1st Solicitation for Single Investigator Research Grants (AFC113)

ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

Final Technical Report

1.0 Cover Page

Project Title: Enhanced Mobile Equipment Experiential Learning and Safety Technology Demonstration

Grant Number: AFC113-16

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West Virginia University

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Period of Performance: November 1, 2013 – October 31, 2015

Acknowledgment and Disclaimer:

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

2.0 EXECUTIVE SUMMARY

According to the Mine Safety and Health Administration (MSHA), between 2000 and 2010 nearly 800 miners were injured and 16 killed in accidents involving shuttle cars and scoops in underground coal mines. Most of these accidents occurred because the equipment operator was not aware of the presence of personnel near the mining equipment. Despite the availability and delivery of specific training on the dangers presented by mobile underground mining equipment, accidents involving mobile equipment continue to be a significant share of total fatal and non-fatal accidents in underground coal mines. Machine mounted cameras and proximity detection systems can improve the ability of equipment operators to know when individuals may be in harm's way. However, without proper training, there may be a tendency for operators to rely too much on this technology and neither represents a failsafe system. Realistic experiential training for all operators and apprentice miners is needed to impart the dangers presented by mobile equipment, the limitations of any technological aids, and best safety practices followed to reduce the number of accidents involving mobile equipment significantly.

The Department of Mining and Industrial Extension (MIE) at West Virginia University (WVU) proposed to create and provide the research-based experiential training necessary to improve the safe operation of scoops equipped with proximity detection and camera systems running in underground coal mines. The Training Intervention Effectiveness Research (TIER) model along with the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional design model provided the framework for developing a pilot training curriculum. This training curriculum included the implementation of classroom and hands-on sessions designed to expose prospective trainees to the characteristics, functionality and limitations of proximity detection and camera systems. The development of training materials also included input provided by scoop operators and safety managers of companies currently using proximity detection and camera systems in their mining operations.

The training materials developed as part of this effort were delivered to a group of 68 volunteers recruited from the WV Mine Foreman/Fireboss Certification class as well as WVU mining engineering students. These volunteers were exposed to the training program in six groups of eight (8) to fourteen (14) participants per group. Each group participated in a classroom session followed by a hands-on session conducted in the simulated mine of the WVU Academy for Mine Training and Energy Technologies and utilized a battery-powered scoop equipped with a proximity detection system and a camera system procured as part of this project. After completing the training sessions, each group of volunteers completed questionnaires to assess their reactions and perceived learning as well as to measure the effectiveness of the proposed training effort.

The analysis of the data collected from the questionnaires indicates that trainees clearly preferred experiential training that includes hands-on activities instead of learning through the classical classroom setting. The main impact of this research effort is the creation of a training program in which the trainees were able to experience the functionality of proximity detection technology installed on a battery-powered scoop within an environment of reduced visibility created in the simulated mine at WVU. The implementation of a training program that included an operating battery-powered scoop equipped with the proximity detection system and cameras provided an element of realism to the training efforts that was not previously achievable in the simulated environment, and also provided a platform for the creation of future training scenarios.

It is also noted that during this research, new West Virginia and MSHA rules were promulgated. The requirement of implementation of proximity detection or camera systems, in combination with additional reflective clothing and marking of hazardous work sites, provides a set of layers of protection that can increase miner's safety. However, none of these measures are completely failsafe individually, and further emphasis on training workers to not rely on only one safety measure is needed.

3.0 PROBLEM STATEMENT AND OBJECTIVES

3.1. Focus Area

The focus area of this work is Safety and Training.

3.2. Problem Statement

According to the Mine Safety and Health Administration (MSHA), between 2000 and 2010 nearly 800 miners were injured and 16 killed in accidents involving shuttle cars and scoops in underground coal mines. Most of these accidents occurred because the equipment operator was not aware of the presence of personnel near the mining equipment. Despite the availability and delivery of specific training on the dangers presented by mobile underground mining equipment, accidents involving mobile equipment continue to be a significant share of total fatal and non-fatal accidents in underground coal mines.

Machine mounted cameras and proximity detection systems can improve the ability of equipment operators to know when individuals may be in harm's way. However, without proper training, there may be a tendency for operators to rely too much on this technology and neither represents a failsafe system. Realistic experiential training for all operators and apprentice miners is needed to impart the dangers presented by mobile equipment, the limitations of any technological aids, and best safety practices followed by everyone to reduce the number of accidents involving mobile equipment significantly.

3.3. Main Objective of This Work

The West Virginia University Mining and Industrial Extension (WVU-MIE) Department proposed to create and provide the research-based experiential training necessary to improve the safe operation of shuttle cars and scoops in underground coal mines.

3.4. Specific Aims

There are three specific aims:

Specific Aim #1: Development of Training Curriculum. The first specific aim is to create key components of a training curriculum based on experience and limitations observed by equipment operators and management of currently operating mines.

Specific Aim #2: Conduct Training Program. The second specific aim is to execute the training curriculum that includes training exercises at the simulated mine facility and demonstrations of mine safety technology for industry, research organizations, and government regulators.

Specific Aim #3: Assess Impact and Effectiveness of Training Effort. The third specific aim is to provide evidence that the training conducted as part of this effort has been effective.

Specific Aim #4: Validation of Hypothesis. Based on the training exercises conducted, generate supporting data to validate or disprove the project hypothesis that providing the necessary information on safety technology and demonstration in a simulated mine environment will aid in technology adoption and that trainees will prefer experiential training over typical classroom instructional methods.

4.0 RESEARCH APPROACH

4.1. Research Strategy

The framework provided by the Training Intervention Effectiveness Research (TIER) model [1] was implemented in this endeavor. The main stages and overview of their corresponding research tasks implemented in the TIER model included:

Stage 1 - Formative Research

It is at this stage where the training efforts were conceived, reviewed and structured. It is also at this stage that the population to be served, their needs, and the main objectives of the training were defined along with assessment instruments and training materials. During this stage, the researchers collaborated with potential end users to define preferred communication channels, learning styles, and instructional materials as well as content experts who provided technical and input reviews.

Specifically, during this stage, a startup committee of three equipment operators and three management representatives was created for the purpose of gathering coverage of areas of concern regarding the safe operation of shuttle cars and scoops in underground coal mines as well as on the implementation of proximity detection and camera systems in haulage equipment. The information obtained from the committee was used to formulate a training curriculum to address these concerns.

This stage required the creation of a training curriculum that incorporated different topics related to safe operation of haulage equipment, particularly scoops, as well as the principles of the functionality of proximity detection and camera systems. The training curriculum was designed to have classroom and hands-on sessions. A preliminary version was presented to the startup committee who provided comments and input for modifications and additions to the curriculum and assessment instruments.

Stage 2 – Process Research

In this stage, training materials, proposed instructional approaches, and research instruments were tested in several pilot tests. The information collected in the initial trial was used to adjust the training materials developed in Stage 1 to increase the confidence in the approaches taken.

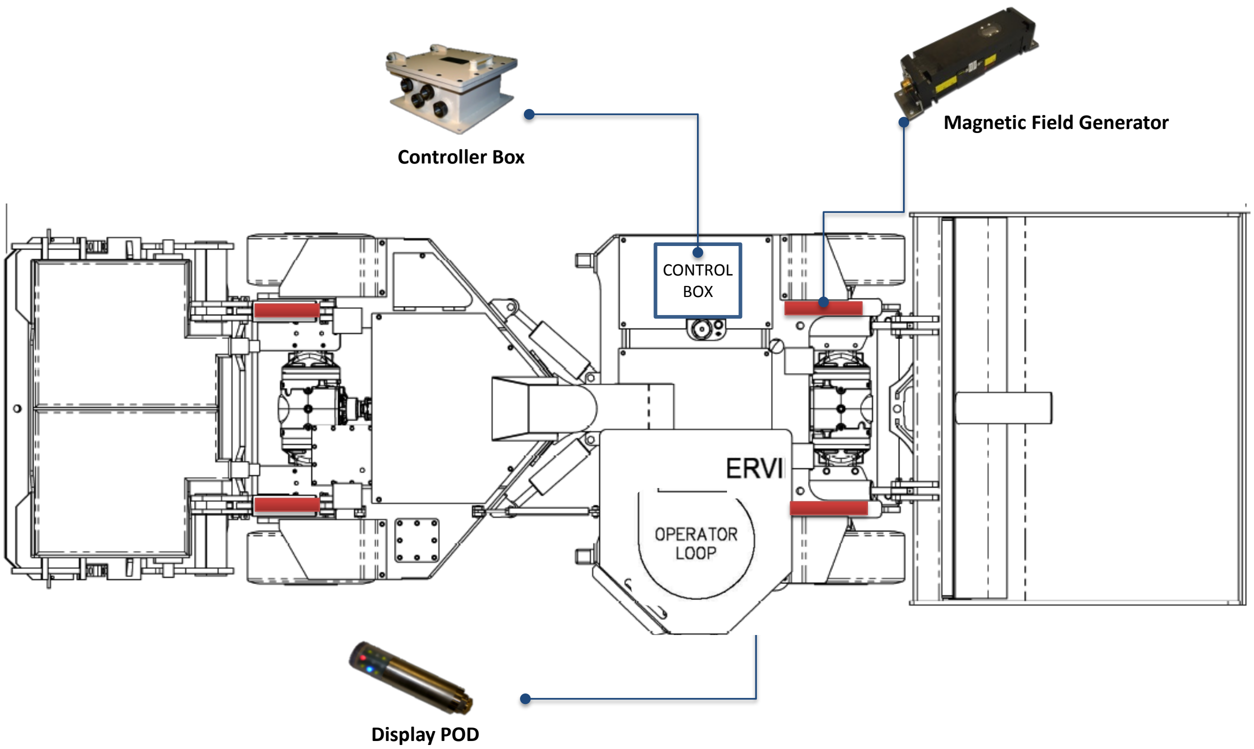
The classroom and hands-on sessions of the training curriculum were delivered in the training facilities of the West Virginia University Academy for Mine Training and Energy Technologies located at Core, WV. The hands-on portion of the training was imparted at the simulated mine available at the training facilities. A CAI OEM 4880 electric scoop, equipped with cameras and a Strata four generator proximity detection system with six readers or person wearable devices (PWDs), procured as part of this project, was used as a training tool to implement the hands-on portion of the proposed training curriculum. The battery scoop was used to meet the following purposes:

- Demonstrate the implementation of mine safety technology in a simulated mine environment.

- Enhance miner training by having a scoop equipped with the most current safety technology that will provide students with the opportunity to experience the limited visibility of the equipment operator in a simulated mine environment.
- Discuss and revise safe work instructions in an experiential learning environment that include the confined spaces and poor visibility typical in a working mine.

