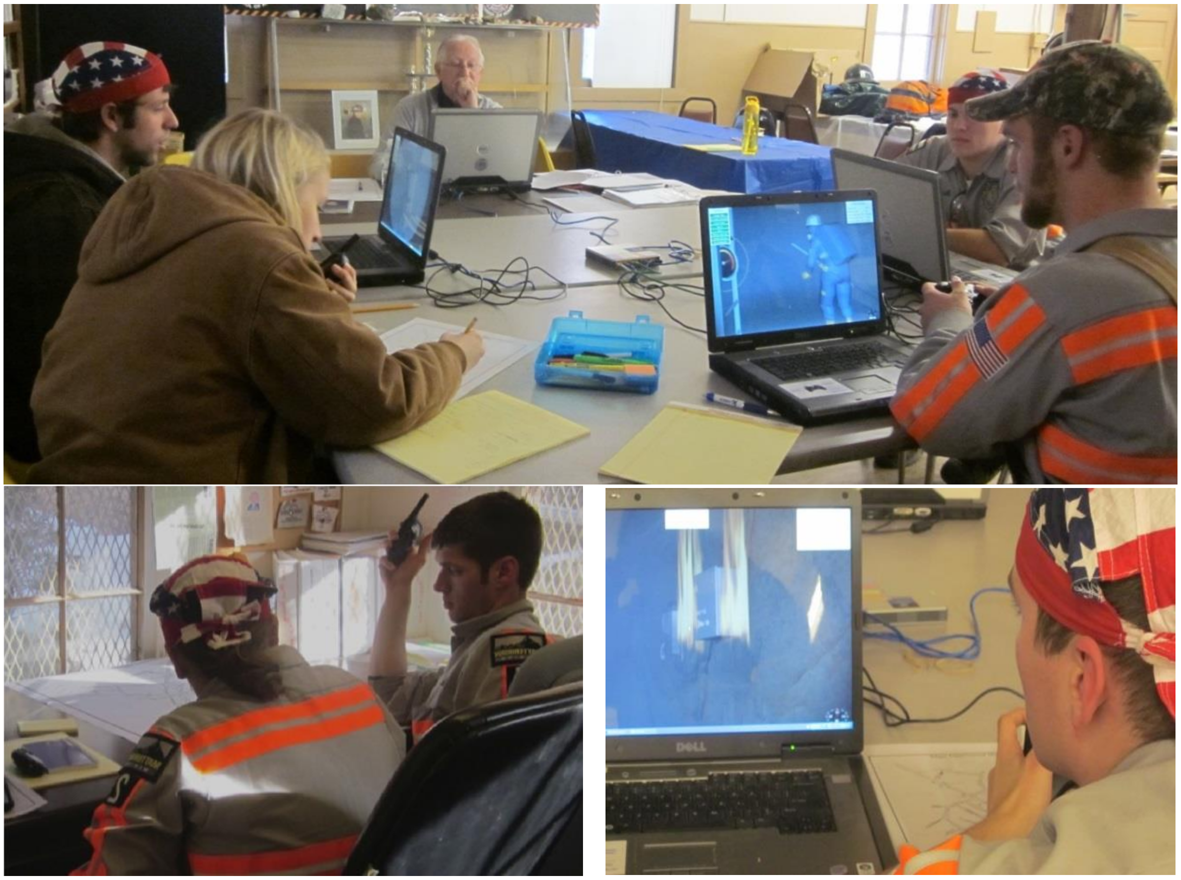

Figure 1. Students from the Missouri University of Science and Technology are shown using the computer simulator and serving in the command center.

Advantages and disadvantages of the computer simulation training included:

ADVANTAGES

1. Ability to learn skills without the stress
2. Good for practicing communications
3. Teaches decision-making skills
4. Learning proper procedures in a controlled environment
5. Students are not in harm's way

DISADVANTAGES

- Do not get to experience smoke or physical exhaustion
- Game controller operation was initially confusing
- Improved sound effects were needed

Ninety-seven percent of the trainees thought the computer simulation training would be useful in their job and 96 percent of trainees thought it would be helpful in improving their performance during mine rescue exercises. Almost all of the trainees thought the simulator training was useful for learning how to communicate (97percent) and to make decisions (96 percent) during a mine emergency. The trainees also thought the simulator was easy to use. Additional information from the evaluations is provided in Table 10.

Table 10. Combined evaluation results for all Computer Simulation courses.

Computer Simulation	Yes (%)	No (%)
Will the training you received be useful in your job?	97	3
Was the simulation training helpful for improving performance during mine rescue exercises?	96	4
Was the simulator useful for learning how to communicate during rescue exercises?	97	3
Was the simulator useful for learning how to make decisions during a mine emergency?	96	4
Was the simulator useful for learning how to recognize hazards?	87	13
Was the simulator easy to use?	95	5

Advanced Mine Rescue Skills Training

Evaluation results received from trainees who participated in these courses indicated that 96 percent rated them as excellent or very good. Significant strengths of these courses as identified by trainees included knowledgeable instructors, being able to train in an actual mine while in smoke, and having the opportunity to learn new rescue skills.

Overall, the ***Air Bag Heavy Lift*** training course was rated as excellent or very good by 96 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 96 to 100 percent of the trainees. The most significant strengths of this course included learning how this system worked and learning newer and safer rescue techniques. The most significant weakness included not having enough time to do more lifts. Ninety-three percent of the trainees thought the course would be useful in their job, particularly for emergencies; however, two trainees did not rate it as useful since their mine did not have the necessary equipment to conduct the lifts. Additional information from the evaluation is provided in the Tables 11 and 12. Figure 2 shows a team member placing an air bag.

Figure 2. Mine rescue team member placing an air bag prior to performing a heavy lift.

Table 11. Combined evaluation results for all Air Bag Heavy Lift courses.

Air Bag Heavy Lift*	Excellent	Very Good	Good	Fair	Poor
Content	40	33	8	0	0
Pace	35	27	15	1	0
Level	38	27	15	1	0
Visual Aids	44	22	13	0	0
Course Material	35	28	10	1	0
Opportunity for Discussion	56	17	7	0	0
Opportunity to Interact with Instructors	41	13	6	0	0
Opportunity to Interact with Participants	37	19	4	0	0
Overall Evaluation	50	26	4	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 12. Combined evaluation results for all Air Bag Heavy Lift courses.

Air Bag Heavy Lift	Yes (%)	No (%)
Will the training you received be useful in your job?	93	7
Was the course material easy to understand?	100	0
Do you feel that you now understand basic techniques for heavy lifting with air bags?	100	0
Do you believe that you could safely perform a basic heavy lift in a rescue or general situation?	100	0
Do you think that you know how to effectively communicate while directing or performing a basic heavy lift??	100	0
Was the training helpful to improving performance of actual rescue exercises?	100	0

Overall, the ***Fire Brigade*** training courses were rated as excellent or very good by 100 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 86 to 100 percent of the trainees. The most significant strengths of this course included knowledge of the instructors, being able to train in smoke, and maneuvering through the maze. The most significant weakness was not being able to have a real fire in the mine. One hundred percent of the

Figure 3. Fire brigade team extinguishing a fire in a burn pan.

trainees thought the training at the Edgar facility would improve their performance during an actual underground rescue. Additional information from the evaluations is provided in Table 13. Figure 3 shows a fire brigade team extinguishing a fire in a burn pan.

Table 13. Evaluation results for all tasks completed by two Fire Brigades.

Fire Brigade*	Excellent	Very Good	Good	Fair	Poor
Content	8	8	0	1	0
Pace	10	5	2	0	0
Level	8	5	4	0	0
Visual Aids	10	4	3	0	0
Course Material	14	3	0	0	0
Opportunity for Discussion	5	4	0	1	0
Opportunity to Interact with Instructors	6	6	2	0	0
Opportunity to Interact with Participants	9	8	0	0	0
Overall Evaluation	10	6	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Additional information from the evaluations for specific tasks completed during the Fire Fighting Training is provided in Tables 14 through 17.

Table 14. Combined evaluation results for using a Bull Ex Fire Training System.

Extinguishing Fires* (Bull Ex Training System)	Excellent	Very Good	Good	Fair	Poor
Content	19	15	5	0	0
Pace	23	10	6	0	0
Level	16	12	7	4	0
Visual Aids	17	14	3	0	0
Course Material	21	11	5	0	0
Opportunity for discussion	25	13	1	0	0
Professional Value to You	26	11	2	0	0
Overall Evaluation	15	11	2	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 15. Combined evaluation results for extinguishing fires in a burn pan.

Extinguishing Fires* (Burn Pan)	Excellent	Very Good	Good	Fair	Poor
Content	45	25	4	0	0
Pace	41	24	7	0	0
Level	39	24	9	1	0
Visual Aids	29	13	2	0	0
Course Material	32	12	3	0	0
Opportunity for discussion	53	16	4	0	0
Opportunity to interact with instructors	19	6	1	0	0
Opportunity to interact with other participants	21	5	1	0	0
Professional value to you	34	12	3	0	0
Overall Evaluation	40	21	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 16. Combined evaluation results for exploring the Maze Room in the Edgar Mine.

Maze Exploration*	Excellent	Very Good	Good	Fair	Poor
Content	5	3	0	0	0
Pace	6	2	0	0	0
Level	5	1	2	0	0
Visual Aids	6	0	2	0	0
Course Material	3	3	2	0	0
Opportunity for discussion	5	3	0	0	0
Professional Value to You	6	1	1	0	0
Overall Evaluation	6	2	0	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 17. Combined evaluation results for the underground exploration task.

Underground Exploration*	Excellent	Very Good	Good	Fair	Poor
Content	31	15	2	0	0
Pace	23	14	11	0	0
Level	23	18	7	1	0
Visual Aids	21	14	6	0	0
Course Material	28	13	7	0	0
Opportunity for discussion	27	7	3	0	0
Professional Value to You	32	15	1	0	0
Overall Evaluation	25	10	0	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

The ***Basic Technical Rope Rescue*** training was rated as excellent or very good by 97 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 94 to 95 percent of the trainees. The most significant strengths of this course were learning the knots and how to use mechanical advantage when lifting heavy loads. The most significant weakness was the amount of information that had to be learned in a short period of time. One hundred percent of the trainees thought the training would improve their performance during an actual underground rescue, and thought the course material was easy to understand. Additional information from the evaluations is provided in Tables 18 and 19. Figure 4 shows a coal mine rescue team learning how to use ropes to rescue a victim.

Table 18. Combined evaluation results for all Technical Rope Rescue courses.

Technical Rope Rescue*	Excellent	Very Good	Good	Fair	Poor
Content	41	21	2	0	0
Pace	32	24	8	0	0
Level	39	22	3	0	0
Visual Aids	46	14	4	0	0
Course Material	38	20	6	0	0
Opportunity for Discussion	48	12	3	0	0
Opportunity to Interact with Instructors	53	7	4	0	0
Opportunity to Interact with Participants	51	9	3	0	0
Overall Evaluation	49	11	2	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 19. Combined evaluation results for all Technical Rope Rescue courses.

TECHNICAL ROPE RESCUE	Yes (%)	No (%)
Will the training you received be useful in your job?	92	8
Was the course material easy to understand?	100	0
Do you feel that you now understand the basic techniques for general rope operations?	100	0
Do you believe that you could safely use ropes or mechanical advantage systems to perform basic lift in a rescue or general situation?	93	7
Do you think that you know how to effectively communicate while directing or performing a basic rope rescue operation (Incident Command/Operator)?	93	7
Was the rope rescue training helpful to improving the performance of actual rescue exercises?	100	0

Figure 4. A coal mine rescue team setting the ropes and then lowering a team member to the level below.