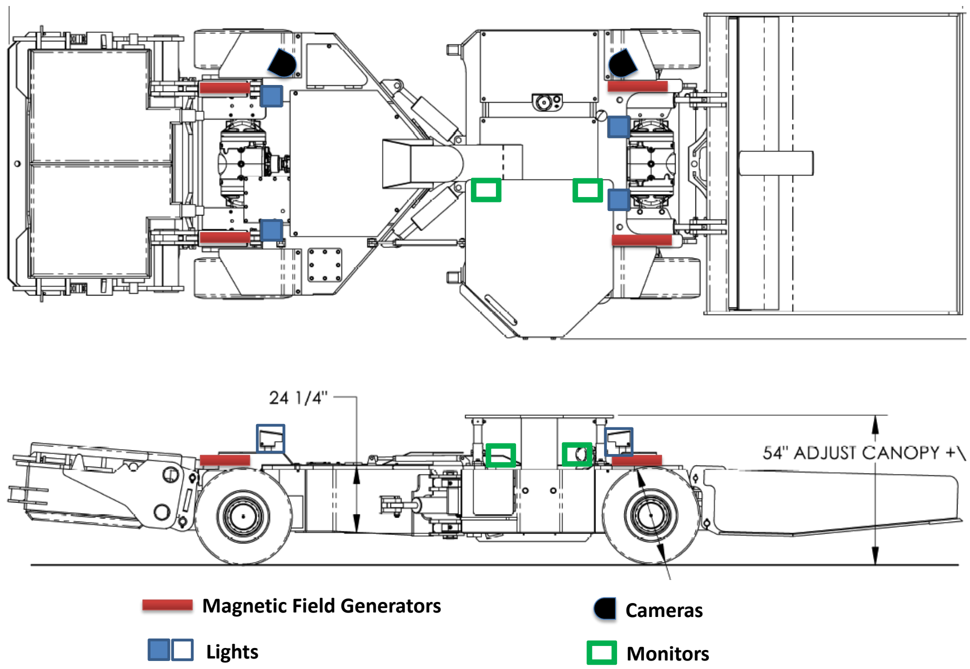
Additionally, the battery scoop provided material handling support to enhance the training activities in the simulated mine that require reconfiguration of the mine layout (moving conveyor structure, mock pieces of mining equipment, cribs and other materials). Figure 1 shows an overview of the battery scoop used for the training sessions along with schematics of the position of main components of the proximity detection and camera systems.

(a)


Controller Box
Magnetic Field Generator
CONTROL BOX
ERVI
OPERATOR LOOP
Display POD

(b)

(c)



(d)

Figure 1. Battery scoop with proximity detection and camera systems: (a) General overview of the scoop machine; (b) Position of main components of proximity detection system; (c-d) Overview of the driver's compartment and position of lights and camera system.

Stage 3 – Outcome Research

This stage included controlled evaluation studies. At the end of this stage, the results of the training effort were documented. The results of this stage provided a better understanding of the population trained; the subject matter addressed, and the instructional methods implemented.

This stage comprised the assessment of reactions and perceived learning of trainees after being exposed to the training materials. The purpose of the assessment was to evaluate the effectiveness of the proposed training materials. Moreover, the analysis of outcomes allowed the evaluation of the main hypothesis of this work.

Stage 4 – Impact Research

Typically, this stage involves longitudinal studies conducted with the purpose of examining the impact of study-related materials as they are applied to practice. Usually, the end product of Stage 4 is similar to those of Stage 3, but the emphasis is on longer-term impact instead of immediate outcomes.

The execution of longitudinal studies normally requires the implementation of training activities over a period of several years, following a determined group of trainees in their normal work environment. This type of follow-up is beyond the scope of this project. Only a limited assessment of the immediate impact of the training efforts was completed as part of this effort.

Overall, Stages 1 and 2 are part of a formative effort in which the objectives and process of training are conceived, built, and refined before proceeding to the next two stages. Stages 3 and 4 are part of a summative evaluation effort performed to determine if the developed training is meeting the objectives as planned or desired [1].

4.2. Research Tasks for Stage 1 (Formative Research)

Tasks developed as part formative research corresponding to Stage 1 followed the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional design model. The ADDIE model is traditionally used by instructional designers and training developers [2, 3]. This model provided a structure for the development of the different tasks. An overview of different components of the ADDIE model can be found in Appendix 1. Three phases of the ADDIE model were implemented during this Stage.

4.2.1. Analysis Phase

In the process of defining what needed to be discovered, the following questions grouped into four categories were considered.

1. Problem Identification

a. *What is the context of the problem?*

Between 2000 and 2010 nearly 800 miners were injured and 16 killed in accidents involving shuttle cars and scoops in underground coal mines [4]. Some examples of fatal accidents include:

- In February 2008, a surveyor with eight years of mining experience was fatally injured while surveying in an active underground mining section. The victim was struck by a loaded shuttle car as it traveled through a run-through check curtain.
- In May 2008, a general inside laborer with four weeks' experience was fatally injured when a battery-powered scoop struck him. The victim was helping two other miners repair a haul road. The victim was walking and was being followed by the scoop and a diesel road grader.
- In July 2010, a section electrician was fatally injured when he was run over by a shuttle car. The miner was walking in an entry toward the face when he was struck by the shuttle car.

Many nonfatal accidents also involve mobile underground coal mining equipment. Most of these accidents occur because the equipment operator is not aware of the presence of personnel near the mining equipment. Visibility is often low due to the design of the equipment, low lighting, and dust in the air. Ambient noise is such that individuals may not be heard, and the confined space typical of underground coal mines leaves little room to maneuver or respond once personnel in the critical path are recognized.

In 2010 Mine Safety and Health Administration (MSHA) introduced an initiative titled ''Safety Practices around Shuttle Cars and Scoops in Underground Coal Mines''. Under this initiative, MSHA started a safety campaign to raise the mining industry's awareness of pinning, crushing, or striking hazards associated with mobile mining machines. This initiative included training programs and best practices to encourage mine operators to train underground coal miners to exercise caution when working around mobile machines [5].

Several of the training initiatives that are currently being provided are through presentations and lectures in varied formats. They are generally in the form of statements provided to equipment operators, miners working around mobile equipment, and mine management. As an example, MSHA recommendations describe the following best practices for shuttle car and scoop operators [4]:

- Pay attention to your surroundings, especially in areas of limited visibility.
- Make sure you are aware of other mobile equipment operating in your area.
- Make sure that all persons are in the clear before tramming mobile equipment.
- Always sound audible warning device:
    - Before tramming
    - Before traveling through check curtains
    - Before changing direction of travel
    - When visibility is obstructed at tight turns
- Keep equipment decks clean of accumulated coal, mud, grease, etc.
- Lubricate operator controls, including brake and accelerator, to prevent sticking.
- Ensure that the equipment is in good operating condition.
- Keep your hands and feet in the operator's compartment.
- Face in the direction of travel.
- Use speeds consistent with roadway conditions.
- Use lights in the direction of travel.

In the same line, MSHA also offers a set of recommendations for miners, including [4]:

- Pay attention to your surroundings.
- Wear reflective clothing.
- Make sure that mobile equipment operators know where you are by signaling or other means of communication.
- Walk behind moving equipment when traveling in the same entry.
- Make yourself visible to equipment operators underground and avoid standing or stooping near blind spots or on the opposite side of brattice cloth where a driver may not see you.
- Don't put yourself in an area or location where an equipment operator cannot see you.
- Don't assume that an equipment operator can see you.
- Don't assume that an equipment operator will stop for you.

Again, all of these are logical best practices but still subject to the same failures. Ideally, all these best practices should be followed at all times to ensure the safest operating environment. The issue is that they are all subject to human error. Also, visibility is limited by many factors and in some cases may be even more limited by the supplementation of additional safety measures, i.e. canopy structure, and protections installed in the operators' compartments.

On the other side, many mines evaluate new safety and health technology in a rather isolated situation in cooperation with the technology vendor with little sharing of obstacles encountered or results with others in the mining industry. There are several companies and individual mines operating in WV, VA, PA, KY and other states that are changing the norm by sharing their experience.

Even with the introduction of the 2010 MSHA initiative [4] and shared experience among companies across different states, there were 41 pinning, crushing, or striking accidents involving coal hauling machines and scoops have occurred since 2010. Among these 41 incidents, 23 involved coal hauling machines and 18 involved scoops. Moreover, a total of three fatalities occurred in 2013, one involving a scoop and two involving coal hauling machines; while one fatality occurred in 2014 involving a scoop [6]. Despite the reduction in the number of incidents, from nearly 800 in the period 2000-2010 to about 41 in the period 2010-2014, which is attributed to the increase of industry's awareness of pinning, crushing and striking hazards introduced by the 2010 MSHA initiative, it is clear that additional measures are needed to continue reducing the number of incidents involving haulage equipment.

Recent evaluations made by MSHA of accident reports involving coal hauling machines and scoops indicated that the implementation of proximity detection systems (PDS) *could have* prevented 42 fatalities and 179 injuries that occurred between 1984 and 2014 [6]. A similar evaluation was performed for remote controlled continuous mining machines for the same period [29]. Although these analyzes may appear speculative, they suggest that the accidents can be prevented with the implementation of additional protection for the miners. Figure 2 summarizes the number of fatal accidents that might have been prevented by using a PDS in equipment typically used in coal mines in the US and WV during the period 1984 to 2013 [7]. For the same period, but with the information organized by type of equipment, Figure 3 compiles the number of fatal accidents that might have been prevented by using a PDS in coal mines. Note that the combination of accidents involving shuttle cars and scoops is similar to the number of accidents with continuous mining machines.

In general terms, proximity detection is a technology that uses electronic sensors to detect motion or the location of one object relative to another. Proximity detection systems provide a warning and stop mobile machines before a pinning, crushing, or striking accident occurs that could result in injury or death to miners [6].

In the late 1990s, NIOSH developed an active proximity warning system called HASARD (Hazardous Area Signaling and Ranging Device) which employs low-frequency, low-power magnetic fields and initially designed to operate on continuous mining machines [8-9]. Since then, several private companies have been developing different prototypes designed to implement different types of proximity detection technology. Since the early 2000s, MSHA has observed and evaluated different proximity detection technology for the remote control continuous mining machines, shuttle cars, roof bolting machines, feeder breakers, and scoops. The technologies investigated included ultrasonic, radar, infrared, and electromagnetic tag-based systems. Among these three, the electromagnetic tag-based technology seemed to offer the greatest potential for success on the specific remote control continuous mining machines [10-11]. Also, a compilation of developments and evaluations of proximity detection technology completed in the past decade by NIOSH can be found in references [12-13]. Proximity detection technology has been in use in underground mines in South Africa and Australia for several years, and their experience has helped to expand its implementation in the US [14].