The overall evaluation of the ***Underground (UG) Rescue Exercises*** were rated as excellent or very good by 97 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 84 to 86 percent of the trainees. The most significant strength of this course was the realistic training environment, including the smoke. The most significant weakness was an issue with the radios not working properly. One hundred percent of the trainees thought the training would improve their performance during an actual underground rescue, and 100% thought it was useful to learning how to make decisions during a mine emergency. All of the trainees who completed the Computer Simulation training prior to participating in UG Rescue Exercises in the Edgar Mine thought completing the computer simulation training was helpful in completing the same exercise in an underground environment, and 67% of the trainees thought the computer simulation training was helpful in completing a different exercise conducted in a different area of the Edgar Mine. Additional information from the evaluations is provided in Tables 20 and 21.

Table 20. Combined evaluation results for all Edgar Mine Rescue Exercises.

UG Rescue Exercises*	Excellent	Very Good	Good	Fair	Poor
Content	44	46	6	1	0
Pace	33	40	15	9	0
Level	37	40	20	0	0
Visual Aids	23	17	11	0	0
Course Material	15	27	9	0	0
Opportunity for Discussion	43	38	14	1	0
Opportunity to Interact with Instructors	42	28	9	2	2
Opportunity to Interact with Participants	31	32	10	0	0
Overall Evaluation	35	39	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 21. Combined evaluation results for all UG Rescue Exercise.

UG Rescue Exercises	Yes (%)	No (%)
Will the training you received be useful in your job?	100	0
Was the training useful for learning how to make decisions during a mine emergency?	100	0
Was the training useful for learning how to communicate during an actual rescue exercise?	91	8
Was the training useful for learning how to recognize and mitigate or avoid hazards?	100	0
Will the training improve your performance during an actual underground rescue?	100	0
Were the UG exercises useful for learning how to utilize a command center?	100	0
Do you believe the computer simulation training improved your performance when completing the same exercise underground?	100	0
Do you believe the computer simulation improved your performance when completing a different exercise underground?	63	37

Overall, the ***Ground Support*** training course was rated as excellent or very good by 82 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 74 to 82 percent of the trainees. The most significant strengths of this course included being able to install both timbers and rescue struts, the hands-on activities, and the qualified instructors. The most significant weaknesses included not having all of the available accessories for the struts, more information should have been provided regarding different applications of the struts and the theory of using struts rather than timbers.   Ninety-seven percent of the trainees thought the course would be useful in their job, and 100% of the trainees thought the training would improve their performance during an actual rescue. Figures 5 and 6 illustrate the installation of the struts in an underground environment. . Additional information from the evaluation is provided in Tables 22 and 23.

Figure 5. Installation of rescue struts for both roof and rib ground control.

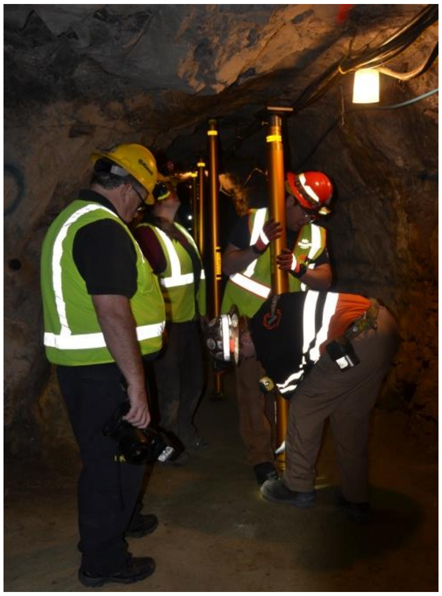

Figure 6. Installation of rescue struts in two different sized drifts, less than 8 feet (left photo) and greater than 10 feet (right photo) in height.

Table 22. Combined evaluation results for all Ground Support courses.

Ground Support*	Excellent	Very Good	Good	Fair	Poor
Content	16	12	7	0	0
Pace	13	12	9	1	0
Level	13	13	7	2	0
Visual Aids	16	9	6	0	1
Course Material	13	12	6	0	0
Opportunity for Discussion	18	9	7	0	1
Opportunity to Interact with Instructors	19	9	5	1	0
Opportunity to Interact with Participants	19	7	7	2	0
Overall Evaluation	17	12	6	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 23. Combined evaluation results for all Ground Support courses.

Ground Support	Yes (%)	No (%)
Will the training you received be useful in your job?	97	3
Was the course material easy to understand?	100	0
Do you now understand the basic techniques for ground support using rescue struts?	100	0
Do you believe that you could safely use rescue struts to provide ground support in a rescue or general situation?	100	0
Was the ground support training helpful to improving the performance during an actual rescue exercises?	100	0

The ***Confined Space Entry and Rescue*** training was rated as excellent or very good by 98 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 92 to 98 percent of the trainees. The most significant strengths of this course were the hands-on training, learning to work as a team, having an opportunity for the mine and mill rescue teams to work together, and the quality instruction. The most significant weakness was that there was not enough time. One hundred percent of the trainees thought the training would improve their performance during an actual underground rescue, and thought the course material was easy to

Figure 7. Measuring air contaminants prior to entering confined space.

understand. Figures 7 through 9 illustrate various steps taken when safely removing a victim from a confined space. Additional information from the evaluations is provided in Tables 24 and 25.

Figure 8. Victim being moved onto the Yates for packaging.

Figure 9. Rescuer being removed from the confined space.

Table 24. Combined evaluation results for all Confined Space Rescue courses.

Confined Space Rescue*	Excellent	Very Good	Good	Fair	Poor
Content	39	12	1	0	0
Pace	26	16	9	1	0
Level	38	11	3	0	0
Visual Aids	37	13	2	0	0
Course Material	41	9	2	0	0
Opportunity for Discussion	35	14	3	1	0
Opportunity to Interact with Instructors	40	11	1	0	0
Opportunity to Interact with Participants	41	8	3	0	0
Overall Evaluation	41	10	1	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 25. Combined evaluation results for all Confined Space Rescue courses.

Confined Space entry and Rescue	Yes (%)	No (%)
Will the training you received be useful in your job?	100	0
Was the course material easy to understand?	100	0
Do you feel that you now understand the basic techniques for confined space operations?	96	40
Do you believe that you could safely use ropes or mechanical advantage systems to perform basic lift in a rescue or general situation?	88	12
Do you think that you know how to effectively communicate while directing or performing a basic confined space rescue operation?	98	2
Was the rope rescue training helpful to improving the performance of actual rescue?	100	0

The overall evaluation of the ***Abandoned Mines*** training was rated as excellent or very good by 100 percent of the trainees. Having opportunities for discussion and interacting with the instructors or other trainees were rated as excellent or very good by 100 percent of the trainees. The most significant strengths of this course were the knowledgeable instructors, the hands-on experience with the equipment (Draeger BG-4s), and enhancing their knowledge of the hazards of entering an abandoned mine. The most significant weakness was that the training did not include specific information on conducting a rescue from a refuge chamber and more structural information. One hundred percent of the trainees thought the training would improve their performance during an actual emergency, and that it was relevant to their organization. Additional information from the evaluations is provided in Tables 26 and 27. Figures 10 and 11 show members of the Golden Fire Department participating in various activities that were part of the course.

Table 26. Combined evaluation results for the Abandoned Mines course.

Abandoned Mines*	Excellent	Very Good	Good	Fair	Poor
Content	11	2	0	0	0
Pace	9	4	0	0	0
Level	9	4	0	0	0
Visual Aids	13	0	0	0	0
Course Material	11	1	0	0	0
Opportunity for Discussion	13	0	0	0	0
Opportunity to Interact with Instructors	13	0	0	0	0
Opportunity to Interact with Participants	13	0	0	0	0
Overall Evaluation	12	1	0	0	0

Table 26. Combined evaluation results for the Abandoned Mines course.

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 27. Combined evaluation results for the Abandoned Mines course

Abandoned Mines	Yes (%)	No (%)
Will the training you received be useful in your job?	100	0
Was the training relevant to your agency's interests?	100	0
Was the training useful to learning how to recognize hazards?	100	0
Was this training useful to learning how to make decisions during an emergency?	100	0
Was the training helpful to improving performance during emergencies?	100	0

Figure 11. Members of the Golden Fire Department learning about hazards found in underground mines.

Figure 10. Members of the Golden Fire Department learning how to bench a Draeger BG4 breathing apparatus.

2013 Collegiate MERD

Figure 12. Student mine rescue team members and support staff participating in the collegiate MERD.

The ***Collegiate MERD*** was rated as excellent or very good by 70 percent of the participating students. Having opportunities for discussion and interacting with the mentors or other students were rated as excellent or very good by 63 to 71 percent of the students. The most significant strengths of the MERD were using a real mine, interactions with mentors and other teams, the ICC experience, and the knowledge given to students. The most significant weaknesses were related to the judges, who were not familiar with the problem, which caused confusion and significant delays. One hundred percent of the trainees thought the training would improve their performance during an actual underground rescue. Additional information from the evaluations is provided Tables 28 and 29. Students participating in the MERD and support staff are shown in Figure 12. Figure 13 shows various team members performing tasks that were part of the MERD.

Table 28. Combined evaluation results for the Collegiate MERD.

Collegiate MERD*	Excellent	Very Good	Good	Fair	Poor
Content	6	16	8	0	0
Pace	2	3	14	11	1
Level	5	13	13	0	0
Visual Aids	4	10	11	3	2
Course Material	4	7	16	1	2
Opportunity for Discussion	1	10	12	6	2
Opportunity to Interact with Instructors	17	5	3	4	2
Opportunity to Interact with Participants	9	10	6	5	0
Overall Evaluation	3	18	9	0	0

* The values shown in this table represent the number of trainees providing the specific rating and answering the question.

Table 29. Evaluation results for the Collegiate MERD.

Collegiate MERD	Yes (%)	No (%)
Will the training you received be useful in your future job?	94	6
Was the UG exercise useful to the team, FAB, and ICC in learning how to recognize hazards?	94	6
Was the UG exercise useful to the team, FAB, and ICC in learning how to make decisions?	89	11
Was the UG exercise useful to the team, FAB, and ICC in learning how to communicate?	97	3
Will the MRED help to improve performance of actual UG rescues?	100	0

Figure 13. Student mine rescue team members referring to their map during an underground exercise, competing in the benching task, and performing first aid on a victim.

SPECIFIC AIM 4 – EVALUATION OF TRAINING PROGRAM

Evaluation results were obtained for the two presentations given at the Annual Joint Western Regional Mine Safety and Health Conference that was held on October 25-26, 2011. The results indicated that overall the instructional environment was conducive to learning, the intended needs of the participants were met (accident prevention presentation only), and the participants would recommend both presentations to others. When asked for suggested improvements, it was recommended that animation should be used on the presentation slides for the computer simulation presentation, and the fatalgrams that were discussed during the accident prevention materials should be provided online. Specific recommendations proposed that instructors review the suggested improvements, and that additional feedback be sought regarding why the participants thought their organizations would not support using computer simulations as a training tool.

The results from the New Miner and Annual Refresher courses indicated that the participants were "highly satisfied with their learning experiences, were committed to applying their learning to their respective jobs, and were confident in their ability to do so. In addition, the participants considered the instructors to be a "significant strength of the program." Suggestions for improvements were to:

1. Include more active learning exercises to promote higher levels of interaction amongst individuals
2. Ensure completion of sessions within the allotted time
3. Revise the training presentations that may include outdated materials
4. Include ways to overcome barriers participants may encounter when attempting to apply what they learned from the training to their jobs.

In response to recommendations, actions completed during the second year involved incorporating more hazard recognition activities requiring participation by trainees, updating training presentations when more recent information was available, and revising the training schedule to avoid running late in completing training presentations. Using clickers/polling devices in our training sessions that promote participation were also explored, and hazard recognition activities based on fatalities and near misses were posted on the internet as downloadable files.