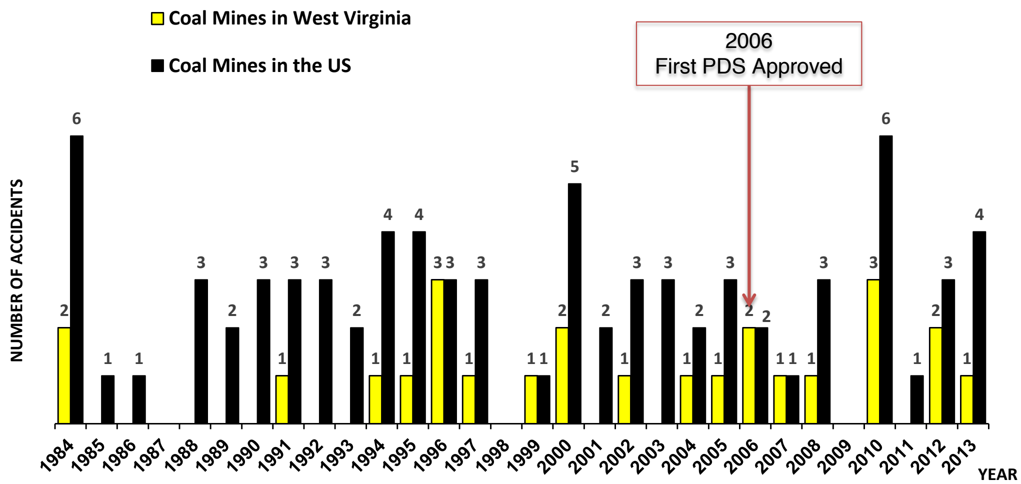


Figure 2. Fatal accidents that might have been prevented by using a PDS in different equipment typically used in coal mines (data organized by year) [7].

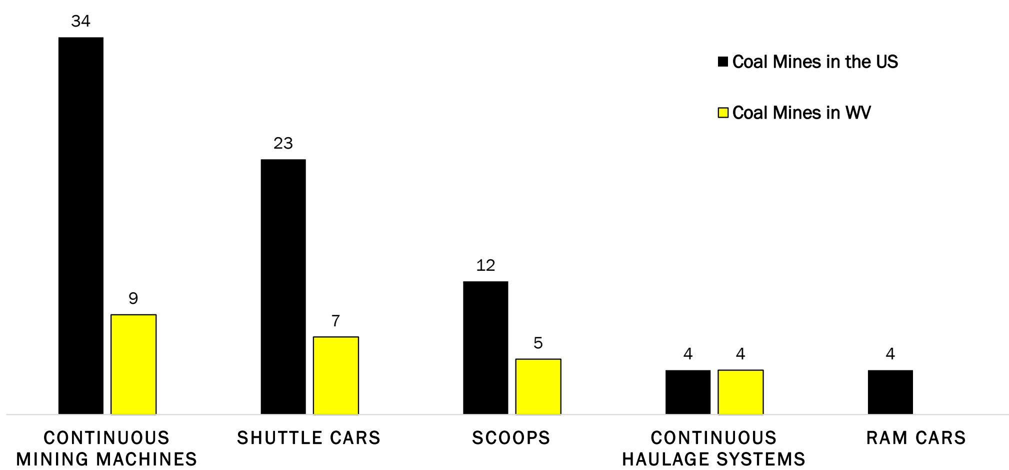


Figure 3. Fatal accidents that might have been prevented by using a PDS in coal mines in the period of 1984-2013 (data organized by type of equipment) [7].

At present, there are four proximity detection systems approved by MSHA under existing regulations for permissibility [11]. A summary of basic features of the systems available in the market is presented in Appendix 2-A. For these systems, it is important to mention that the approvals are intended to ensure that the systems will not introduce an ignition hazard when operated in potentially explosive atmospheres, i.e. they are not initially evaluated under a performance standard. However, the recent (2015) approval of the MSHA's final rule on "Proximity Detection Systems for Continuous Mining Machines in Underground Coal Mines" establishes a set of performance requirements for the proximity detection systems, including [29]:

1) A proximity detection system cause a machine, which is tramming from place-to-place or repositioning, to stop before contacting a miner except for a miner who is in the on-board operator's compartment;

2) Provide an audible and a visual warning signal on the miner-wearable component and a visual warning signal on the machine that alert miners before the system causes a machine to stop. These warning signals must be distinguishable from other signals;

3) Provide a visual signal on the machine that indicates the machine-mounted components are functioning properly.

Similar requirements are being proposed for proximity detection systems for mobile machines in underground mines [6].

All four MSHA-approved proximity detection systems are based on electromagnetic technology, and all of them require a miner to wear a component. A microprocessor installed in the machine sends a signal to activate a warning signal or stop the movement of the machine when a miner wearing the component is within a distance pre-set for the machine and mine conditions [6].

During the implementation of the different models available in the market, some limitations and issues were observed by the users in the industry and recognized by the manufacturers. Some of them included parasitic coupling in which a signal gets induced on nearby cables distorting the magnetic field created by the electromagnetic generators. Magnetic interference was also observed in the presence of large metal objects located in the surrounding areas of operation (such as metallic wire mesh used for roof control in some mines). The presence of metallic objects interferes with the electromagnetic generators by increasing the size of the warning and danger zones, which means that the workers have to be further away from the machine to avoid contact. This situation can affect the normal operations and productivity of the working area. In the past few years, manufacturers of proximity detection systems continued working to eliminate or reduce the influence of the different types of interference on the performance of the systems [15-16].

b. What is the learning problem or knowledge problem?

As described above, and despite the availability and delivery of specific training on the dangers presented by mobile underground mining equipment, accidents involving mobile equipment continue to be a significant share of total fatal and non-fatal accidents in underground coal mines.

Machine mounted cameras and proximity detection systems can improve the ability of equipment operators to know when individuals may be in harm's way. However, without proper training, there may be a tendency for operators to rely too much on this technology. Neither represents a failsafe system. Realistic experiential training is needed to impart the dangers presented by mobile equipment, the limitations of any technological aids, and best safety practices by everyone to reduce the number of accidents involving mobile equipment significantly.

However, the reduction of accidents involving haulage equipment with the implementation of the proximity detection systems will not be immediate. A transition period will be necessary in which miners will need new training to operate and work nearby machines equipped with proximity detection systems. The experience accumulated in the past years by mine operators, manufacturers, and regulators, supports the perception that machinery equipped with proximity detection systems provide an additional layer of safety that complements the basic rules and recommended best practices. However, miners working with and around machinery equipped with proximity detection systems will require additional training to handle different machine operating procedures, machine positions, and movements, as well as new visual and audible signals coming from the wearable components of the proximity systems. Furthermore, safe work instructions will need modifications to account for the modifications and updates required for the functionality of proximity detection systems installed in the machinery. Therefore, the adoption of proximity detection systems will require new task and equipment training on the proper functioning of the proximity detection system before requiring miners to operate or work in the vicinity of a machine equipped with a proximity detection system [6].

c. What are the target audience and performance gaps?

The target audience who will benefit from the instructional experience includes machine operators, particularly scoop drivers, and apprentice miners who typically have little to no experience in underground mining operations involving haulage machinery.

2. Characteristics of the Potential Audience

a. Who are the learners? What are their characteristics?

The characteristics of the target group who would benefit from the training effort under development were determined by surveys sent to five coal mining companies with operations in West Virginia, Virginia and Pennsylvania. The surveys were targeted to scoop operators currently employed by the five companies (Arch Coal, Patriot Coal, United Coal, Consol Energy and Mepco) who agreed to participate in this study. The surveys included questions related to the experience, previous training, duration of training, challenges in the operation of haulage equipment, among others as summarized in Appendix 2-B. A preliminary estimation of the sample size for the surveys was based on approximate number total number of mobile equipment in WV (~1,800 by the end of 2013), as well as on the approximate total number of mobile equipment with proximity detection and camera systems operating in WV (~150 by the end of 2013). Considering a confidence level of 95% and a confidence interval of 10%, the range of the sample size was determined to be in the range of 50 to 90 respondents. With this range as a target, surveys were distributed to the companies. In the end, a total of 48 scoop operators responded to the survey during the period May 2014 to August 2014. This number is slightly smaller than the lower limit of the target range but still considered representative of the potential population that would benefit of the training effort being developed under this project.

Some of the most significant results extracted from the surveys indicate that:

- Regarding experience operating scoops, 19% of the respondents have less than one year of experience; 48% of the respondents have between one to five years of experience; and 33% of the respondents have more than five years of experience.

- In terms of training, 60% of the respondents indicated that they were trained by a combination of Safe Work Instructions (SWI), a demonstration and a period of practice; 32% of the respondents indicated that were trained by a combination of SWI and a period of practice; and only 8% of the respondents indicated that they were trained only with SWIs.

- Considering the duration of the training, 27% indicated that they were trained in less than a day; 33% was trained for more than a day but less than a week; 21% was trained for more than a week and less than a month; and finally, 19% of the respondents indicated that they were trained for more than a month. Although not specifically addressed by the miners completing the survey, the 19% responding they were "trained" for more than a month, did so by operating the scoop on an intermittent basis.

- Considering the challenges that the operators faced while learning to operate a scoop, 53% of the respondents indicated that the extent of visibility in the mine was the biggest challenge for them; 25% indicated that turning maneuvers were the biggest challenge, while the remainder of the respondents (~22%) considered challenging the size of the machine and the position of the driver.

- When the participants were asked to estimate the percentage of reduction in the visibility because of the presence of the protective guard, 46% estimated about a 25% reduction, 31% estimated a 50% reduction (77% combined between 25 to 50% reduction). About 13% estimated a reduction of 10% and just 10% estimated that the reduction of visibility was about 75%.

- When the participants were asked about their involvement in a "near miss" or safety incident related to lack of visibility, 87% indicated that they were not involved in those types of situations, while 13% admitted being involved in a near miss.

Considering the demographics of the potential trainees, preliminary surveys indicated that the age of the participants of the proposed training is in the range of 18 to 45 years of age, with about two-thirds in the range of 25 to 45 years of age. Experience in the mining industry ranged between 1 to 20 years, with about three-quarters in the range of 1 to 10 years. Considering education levels, about 30% of the participants are high school graduates; about 50% of the participants have some college education with no degree; and the remainder 20% have associate degrees or bachelor degrees. This information was collected from participants currently fully employed in the mining industry in West Virginia.

b. What type of learning constraints exist?

Some of the fundamental questions for the success of the implementation of new technology for improving the safety of workers is how they are trained and how they learn to deal with the new situations and the environment. As pointed out by Camm and Cullen [17], "for a significant proportion of workers, most formal training has taken place in a school in grades K-12. For many, memories of school and sitting in a classroom are memories of boredom and tedious exercises with little relevance to real life. The idea of sitting through a lecture with a test at the end does not stir pleasant emotions. Most of the models we have for teaching are based on teaching school children. When we consider the experiences most blue-collar workers had in school, it is no surprise that their reaction to these traditional learning settings tends toward ambivalence, reluctance, or even hostility. Yet, this is still the most common approach used for training adults in a work setting". In this context, Camm and Cullen [17] also emphasize that traditionally, students were raised to do "seatwork" when they were in the classroom, with most or all of the class time spent with the instructor in front of the room lecturing to the students.