During the third year of the project, MSHP continued to update the presentations to make them more interactive. We obtained Turning Technologies polling software and a set of clickers that allowed polling questions to be added to presentations, and we converted our paper pre and post-tests to electronic versions that were then completed with the clickers. We also changed our training scheduled to have fewer but longer breaks, as compared to more frequent, but shorter breaks, which helped the presenters keep on schedule.

CONCLUSIONS

The mine safety and health training program offered by CSM has received overwhelming acceptance, respect, and approval by those mine workers who have attended the courses. Findings obtained from this project provide suggestions to other organizations on ways to enhance their training programs. The approach taken by CSM in designing the training program has resulted in a valuable service to the mining industry.

APPENDIX

MINE RESCUE COMPUTER SIMULATION ARTICLE

Colorado School of Mines
mine rescue simulator

by C. Geier, E. Keogh and J. Torma-Krajewski

Abstract ■ Previous mine incidents show weaknesses in mine rescue preparedness from poor training in decision making, leadership and incident command center (ICC) protocols. Computer simulations offer a larger range of training opportunities for mine rescue teams focusing on exploration and communications. The mine rescue simulator developed by the Colorado School of Mines and Rite Solutions Inc. utilizes four computers for the instructor and team, with the instructor monitoring the team's progress. As the team explores, it relays information back to the Fresh Air Base, which then reports to the ICC. This forces a three-step communication procedure, enhancing the team's overall communication skills and developing ICC protocols. The simulator is decision-based, demanding team decisions be made quickly. Upon completion, teams commented positively. Generally, participants said that the simulator is useful for learning how to communicate and make decisions during mine rescue emergencies. This mine rescue simulator improves team training, providing effective communications practice with an easy setup and no production interruption.

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Introduction

Our national interests are best served by having well-trained first responders available for rapid response to emergency situations in underground mines. However, recent mine disasters have indicated that focused training on hazard recognition, decision making, leadership and incident command center protocols needs to be part of a comprehensive training plan for all personnel involved in a mine rescue. A report on the Sago Mine disaster indicated the command center lacked organization, preparedness and control, leading to a poor emergency response (Gates et al., 2007; McAteer et al., 2006; UMWA, 2007). A report on the Upper Big Branch Mine disaster concluded that the command center failed to follow protocols and maintain effective communication (Page et al., 2010; UMWA, 2011; McAteer et al., 2011). A report in 2006 from the Mine Safety Technology and Training Commission listed some improvements for mine safety training and technology and stated that the minimum training time should be increased to eight hours a month, and there should be training for common command centers for the mine managers and mine rescue teams. In particular, the training should focus on decision making and effective communication to strengthen coordination between the command center and teams.

C. Geier, E. Keogh, member SME, and J. Torma-Krajewski are training assistants and director, respectively, at the Mine Safety and Health Program, Colorado School of Mines, Golden, CO. **Paper number TP-12-055. Original manuscript submitted November 2012. Revised manuscript accepted for publication August 2013. Discussion of this peer-reviewed and approved paper is invited and must be submitted to SME Publications by May 31, 2014.**

Currently, there are very few training opportunities for the mining professionals responsible for making the crucial decisions needed during a mine emergency. With recent technical advances, it is now feasible to use a computer-based simulator to train mine rescue personnel for mine emergencies in their mine or any other mine at a convenient location without interrupting normal mining operations. There is currently no information on how the use of computer simulators could be beneficial for mine rescue specifically. This simulated environment teaches underground search and rescue procedures, communications and decision making based on real-time information and hazard recognition. It provides another type of training for mine rescue personnel, while providing a safer environment to work in by avoiding the inherent risks associated with training in a real mine.

Since 2010, the Colorado School of Mines (CSM) has offered computer simulated mine rescue training using an incident command center (ICC) directed toward enhancing decision making and communication skills. To support this training, CSM partnered with Rite Solutions Inc. to modify, enhance and create simulation software for mine rescue applications. Rite Solutions was chosen based on its prior experience in developing emergency response simulation software for the maritime industry. The focus of this partnership was to modify existing simulation technology to address the unique nature of

Figure 1

A team during a training session with the mine rescue simulator.

Figure 2

Screenshots from the simulator: The left image is what the team would see (first person mode). The right image is what the instructor can see.

underground rescue operations, make it applicable to any underground operation, create generic scenarios and develop customized computer simulations, including scenarios, for specific sites.

The purpose of this study was to determine (a) if the quality of the graphics was an important factor in the training experience when learning skills was the primary objective, rather than reproducing an experience, and (b) if the experience level of the teams impacted the value of the simulation training as a learning experience. For novice teams, who have little or no experience in following mine rescue procedures, the simulation training addressed learning these procedures, as well as learning communication skills and decision making skills needed to effect a successful rescue. On the other hand, experienced and expert teams already have knowledge of mine rescue procedures, so the focus of the simulation training as a learning experience for these teams was more on communication and decision-making skills, but also allowed the teams to practice mine rescue procedures, which would enhance their overall level of proficiency regarding these procedures.

Need. The CSM mine rescue computer simulator helps mine rescue teams train for mine disasters where they would be deployed. It provides additional, readily accessible opportunities to train without affecting mining operations. While the simulator lacks the physical demands of a rescue situation, it is very effective for teaching mine rescue procedures, as rescuers seamlessly walk through the process and work out issues before going underground. The mine rescue simulator also introduces students to coordinate through an ICC, which stresses the use of effective communication and hones decision-making skills. Most of the mine rescue teams participating in this study had never trained with an ICC controlling the actions of the mine rescue team, making this an extremely valuable training opportunity. In addition, the mine rescue computer simulator allows instructors to modify mine rescue scenarios and tailor the scenarios to each team's individual needs, resulting in a more versatile training experience. The goal is to ensure that all teams receive the maximum benefit from each training session.

Methodology

Training. Training was conducted with four computers, one for the instructor, and three for team members (captain, gas person and co-captain), who can be seen using the simulator in Fig. 1. The individuals in the fresh air base (FAB) and the ICC did not have computers, but instead relied upon verbal communications from the rescue team as would normally occur during an actual emergency. The instructor's computer was used to initialize the simulation, make any necessary changes to the scenario, and to monitor the team's progress through the mine. The other three computers were nearly identical, except that the captain had extra items in his/her inventory, such as a scaling bar and hammer. Screenshots of the simulator can be seen in Fig. 2. The simulation was conducted similar to how the team would proceed through the mine in an actual exercise, with the captain leading, the gas person taking gas measurements and the co-captain reporting back to the FAB, who reports back to the ICC. The map person tracked the team's movement through the mine, as normally would be done, and the first aid person determined what actions should be taken when the team found victims. For this study, the rescue team, FAB and ICC were located in the same building but in three different rooms, and all communications were conducted with radios.

Prior to starting the training, the team members completed an orientation on how to use the simulator, which included some hands-on practice. The team members were also given instructions regarding the use of an ICC. Once the team members were confident in operating the simulator, the rescue problem was read to all participants. At the end of the training, each participant was asked to complete an evaluation questionnaire, which was done on a volunteer basis and anonymously.

Simulation software. The simulation software was developed by Rite Solutions Inc. and is a specialized configuration of Rite-EMTTM, which uses Real World databases (Terrain, Bathymetry, Imagery, 3D Models, Digital Nautical Charts, etc.) to automatically build a virtual training scenario at any location. Scenarios run on Windows-based laptops and desktop computers with 3D capable graphics cards. The scenarios are run in first-person mode, providing a graphical perspective from the viewpoint of the player character, where what is seen on the screen represents what the character would see with their own eyes. All movement and decisions by participants are recorded on an instructor station for immediate after-action review and can be used to develop multimedia training products. The mine model used for the simulations was the Edgar Experimental Mine.

During the past three years, the software has been upgraded based on user input. Three different versions of the

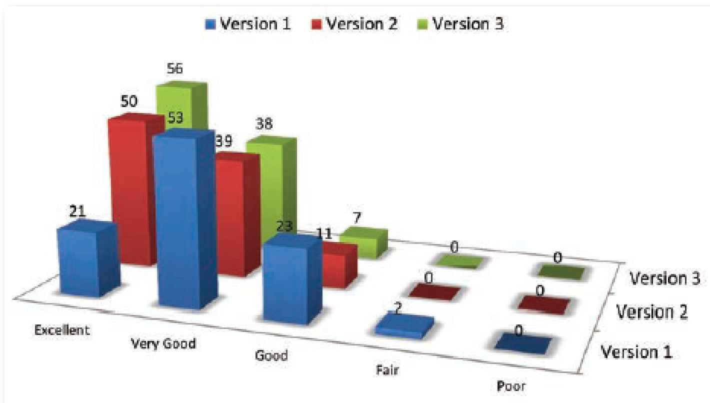
Table 1

Number and type of rescue teams using the different versions of the simulation software.

	Version 1	Version 2	Version 3
Coal MR teams	2	0	0
M/NM MR teams	3	1	5
Student MR teams	0	2	0
Novice UG S&R teams	0	3	3

Figure 3

Overall evaluation ratings for all three software versions.



simulator were tested and used to train mine rescue teams. As the simulator was modified, more interactions were added to the software and the graphics improved slightly. The first version of the simulator software used placards to display gas readings and hazards, and very little interaction occurred between the characters and the mine. Objects in the mine were static and there was no smoke or change in lighting. Only doors could be opened and closed. The second version of the software incorporated more interactions, though they were still overall fairly limited. The team members could now open and close airlocks and place ventilation curtains at preset locations. Hazards could be seen but, again, no abatement of the hazards could be accomplished. With the third version of the simulation software, more interactions between the team members and the mine were added, including the most notable change – gas and smoke regions. Regions with heavy smoke drastically decreased visibility, along with cap lamp lighting, which gave a more realistic feel to what it would be like being in an underground mine. It was also possible to place ventilation curtains at any location in the mine model, take gas readings, pick up objects and victims, and correct hazards. The team members could now see some of the effects of their decisions. For example, when the team encounters a fire, they have the option to use different types of extinguishers. If they use the right one, the fire will be extinguished or lose intensity, but if they use the wrong one, the fire will become more intense. The other difference between Versions 1 and 2 and Version 3 was the controller. For the first two versions, joysticks were used to run the simulation, while game controllers were used to run the third version.

Rescue teams. A total of 19 rescue teams participated in this study. Eleven of the teams were mine rescue teams, who were grouped into one of two experience levels. Teams competing in national mine rescue contests were considered "experts," and teams who had not competed at this level, but had several years of experience were considered "experienced." There were four teams in the first group, with one team winning a national mine rescue contest, and seven teams in the second group. At the novice level were teams with little or no mine rescue experience, two college student teams and six U.S. Army Technical Rescue teams. The total number of team members participating in this training was 120.

Evaluation results

The evaluation data collected from the participants were analyzed according to the version of software used for the simulation training, and by experience level of the rescue teams.

Grouping by software version. Table 1 shows the type of rescue teams who used each version of the simulation software. Version 1 was used by two coal and three metal/nonmetal (M/NM) mine rescue teams, while Version 2 was used by one M/NM mine rescue team, two student teams and three U.S. Army rescue teams. Five M/NM teams and three U.S. Army teams used Version 3.

One of the evaluation questions asked the participants to give an overall rating for the simulation training. The results for this question are shown in Fig. 3. As the software improved from Version 1 to Version 3, there was an increase in the percentage of people who thought it was "excellent" (21% to 56%) and fewer who thought it was "very good" (53% to 38%) or "good" (23% to 7%). None of the versions received any "poor" ratings, and only Version 1 received any "fair" ratings (2%). When combining the percentage of "excellent" and "very good" ratings, the percentage of participants selecting either of these two ratings increased from 74% in Version 1 to 94% in Version 3.