With these considerations, Kowalski and Vaught [18] point out that it's very important to understand and integrate principles of adult learning in the training efforts of miners. They also emphasize that the implementation of more effective and efficient training methods should pay attention to the miner population itself and how the individuals learn and respond to information.

Current adult learning theory addresses the following characteristics of adult learners (Knowles et al. [19]).

- A need to know Why, What and How: adults need information and involvement before learning.
- Self-directed learners: most people learn best when a variety of learning methods is offered, but each person typically has a learning-style preference. Some of them learn best visually, others by hearing and some others with hands-on or tactile training.
- Prior experience: taking advantage of the wide range of individual differences among workers being trained adds a rich source of learning.
- Readiness to learn: adults tend to prefer learning things that will help them deal with existing situations.
- Motivation: adults are motivated to engage in learning experiences they see as practical and relevant to their lives, which either help them in solving problems in their lives or that have internal payoffs.
- Orientation to learning and problem solving: adults are motivated to learn to the extent that they perceive that learning will help them perform tasks or deal with problems that they confront in their life situations. Furthermore, they learn new knowledge, understandings, skills, values, and attitudes most effectively when they are presented in the context of application to real-life situations (Knowles et al. [19]).

However, Kowalski and Vaught [18] suggest that there is no one theory or one best theory of adult learning. They also indicate that those theories that recognize that adult learners come to the learning situation from a particular environment and with a personal history seem most appropriate. With these considerations, Caudron [20] suggested that adult trainers should take into consideration that the training experience should include collaborative interaction, an atmosphere where learners and instructors support each other both in and out of the formal learning within a climate of cooperative communication. According to Kowalski and Vaught [18], it is important for the trainer to understand how adults learn to plan an appropriate and effective training.

Considering how adults acquire the knowledge, Ference and Vockell [21] point out that adults respond best to learning that is active and experienced-based. Adults like interactive learning and learning that can relate to the basis of their experiences. Therefore, examples and illustrations included in training materials should be relevant to the trainees. This expertise needs to be recognized and may be used to meet the learning goal. They are real-life centered and prefer problems, examples, and descriptions of the real world.

Furthermore, practice is an important part of the learning process. Most importantly, how the practice is done makes a significant difference. Simon [22] found that in the long term, integrated practice led to better learning than did block practice. The same study found that "people is often poor assessors of what they have learned". In this regard, Kowalski and Vaught [18] pointed out that this is not serious in some cases, but in others, such as machinery operation or putting on an emergency breathing apparatus, the consequences can be very serious.

In summary, some key aspects to be taken into account for the development of training materials include:

- Taking advantage of learner's experience and previous experiences.
- Understanding that adults learn best by doing.
- Learning activities have more relevance when they relate directly to learner's circumstances.
- Engagement in learning activities and encouragement to be self-directed.

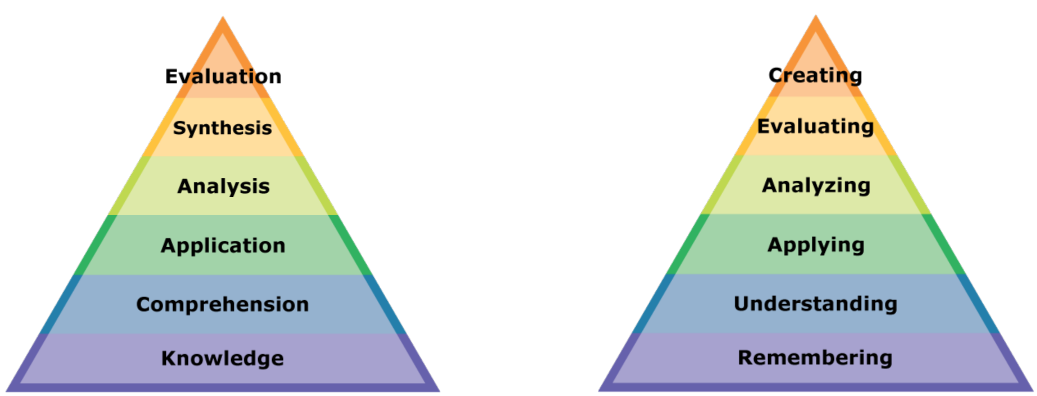
Some of the recommendations outlined by Kowalski and Vaught [18] are to be considered as well, including:

- The evolution of the mining population. Some demographic aspects such as age, ethnicity, culture, and social climate all influence the changing workforce. These changes require new approaches for miner's training. Traditional training is less and less effective for today's miners.
- Most training is still done in lecture format. However, traditional lectures are not appropriate for adult learners today. They are more likely to forget lecture material than material gained through experience.

3. Instructional Goals and Objectives

a. How the learning outcomes are defined?

The learning outcomes were defined based on the implementation of the cognitive domain of the Bloom's taxonomy [23]. Within this domain, learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels. Skills in the cognitive domain revolve around knowledge, comprehension, and critical thinking on a particular topic. According to the original Bloom's taxonomy, there were six developmental categories, moving through the lowest order processes to the highest as illustrated in Figure 4(a) [23]. In the 1990's, a former student of Bloom's proposed an updated version of the taxonomy (Figure 4(b)) in which the nouns associated with each level changed to verbs to indicate actions because thinking implies active engagements.



(a) (b)

Figure 4. (a) Original Bloom's learning taxonomy [23]; (b) Modified Bloom's taxonomy [24]. Images originated by Coffey [25].

In the modified Bloom's taxonomy, each level comprises:

Remembering: Exhibit memory of learned materials by recalling facts, terms, basic concepts, and answers. Examples of keywords that represent intellectual activity at this level include: arrange, define, duplicate, label, list, memorize, name, order, relate, recall, and repeat.

Understanding: Demonstrate an understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating the main ideas. Examples of keywords that represent intellectual activity at this level include: classify, describe, discuss, explain, express, identify, indicate, locate, recognize, understand, report, restate, review, select and translate.

Applying: Using acquired knowledge, solve problems in new situations by applying acquired knowledge, facts, techniques and rules. Examples of keywords that represent intellectual activity at this level include: apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, and write.

Analyzing: Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations. Examples of keywords that represent intellectual activity at this level include: analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, and test.

Evaluating: Present and defend opinions by making judgments about information, the validity of ideas or quality of work based on a set of criteria. Keywords that represent intellectual activity at this level include: evaluate, appraise, argue, assess, attach, choose, compare, defend, estimate, judge, predict, rate, core, select, support, and value.

Creating: Builds a structure or pattern from diverse elements. It also refers the act of putting parts together to form a whole. Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions. Keywords representing intellectual activity at this level include: arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, and write.

4. Environment, Timeline, and Delivery Options

a. *What is the instructional setting?*

The instructional setting refers to the location and physical characteristics of the area in which instruction takes place. The setting can be in a classroom, a laboratory, a field, or workplace location. For the proposed training effort, two settings are considered for imparting the training materials. First, a classical classroom equipped with a projector and large screen for presentations and display of text, images, and video. Second, a simulated mine consisting of three entries and seven crosscuts. Entry width is approximately 18.5 feet by 7.5 feet, with crosscuts occurring on 40-foot centers. The entire facility covers an area 340 feet long by 110 feet wide. Belt conveyors, shuttle cars, and other mock equipment and obstructions are placed throughout the simulated mine. This facility provided an excellent environment for a variety of mine training programs and would provide an appropriate setting for hands-on demonstrations.

b. What are the delivery options?

Among the multiple available delivery options, two educational delivery methods were considered:

- Classroom setting: Presentations in PowerPoint format, complemented with videos and handouts with the content of the presentation.
- Simulated mine setting: Exercises and hands-on experience to illustrate the concepts presented in the classroom setting.

During the implementation of the proposed training curriculum, the same extension agents, and research faculty delivered the training materials and exercises to minimize procedural bias.

c. What is the timeline for project completion?

The collection of information and development of training curriculum and training materials was expected to take approximately eight months. The implementation of training sessions, distribution of surveys, and analysis of collected data from different groups that were exposed to the training materials took approximately 16 months.

4.2.2. Design Phase

The components of the instructional and training materials were designed based on the considerations outlined in the Analysis Phase. The details are as follows:

<u>Learning Objective</u>

Enhance training of miners by exposing them to the most current safety technology installed on a battery scoop. The exposure will provide to the trainees the opportunity to experience the functionality of the safety technology in a situation of limited visibility provided by a simulated mine environment.

<u>Audience</u>

The training is targeted to apprentice miners or mine foreman students with or without scoop operation experience. The age range of the participants is expected to be between 18 to 45 years, with about two-thirds in the range of 25 to 45 years of age. It is expected that about three-quarters of the participants will have between 1 to 10 years of experience in the mining industry. The most expected levels of education include participants with high school degrees or with some college education without a degree. The training will be offered to participants currently working in the mining industry in West Virginia.

<u>Learning Outcomes</u>

Based on Bloom's learning taxonomy, upon completion of the proposed training, the trainee should be able to:

1. *Recognize* the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine.

2. *Understand* the basics of the operation of a haulage equipment equipped with proximity detection and camera systems.

3. *Understand* the advantages and limitations of proximity detection or camera systems.

4. *Experience* the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine.

Contents

The training sessions will be divided into two main modules:

Module 1. Classroom Session, covering the following topics:

a) Objectives and learning outcomes
b) Selection of equipment
c) Review of MSHA recommended safety practices
d) Examples of accidents
e) Proximity Detection Systems (PDS)
f) Camera systems
g) Overview of Safe Work Instructions
h) Overview State and Federal Regulations on PDS

For this module, topics a) to d) are presented to address learning outcomes #1. Topics e) to g) are presented to address learning outcomes #2 and #4.

Module 2. Hands-on Session, covering the following topics:

a) Overview of simulated mine and location of scoop in simulated mine
b) Putting into practice proximity detection systems
c) Exercises on reduction of visibility

For this module, topics a) to c) are presented to address learning outcome #1 and #2. Topic c) is presented to address learning outcomes #3 and #4.

Lesson planning and media selection

Among the multiple available delivery options, two educational delivery methods will be implemented:

1) Module 1 will be conveyed in the form of lectures offered by extension agents and researchers. The same extension agent and researcher will deliver the training materials to minimize procedural bias. The contents of Module 1 will be delivered by lectures with the aid of PowerPoint presentations and complemented with short videos created or compiled to illustrate specific examples or situations. Handouts with the contents of the presentations will be distributed to the participants for review and as a reference material for their use beyond the training session.
2) Module 2 will be carried out by the trainees with reduced participation of the trainers in order to enhance the active learning. In this module, the participants will be performing hands-on exercises designed to allow them to experience by themselves reduced visibility and the capabilities of a proximity detection system installed on a battery scoop.