Another question asked the participants to provide an overall rating of the graphics used in the simulation software. The results for this question are shown in Fig. 4. With the latest software version, almost 75% of the participants thought the graphics were either "excellent" or "very good," and the "excellent" category had the highest percentage of ratings. Prior versions had fewer "excellent" ratings compared to "very good" and "good" ratings. For Version 1, the category with the highest percentage was "very good," and for Version 2 the category with the highest percentage was "good." All versions had very few "poor" ratings. Most participants also said the simulator was easy to use for all three versions, even though Version 3 was slightly more complicated than

Figure 4

Ratings for simulation graphics for all three software versions.

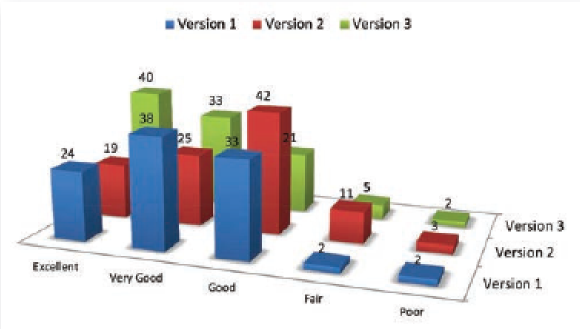
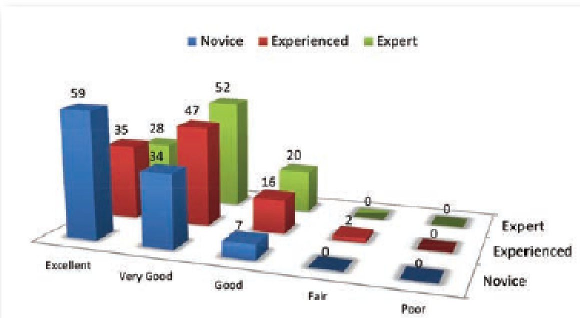


Figure 5

Overall evaluation ratings for all three experience levels.



the prior two versions. Only 10% of the participants using Version 1 thought the simulator was difficult to use, while no one using Versions 2 or 3 thought it was difficult.

Each participant was also asked a series of questions regarding the value of the training for learning certain skill sets and for applying the knowledge gained to their work performance. From these questions, all participants indicated that the simulation training would be useful in their jobs, and 93% (Version 3) to 94% (Versions 1 and 2) indicated it would be helpful for improving performance during a mine rescue exercise. In addition, most people thought that the simulator made them more prepared for specific aspects of a mine emergency – communication, decision making and hazard recognition. When averaging the responses for all three of these questions for each version, the average percentage of positive answers (a "yes" response) for Version 1 was 86%, for Version 2 was 95% and for Version 3 was 93%. Table 2 shows a breakdown of the responses given for each of the questions asked.

Grouping by experience level. Table 3 shows the number and type of team for each level of experience. The "novice" teams included two student mine rescue teams and six U.S. Army rescue teams. The "experienced" teams included two coal mine and five M/NM mine rescue teams, while the "expert" teams included four M/NM mine rescue teams.

When asked to provide an overall evaluation of the simulation training (Fig. 5), a higher percentage of novice participants rated the training as "excellent" when compared to the other two experience levels. When combining the results for the "excellent" and "very good" ratings, the percentage of participants for the novice, experienced and expert groups selecting these two ratings were 93%, 82% and 80%, respectively. Only 2% of the experienced group rated the overall evaluation as "fair." None of the participants for any experience level rated the training as "poor."

When asked about the quality of graphics, more than 50% for all three groups thought the graphics were "excellent" or "very good," while 51% of the novice group rated the graphics as either "excellent" or "very good." The novice group was the only experience level to rate the graphics as "poor" (5%) (Fig. 6). Most participants, grouped by experience level, also said the simulator was easy to use. Only 7% of the experienced group reported some difficulty with using the simulator. No participants from the other two groups

Table 2

Responses to questions regarding the value of the simulation training to learning specific skill sets and job performance. Values are given as percentages of total number of responses for each question.

	Version 1 (*n* = 32 to 40)		Version 2 (*n* = 24 to 35)		Version 3 (*n* = 38 to 45)	
Questions	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Will the training you received be useful in your job?	100%	0%	100%	0%	100%	0%
Was the simulator training helpful for improving performance during mine rescue exercises?	94%	6%	94%	6%	93%	7%
Was the simulator useful for learning how to communicate during rescue exercises?	97%	3%	100%	0%	98%	2%
Was the simulator useful for learning how to make decisions during a mine emergency?	88%	12%	97%	3%	95%	5%
Was the simulator useful for learning how to recognize hazards?	75%	25%	94%	6%	90%	10%

thought the simulator was difficult to use.

Each participant was also asked a series of questions regarding the value of the training for learning certain skill sets and for applying the knowledge gained to their work performance. From these questions, all participants indicated that the simulation training would be useful in their jobs, and 85% (expert) and 95% (experienced and novice) thought it would be helpful for improving performance during a mine rescue exercise. In addition, most participants thought that the simulator made them more prepared for specific aspects of a mine emergency – communication, decision making and hazard recognition. When averaging the responses for all three of these questions for each level of experience, the average percentage of positive answers for the novice group was 97%, for the experienced group 90% and for the expert group 92%. Table 4 shows a breakdown of the responses given for each of the questions asked.

Discussion and conclusion

When developing simulation software that is meant to improve skills, one must determine the point of diminishing returns in terms of investing in enhancements and the level of additional learning achieved as a result of those enhancements. When modifying the Rite-EMTTM software for underground mine environments, a minimal approach was followed. The first version had just enough modifications to make it a functional training tool. The graphics were good enough to simulate basic hazards and placards were used to provide additional information, such as gas readings. For the next two versions, some improvements to the graphics occurred, but were still far less sophisticated than one would find in commercial gaming software. The major changes for these two versions required more interactive tasks associated with making decisions and introduced the presence of smoke and lighting levels similar to actual underground conditions. Analysis of the evaluation results for all three versions indicated that the graphics for Version 3 were rated higher than either Versions 1 or 2; for the overall evaluation results, Version 3 had a higher percentage of "excellent" ratings compared to the other two versions. Therefore, it appeared that the quality of the graphics did have some effect on the results or benefit of the simulation training. Also, when considering the percent-

Table 3

Number and types of teams for each experience level.

	Novice	Experienced	Expert
Coal MR teams	0	2	0
M/NM MR teams	0	6	3
Student MR teams	2	0	0
Novice UG S&R teams	6	0	0

Figure 6

Ratings for simulation graphics based on experience level.

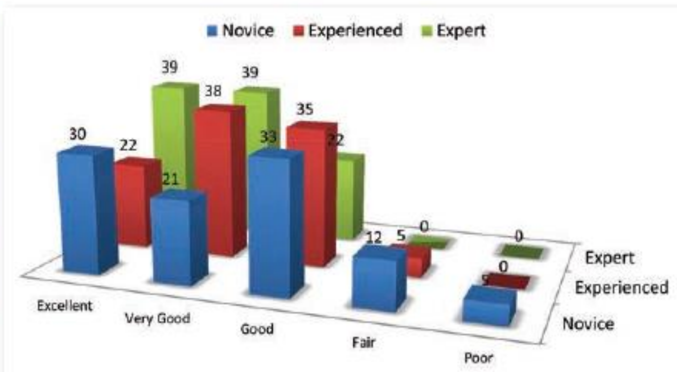


Table 4

Responses to questions regarding the value of the simulation training to learning specific skill sets and job performance based on experience level. Values are given as percentages of total number of responses for each question.

	Novice (n = 39 to 43)		Experienced (n = 42 to 48)		Expert (n = 17 to 28)	
Questions	Yes	No	Yes	No	Yes	No
Will the training you received be useful in your job?	100%	0%	100%	0%	100%	0%
Was the simulator training helpful for improving performance during mine rescue exercises?	95%	5%	95%	5%	85%	15%
Was the simulator useful for learning how to communicate during rescue exercises?	98%	2%	100%	0%	95%	5%
Was the simulator useful for learning how to make decisions during a mine emergency?	100%	0%	89%	11%	95%	5%
Was the simulator useful for learning how to recognize hazards?	93%	7%	80%	20%	85%	15%

age of participants who thought the training had value for learning how to recognize hazards, a specific skill somewhat dependent on the quality of graphics; Version 1 had much lower percentages than either Version 2 or 3. Improving the graphics certainly appeared to lead to an improved learning experience. Because the percentages of participants reporting positive learning experiences for all three versions were relatively high, these results seem to reinforce the concept that when learning skills, the quality of graphics is less important when the objective is for the participants to experience being in a specific environment, such as an underground mine.

As previously discussed in the introduction, following the Sago and Crandall Canyon disasters, deficiencies were identified during the rescue efforts that were related to a lack of command and control (Gates et al., 2007; McAteer et al., 2006; UMWA, 2007). Despite this finding, almost all of the rescue teams participating in this training had no experience with interacting with an ICC while engaged in a rescue exercise. Their training generally included communication with a FAB, but the team was responsible for all decisions. This operational method is typical for how rescue teams function during mine rescue contests. The evaluation results obtained during this study certainly indicated that the participants thought this training was valuable in improving their performance as a mine rescue team, and in learning how to interface with an ICC. The experience level had some effect on the value of this training. A higher percentage of "novice" team members rated the training overall as excellent when compared to the "experienced" and "expert" groups. However, combining the "excellent" and "very good" ratings resulted in high percentages for both of these positive ratings for all three groups, indicating value to the "experienced" and "expert" groups as well. In addition, although the responses to questions related to the usefulness of the training regarding certain skills provided by the "experienced" and "expert" teams were slightly less than the "novice" team responses for some of these questions, all responses were at least 80% or greater.

When considering the results of this study, it is important to acknowledge the limitations associated with study design. The teams were not randomly assigned to the different versions of the simulation software, nor were they selected based on their experience level. The number of participants was not equally distributed among the groups being evaluated, and the participants were also not screened based on their experience with gaming software. For example, the team using Version 2 of the simulation software was mostly comprised of novice teams, who were much younger than the experienced/expert mine rescue team members and more likely to have used gaming software. The prior use of gaming software could have raised their expectations regarding the quality of the graphics and, subsequently, resulted in the lower ratings.

In summary, all mine rescue teams who have participated in the computer simulation training responded positively regarding the value of training. Participants said they benefitted from it because of the ease of setup, more opportunities to train and familiarization with mine rescue procedures. Trainees also reported that the simulator offered excellent communication, decision making and hazard recognition training. Most participants felt that after completing the training, they were better prepared for a mine emergency, and everyone said the training would be useful in their jobs.

Future development

Currently, the CSM Mine Safety and Health Program is continuing to work with Rite Solutions Inc. to improve the mine rescue computer simulator. Future work will focus on making the interface more user friendly for instructors and rescue team members, allowing for movement on multiple levels to enable use of mine models that have multiple levels, and making the simulation more dynamic by allowing changes in gas concentrations and varying levels of smoke intensity whenever any change in ventilation occurs. Even though we continue to enhance the capability of the simulation software, the main objective of this training is still to provide training to mine rescue teams that will focus on improving decision making and communication skills with an ICC during mine emergencies.

Note: In 2009, 2010 and 2011, the CSM Mine Safety and Health Program was awarded Brookwood Sago Grants to offer computer simulated mine rescue training that targeted decision making and communication skills using an ICC, and to support enhancements to the simulation software. During this same time period, NIOSH funding received as a cooperative agreement was also used to enhance the simulation software and to support additional training sessions. ■

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