Duration of Training

It is anticipated that the contents of Module 1 can be delivered between 45 to 50 minutes. The execution of the exercises corresponding to Module 1 is anticipated to last between 45 to 60 minutes depending on the interest and level of participation of the audience.

Assessment instruments

As part of the summative evaluation, the following levels of assessments are considered [26]:

- Level 1, Participant reaction: This level of evaluation helps a trainer gain immediate feedback about participants' experience of being in the training.
- Level 2, Participant Learning: This level of evaluation focuses on immediate changes in knowledge, skills, or attitude-behavior based on exposure to the training session.
- Level 3, Participant Behavior: This level of evaluation helps to determine how the participants demonstrate what they learned in the session in a real-life context.
- Level 4, Impact: This level of evaluation measures the longer-term outcomes or impact of training.

Levels 1 and 2 are implemented along with the implementation of Modules 1 and 2 outlined previously. For both levels, surveys with questions designed and grouped according to the learning outcomes will be distributed to each participant at the end of the training session to assess their immediate reactions and perceived learning. Basic demographic information will be collected as well.

Evaluation levels 3 and 4 are not planned to be implemented in the current effort. It will require the design and creation of evaluation tools implemented at the worksite and for extended periods of time. Evaluation at these levels will allow the assessment of changes in behavior and impact of the proposed training in the participants exposed to the training materials. The implementation of these levels of evaluation exceeds the scope and time span allocated for the completion of this project.

Elements implemented as part of the learning architecture

The following elements will be implemented:

- Module 1: Text, images, graphics and video integrated into a PowerPoint presentation created to support the instructors for conveying materials during the classroom session. Hand-outs containing the materials included in the presentation will be provided to the trainees for after-class review or reference.
- Module 2: Diagrams and actual components of proximity detection and camera systems installed in a battery scoop will be shown and experienced by trainees during the hands-on exercises.

Facilitators

Materials corresponding to Module 1 will be delivered by two facilitators including an extension agent and a research faculty. The extension agent will cover the following contents: objectives and learning outcomes, selection of equipment, review of MSHA recommended safety practices and examples of accidents. The research faculty will cover the following contents: proximity detection systems (PDS), camera systems, state and federal regulations on PDS.

Demonstrations and exercises corresponding to Module 2 will be facilitated by two extension agents and a research faculty. The extension agents will operate the battery scoop with the proximity detection and camera systems installed on it. The research faculty will assist the extension agents in the descriptions and execution of exercises.

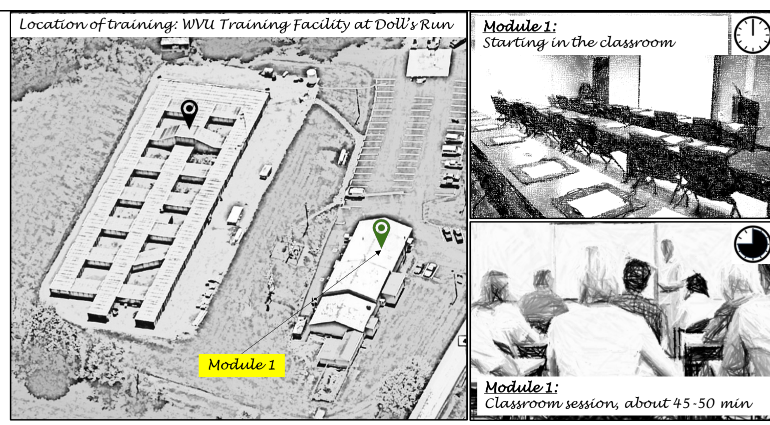
The implementation of the previous considerations is presented in the syllabus of Appendix 3.

4.2.3. Development Phase

Planning

In the planning phase, the contents outlined in the design phase and condensed in the syllabus are assembled. In this phase, it is typical to create graphical storyboards using relatively simple sketches that illustrate the sequence of activities to be carried out during the execution of the training. Storyboards serve as visual organizers. They typically include a series of illustrations displayed in sequence for the purpose of *pre-visualizing* a sequence of training activities before they actually happen. For this project, a storyboard was created to indicate how the contents corresponding to each module will be presented and also to identify the specific learning outcomes corresponding to each part of the training.

The storyboard created for this work is comprised of three main parts: a) General location and timing (Figure 5); b) Module 1 (Figure 6); and c) Module 2 (Figure 7). The frames of Figures 5 to 7 illustrate schematically the sequence of activities to be performed during the training sessions. Contents presented under Module 1 address learning outcomes #1 to #3. Contents presented in Part 1 of Module 2 address learning outcomes #2 and #3. Contents presented in Part 2 of Module 2 address learning outcome #4. Contents presented in Part 3 of Module 2 address learning outcome #1 and #4. The instructional materials prepared for presenting the contents of Modules 1 and 2 are included in Appendix 3.

▪ Module 1: Classroom Session ▪ Place: Classroom Building of the WVU Training Facility at Doll's Run ▪ Duration: 45-60 min	

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- <u>Module 2</u>: Hands-on Session. Experience proximity detection and camera system
- Place: Simulated Mine located at the WVU Training Facility at Doll's Run
- Duration: 45-60 min

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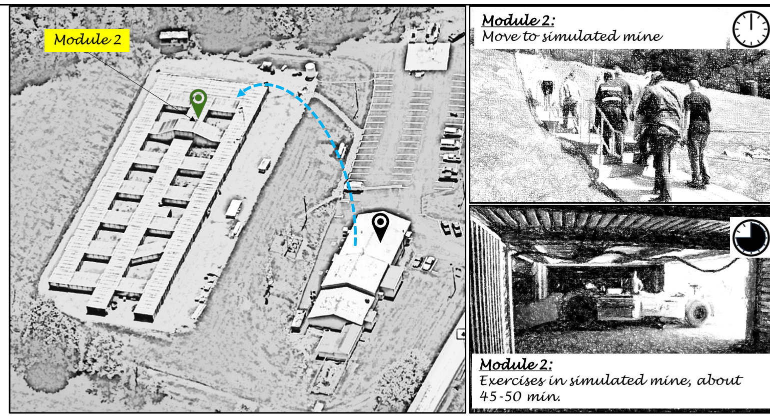

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- <u>Evaluation</u>: Level 1 and 2 evaluations through individual surveys completed by the trainee.
- Place: Classroom Building of the WVU Training Facility at Doll's Run
- Duration: 15-20 min.

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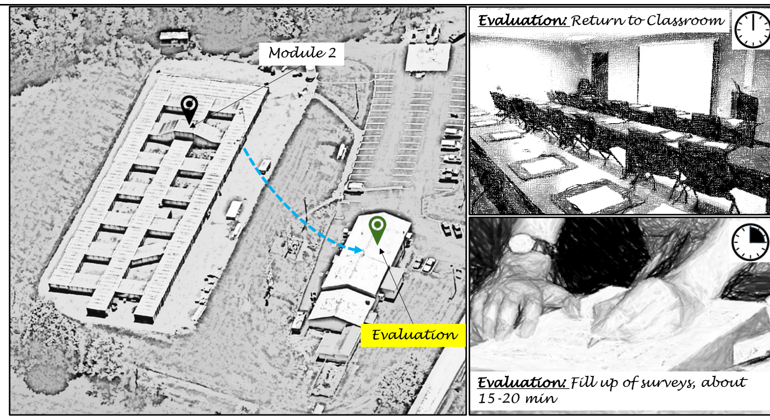

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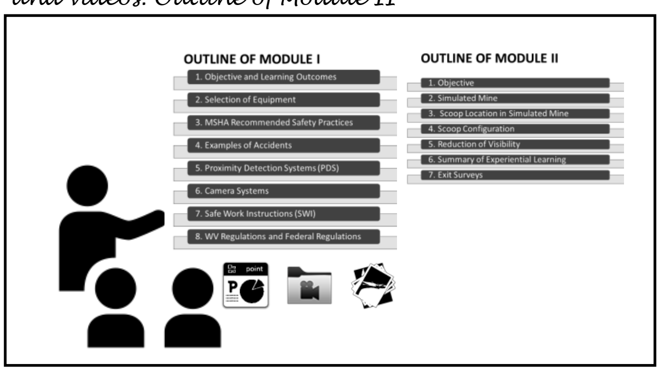
Figure 5. Storyboard for general location and timing.

General lecture assisted by a presentation, images and videos. Outline of Module II



Introduction of Check-out station and distribution of PADs

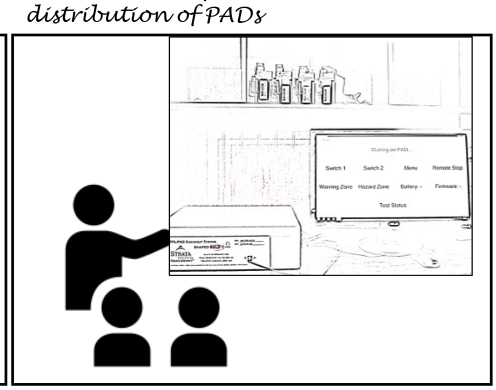
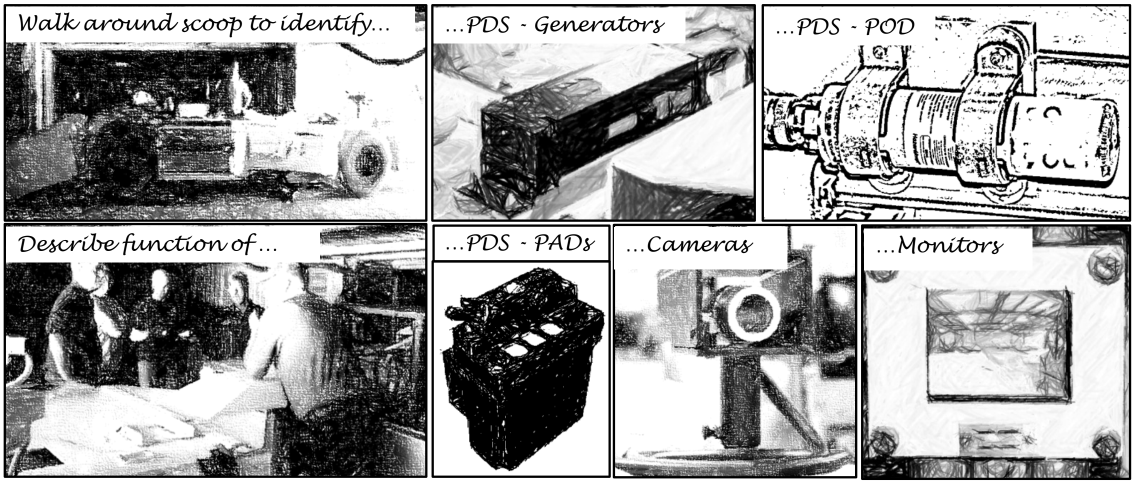


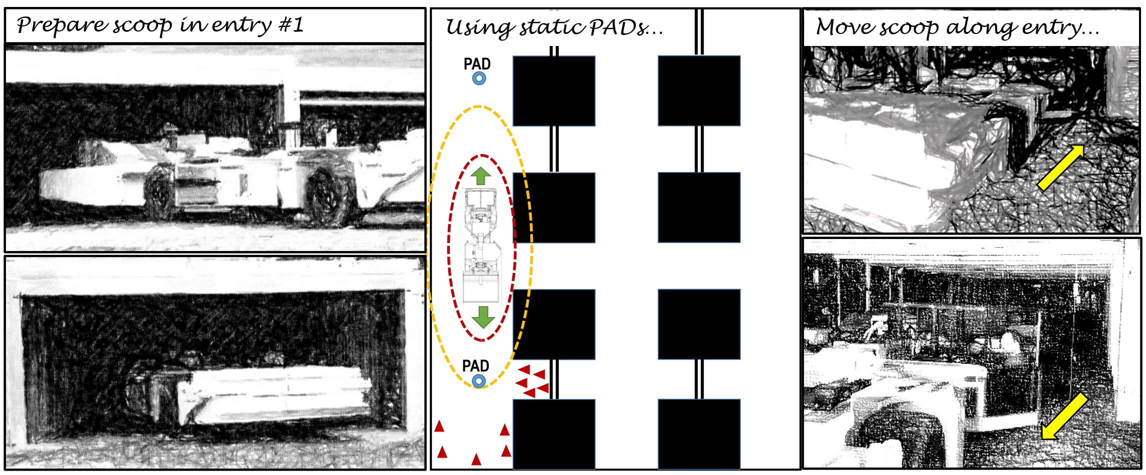
Figure 6. Storyboard for Module 1.

Part 1: Identification of components. Proximity detection and camera systems.



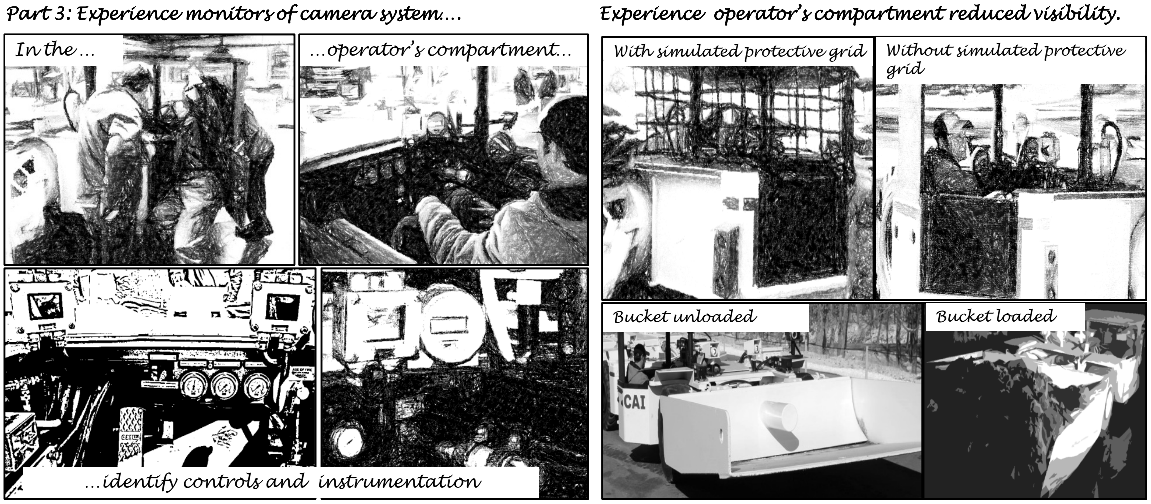
(a)

Part 2: Experience functionality of proximity detection system.



(b)

Part 3: Experience monitors of camera system…. *Experience operator's compartment reduced visibility.*



(c)
Figure 7. Storyboard for Module 2. (a) Part 1; (b) Part 2; (c) Part3.

Pilot Test of Training Materials

An initial trial of the proposed training materials was implemented to debug materials and procedures. On May 23, 2014, a preliminary version of the training curriculum was presented to the startup committee formed by representatives of three mining companies currently operating in West Virginia that agreed to participate in this study. The startup committee was integrated by safety managers and scoop operators with different levels of experience.

The presentation of the pilot training curriculum took place in a meeting at the WVU Academy for Mine Training and Energy Technologies. During this event, the Principal Investigator and the research team introduced the startup committee to the objectives and contents of the proposed training curriculum. During and after the presentation, the committee provided observations and feedback regarding the format and timing implemented in the initial version of the curriculum that were incorporated into the revised design.

Implementation of Assessment Instruments

As mentioned earlier, the following levels of assessments were implemented:

Level 1 – Participant reaction

This level of evaluation contributed to gain immediate feedback about participants' experience of being in the training. At the end of the training sessions, the participants were asked to respond to a set of 16 questions designed to evaluate aspects of the classroom and hands-on sessions (Modules 1 and 2), the preparedness and training organization, participant satisfaction and about the inclusion of other topics in future training sessions. Table 1 summarizes the question numbers that address the outcomes corresponding to Level 1.

Level 2 – Participant Learning

This level of evaluation focused on assessing immediate changes in knowledge, skills, or attitude-behavior based on exposure to the training session. Here again, at the end of the training sessions, the participants were asked to respond to a set of 12 questions designed to evaluate the changes in knowledge, changes in attitude and behavioral intent, and demonstrated skills and abilities in the form of demonstrated understanding of the materials delivered during the training sessions. Table 1 summarizes the question numbers that address each one of the outcomes corresponding to Level 2.

Selected demographic information was collected as well. It included age group, years of experience in the mining industry, and maximum level of education attained by the respondents.

All the questions corresponding to each level of evaluation are included in Appendix 4.

Table 1. Evaluation Levels.

Level	Outcome	Addressed by Question #
Level 1: Participant Reaction	Aspects of Module 1 (Classroom session)	1 – 4
	Aspects of Module 2 (Hands-on session)	5 – 8
	Preparedness/Training organization	9 – 11
	Participant satisfaction	12, 13, 16
	Future topics	14 – 15
Level 2: Perceived Learning	Changes in knowledge	1 – 2
	Changes in attitude, behavioral intent	3, 4, 10
	Demonstrated skills and abilities	5 – 9
	Demonstrated understanding	11 – 12

Identification of study variables for evaluation of training effectiveness

The TIER model defines five types of variables for evaluation of training effectiveness. These variables are Independent, Dependent, Modifying, Intervening, and Confounding. The influence of these variables in the training-learning-action continuum is illustrated in Figure 8. Typically, studies depend on access to measurable data for these variables. A description and examples of the different variables are summarized in Table 2 [1]. Based on the contents, learning objective and learning outcomes specified previously, the variables identified for present work are summarized in Table 3.

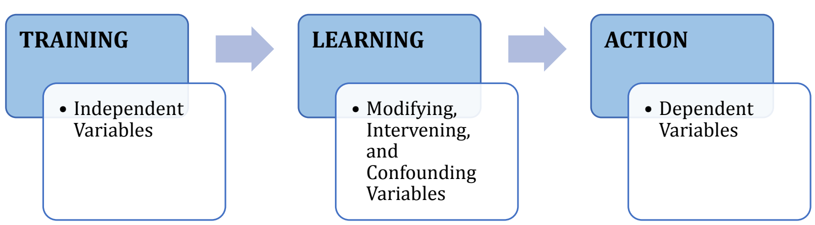


Figure 8. Variables influencing the effectiveness of the training-learning-action continuum (adapted from [1]).

Table 2. TIER model variables [1].

Variable	Description	Examples
Independent	These variables are the training inputs and activities that are implemented and studied. These variables are supposed to cause or influence certain training outcomes.	▪ Timing. ▪ Format. ▪ Location. ▪ Modifications to the training rationale. ▪ Content. ▪ Educational approach.
Dependent	Dependent variables are the intended goals of training, which are expected to result from exposure to the independent variables. As exposure varies, results may differ, allowing effectiveness to be measured. The TIER model differentiates between dependent variables that are immediate effects of training, or "outcomes", and dependent variables that are later-emerging effects of training, also known as "impacts".	For outcomes of training: ▪ Participant satisfaction. ▪ Changes in knowledge. ▪ Changes in attitude, and behavioral intent. ▪ Demonstrated skills or abilities. For impacts of training: ▪ Diffusion of course material into the field. ▪ Retention of knowledge and attitudes. ▪ Transfer of behavioral intent into practice. ▪ Application of learned skills and abilities. ▪ Transfer of training to new populations. ▪ Acceptance of instructional content as normal operating procedure.
Modifying	Modifying variables can modify the influence of independent variables on dependent variables. Therefore, to preserve the integrity of results, modifying variables must be controlled or neutralized for all study conditions	Learner variables: ▪ Age, sex, socioeconomic status. Trainer variables: ▪ Experience, teaching style. Context variables: ▪ Class size. ▪ Classroom instruction vs. apprenticeship training,
Confounding	Factors beyond the learner's control can influence training outcomes. These confounding variables act synergistically with the independent variables and thus are suspected of altering the effects on the dependent variables. Therefore, confounding variables can bias the interpretation of data.	▪ Changes in institutional policy. ▪ Implementation of new technologies.
Intervening	Intervening variables are inferred concepts intended to explain the processes between stimulus (independent variables) and response (dependent variables). Intervening variables cannot be meaningfully observed, manipulated, or measured.	▪ Learner attentiveness. ▪ Ability and motivation to learn. ▪ Learning style. ▪ Individual coping mechanisms when assimilating new material.

Table 3 (a). Summary of Independent Variables.

Independent Variables	Format adopted in this project	Condition
Timing	- Module 1: ~1 hour for the classroom session. - Module 2: ~45 min for hands-on session	- Constant for all the training groups
Format	- Module 1, Classroom session: lecture, videos, and diagrams integrated into a PPT presentation; discussion and Q&A; hand-outs distributed for future reference. - Module 2, Hands-on session: demonstration, interaction, experience functionality of a battery scoop equipped with proximity detection and camera systems; discussion and Q&A.	- Constant for all the training groups
Location	- Module 1, classroom session: WVU Doll's Run training facilities - Module 2, hands-on session: simulated mine at WVU Doll's Run training facilities	- Constant for all the training groups
Educational approach	- Lecture combined with hands-on exercises	- Constant for all the training groups
Content	- Contents prepared for Module 1 and 2. See detailed list of contents in the syllabus (Appendix 3).	- Quasi-Constant (content of Module 1 slightly modified to cover essential material within allocated time. - Constant (content of Module 2 kept constant for all training groups)

Table 3 (b). Summary of Dependent Variables.

Dependent Variables	Format adopted in this project	Measurement tool
General outcome and specific learning outcomes defined in the syllabus	Participant satisfaction and reaction to the training	Set of questions compiled in surveys completed by the participants (Level 1)
	Changes in knowledge	Set of questions compiled in surveys completed by the participants (Level 2)
	Changes in attitude and behavioral intent	
	Demonstrated skills, basic understanding of training materials	
Immediate Impact	Diffusion of course material into the field	Set of questions compiled in surveys completed by the participants (Level 2)
	Retention of knowledge and attitudes	Set of questions compiled in surveys completed by the participants (Level 2)
	Transfer of behavioral intent into practice	Set of questions compiled in surveys completed by the participants (Level 2)
Long-term Impact	Application of learned skills and abilities	Not measured
	Transfer of training to new populations	Not measured
	Acceptance of instructional content as normal operating procedure	Not measured

Table 3 (c). Summary of Modifying Variables.

Modifying Variables	Format adopted in this Project	Measurement tool and condition
Related to the learner	Age of the participants	- Set of questions designed to gather basic demographic information from the participants. - Variable
	Sex of the participants	- Set of questions designed to gather basic demographic information from the participants. - Constant (all participants are males)
	Current employment status	- Set of questions designed to gather basic demographic information from the participants. - Quasi-Constant (majority of fully employed, or mining engineering students)
	Maximum education level	- Set of questions designed to gather basic demographic information from the participants. - Variable
	Years of experience in the mining industry	- Set of questions designed to gather basic demographic information from the participants. - Variable
Related to the trainer	Trainer with experience in scoop operation	- Constant for all the training groups.
	Trainer with expertise in proximity detection and camera systems	- Constant for all the training groups.
Related to the context	Class size	- Training designed for groups of 10-15 students, groups ranged from 8 to 14 participants, average 11 participants. - Quasi-Constant

Table 3 (d). Summary of Confounding Variables.

Confounding Variables	Influence in this Project	Measurement tool
New state regulations on proximity detection systems (2014)	- Given that implementation of proximity detection systems is now mandatory in the state of WV for haulage and other underground mining equipment, the rate of adoption of the technology will be greatly accelerated.	Influence not measured
New federal regulations on proximity detection systems (2015)	- Federal regulations cover only continuous miners, but it will be expanded to the other types of equipment in the near future. - Requirements at the federal level are similar to the state requirements.	Influence not measured
Downsizing of coal mining industry in West Virginia	- The decline in the demand for coal is forcing mining companies to downsize [27]. This decline translated into a reduced need for new training for new technology, which in turn affected the number of volunteers that participated in this study, and potentially affects the number of new trainees that could benefit from the materials developed under this project.	Influence not measured

Table 3 (e). Summary of Intervening Variables.

Intervening Variables	Format adopted in this Project	Measurement tool
Learner attentiveness	As pointed out earlier, intervening variables are inferred concepts intended to explain the processes between stimulus (independent variables) and response (dependent variables). Intervening variables cannot be meaningfully observed, manipulated, or measured.	Influence not measured
Ability and motivation to learn		Influence not measured
Learning style		Influence not measured
Individual coping mechanisms when assimilating new material		Influence not measured

5.0 SUMMARY OF ACCOMPLISHMENTS

5.1 Research Tasks for Stage 2 (Process Research)

The tasks completed during Stage 2 correspond to the implementation phase of the ADDIE model. The implementation phase is where the developed course was put into action. In this phase, updated training materials, proposed instructional approaches, and research instruments were presented to the target audience. The information collected in the initial trial was used to adjust the training materials developed in Stage 1 to increase the confidence in the approaches taken.

A revised version of the proposed training curriculum was implemented for the first time on August 14, 2014. The revised training materials were presented to a group of 13 students who agreed to participate in this study. These students were part of the West Virginia Mine Foreman/Fireboss Certification offered by the WVU Academy for Mine Training and Energy Technologies.

According to the training plan, the students participated in classroom and hands-on sessions. At the end of the sessions, the students completed questionnaires to assess the participant's reaction and perceived learning. The information collected in the surveys was compiled and analyzed to identify further enhancements in the proposed training program. Some additional minor adjustments in the training materials were necessary including streamlining and simplification of some of the content presented in the classroom session and clarification of some of the questions included in the exit questionnaires. These adjustments were incorporated to generate a second version of the pilot training curriculum.

The implementation of the second version of the proposed training curriculum was carried out in five additional sessions. Each session had a different number of volunteer participants as summarized in Table 4. The majority of the volunteers (59/68 or 87%) exposed to the training materials were part of the WV Mine Foreman/Fireboss Certification offered at the WVU Academy for Mine Training and Energy Technologies. The remaining were WVU Mining Engineering students (9/68 or 13%) with no experience working in underground coal mining. Table 4 summarizes the characteristics of each group.

Table 4. Summary of training participants.

Group #	Number of Participants	Type of Audience	Employment Status	Employment Location
1	13	Mine Foreman/Fireboss Certification Class	Full-Time Employee	WV
2	10	Mine Foreman/Fireboss Certification Class	Full-Time Employee	WV
3	8	Mine Foreman/Fireboss Certification Class	Full-Time Employee	WV
4	14	Mine Foreman/Fireboss Certification Class	Full-Time Employee	WV
5	9	WVU Mining Engineering Students	Student	WV
6	14	Mine Foreman/Fireboss Certification Class	Full-Time Employee	WV, PA, KY, VA
Total	68			

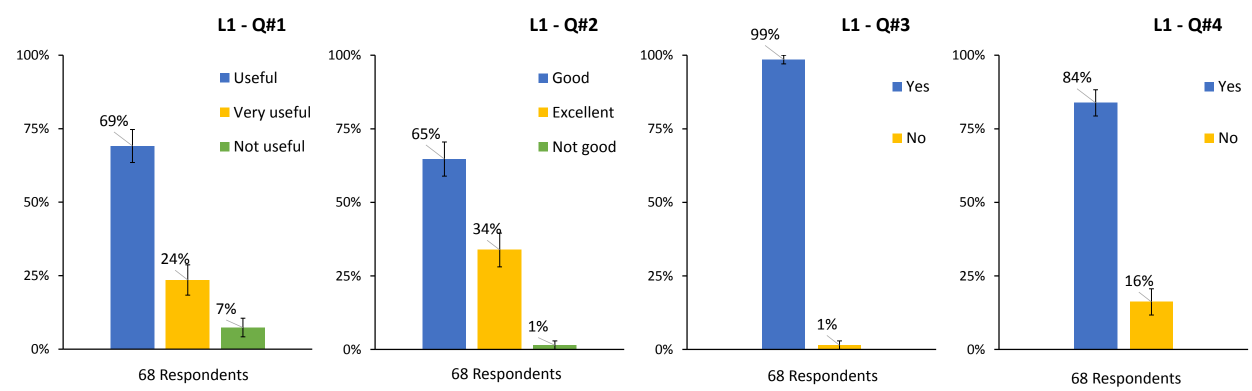
Table 5. Level 1. Participant Reaction. Global Results.

	Questions	Multiple Choice Answers	n	% Responses	Margin of Error	Category
1	How useful was the content of the classroom session to the work you currently perform?	Not useful	68	7%	±3.2%	Classroom Session
		Useful		69%	±5.6%	
		Very useful		24%	±5.1%	
2	How was the quality of the materials presented in the classroom session?	Not good	68	1%	±1.5%	
		Good		65%	±5.8%	
		Excellent		34%	±5.7%	
3	Were the instructors familiar with the material presented in the classroom session?	No	68	1%	±1.5%	
		Yes		99%	±1.5%	
4	Were the videos useful to enhance some of the topics presented in the classroom session?	No	68	16%	±4.5%	
		Yes		84%	±4.5%	
5	Were the hands-on exercises useful to complement the content presented during the classroom session?	No	68	1%	±1.5%	Hands-on Session
		Yes		99%	±1.5%	
6	How relevant was the content of the hands-on session to the work you currently perform?	Not relevant	68	9%	±3.4%	
		Relevant		62%	±5.9%	
		Very relevant		29%	±5.5%	
7	How was the quality of the exercises implemented in the hands-on session?	Not good	68	1%	±1.5%	
		Good		62%	±5.9%	
		Excellent		37%	±5.8%	
8	Were the instructors knowledgeable of the material presented in the hands-on session?	No	68	6%	±2.9%	
		Yes		94%	±2.9%	
9	Were the instructors responsive to questions that arose during both sessions?	No	68	1%	±1.5%	Class/Instructor Preparedness
		Yes		99%	±1.5%	
10	Do you feel that the time for each session was sufficient?	No	68	3%	±2.0%	
		Yes		97%	±2.0%	
11	Was the sequence of presentation of training materials appropriate?	No	68	1%	±1.5%	
		Yes		99%	±1.5%	
12	What did you like best about this pilot training?	The topics of the classroom session	67	6%	±2.9%	Trainee/Student Satisfaction
		The exercises of the hands-on session		67%	±5.7%	
		The whole training		27%	±5.4%	
13	What did you dislike about this pilot training?	The topics of the classroom session	50	68%	±6.6%	
		The exercises of the hands-on session		8%	±3.8%	
		The whole training		10%	±4.2%	
		Other		14%	±5.1%	
14	What other topics would you like us to include in the contents of the classroom session?	More about MSHA's best practices	59	12%	±4.2%	Future Topics/Exercises
		More about proximity detection or cameras		47%	±6.5%	
		More about regulations		27%	±5.8%	
		More about: Other		14%	±4.5%	
15	What other topics or exercises would you like us to include in the contents of the hands-on session?	More reduced visibility exercises	63	48%	±6.3%	
		More about scoop operation		14%	±4.4%	
		Other positions of the scoop in the mine		32%	±5.9%	
		More about: Other		6%	±3.1%	
16	What was your overall impression of the training?	Not good	68	6%	±2.9%	Overall Impression
		Good		66%	±5.7%	
		Excellent		28%	±5.4%	

5.1.1. Results: Level 1 – Participant Reaction

Responses to the set of questions corresponding to the participant reaction to the training are summarized in Table 5. As presented previously in Table 1, responses are organized in groups and presented in graphical summaries. Responses to questions related to the aspects of the classroom session are illustrated in Figure 9. Responses to questions related to the hands-on session are illustrated in Figure 10. Figure 11 summarizes responses regarding preparedness and training organization. Figure 12 summarizes responses related to the participant satisfaction. Figure 13 summarizes responses concerning future topics or content to be included in future training sessions.

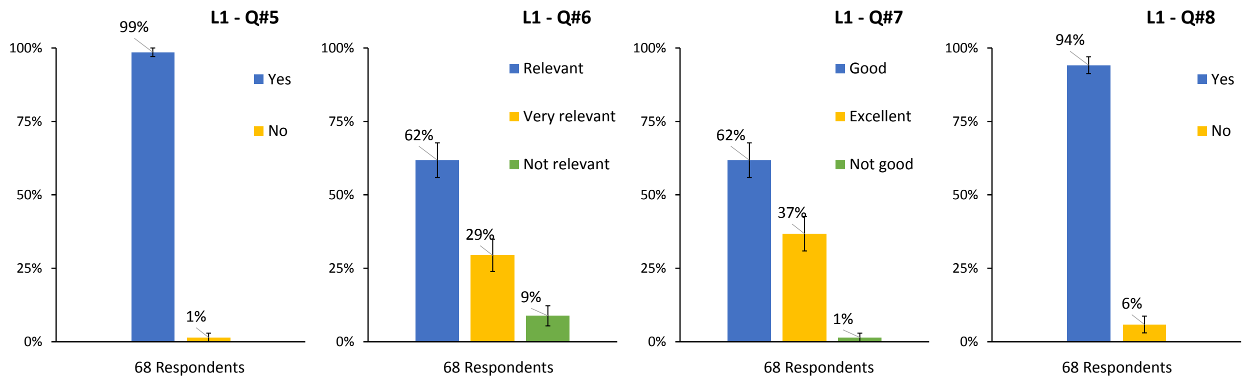
Looking at the responses corresponding to aspects of the classroom session (Figure 9), results show that 93% of the respondents found the contents presented in the classroom session useful or very useful for the work they currently perform (Q#1). Similarly, 99% of the respondents indicated that the quality of the materials presented in the classroom session was good or excellent (Q#2). In the same line, 99% of the respondents thought that the instructors were familiarized with the material presented in the class (Q#3). Moreover, 84% of the respondents found the inclusion of videos useful to enhance the illustration of some topics presented in the classroom session (Q#4).



L1-Q#1. How useful was the content of the classroom session to the work you currently perform?
L1-Q#2. How was the quality of the materials presented in the classroom session?
L1-Q#3. Were the instructors familiar with the material presented in the classroom session?
L1-Q#4. Were the videos useful to enhance some of the topics presented in the classroom session?

Figure 9. Level 1, Participant Reaction, Questions #1 to #4, Classroom session.

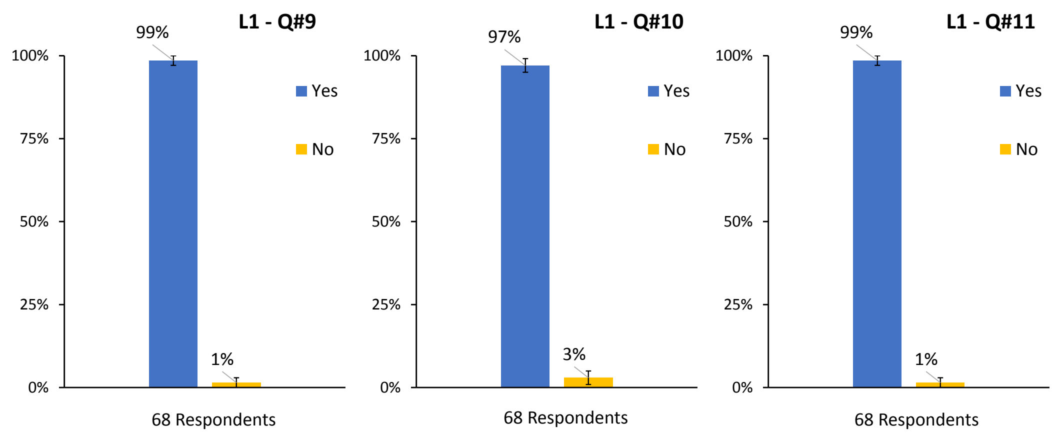
Looking at the responses corresponding to aspects of the hands-on session (Figure 10), results show that 99% of the respondents found the hands-on exercises useful to complement the content presented in the classroom session (Q#5). When asked about the relevance of the content of the hands-on session to the work currently performed by the respondents, 91% indicated that it was relevant or very relevant (Q#6). Moreover, 99% of the respondents indicated that the quality of the exercises implemented in the hands-on session was good or excellent (Q#7). In the same line, 94% of the respondents indicated that the instructors were knowledgeable of the materials presented during the hands-on portion of the training (Q#8).



L1-Q#5. Were the hands-on exercises useful to complement the content presented during the classroom session?
L1-Q#6. How relevant was the content of the hands-on session to the work you currently perform?
L1-Q#7. How was the quality of the exercises implemented in the hands-on session?
L1-Q#8. Were the instructors knowledgeable of the material presented in the hands-on session?

Figure 10. Level 1, Participant Reaction, Questions #5 to #8, Hands-on session.

Considering the level of preparedness and training organization (Figure 11), results show that practically all the respondents (99% for Q#9, 97% for Q#10, and 99% for Q#11) agreed on the responsiveness of the instructors, on the adequacy of the amount of time used for the training, and the sequence of presentation of materials.



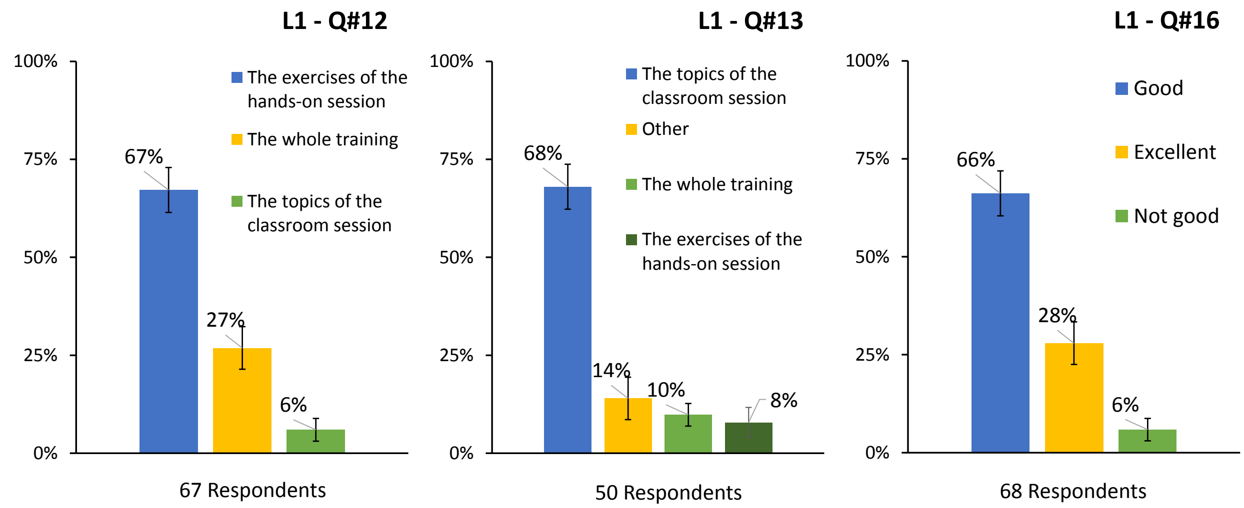
L1-Q#9. Were the instructors responsive to questions that arose during both sessions?
L1-Q#10. Do you feel that the time for each session was sufficient?
L1-Q#11. Was the sequence of presentation of training materials appropriate?

Figure 11. Level 1, Participant Reaction, Questions #9 to #11, Preparedness/Training Organization.

Regarding satisfaction of the participants (Figure 12), 67% of the respondents indicated the best of the training was the exercises of the hands-on session, while 27% liked the entire training, and only 6% of the respondents liked the classroom session (Q#12).

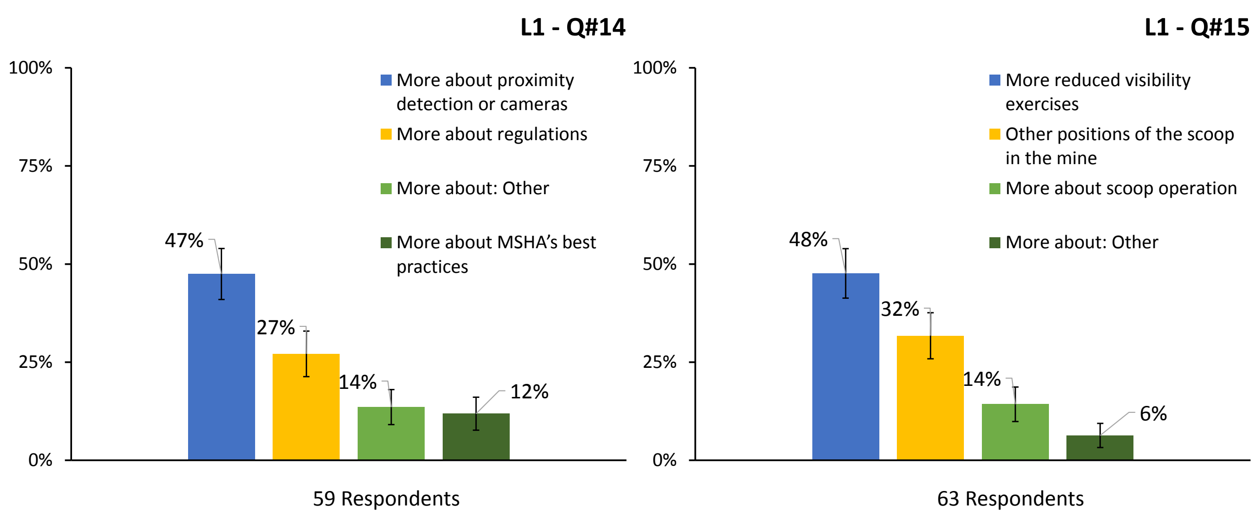
On the other side, the most disliked portion of the entire training was the classroom session (or some topics, with 68%); the remaining 32% of the respondents disliked the exercises of the hands-on session (8%), the entire training (10%) and other (not explicitly specified) reasons (14%), (Q#13).

The overall impression of the training was good for 66% of the respondents and excellent for 28%. Only 6% of the respondents indicated not having a good impression of the entire training (Q#16).



L1-Q#12. What did you like best about this pilot training?
L1-Q#13. What did you dislike about this pilot training?
L1-Q#16. What was your overall impression of the training?

Figure 12. Level 1, Participant Reaction, Questions #12, #13, #16, Participant Satisfaction.



L1-Q#14. What other topics would you like us to include in the contents of the classroom session?
L1-Q#15. What other topics or exercises would you like us to include in the contents of the hands-on session?

Figure 13. Level 1, Participant Reaction, Questions #14, #15, Future Topics.

When the trainees were asked what other topics or additions they would like to see as part of the classroom session (Figure 13, Q#14), 47% indicated that they wanted to see more content related to the proximity detection technology and cameras, while 27% requested more content and details about new regulations on proximity detection systems. Only 12% requested to include more about MSHA's best practices for working around haulage equipment. Regarding additional material for the hands-on portion of the training (Figure 13, Q#15), 48% would like to have more exercises related to reduced visibility, or try the functionality of the proximity detection system with the scoop located at different positions in the simulated mine (32%). Only 14% of the respondents would like to see more training content related to scoop operation.

In summary, from an overall look at the results described above, it seems that the trainees had a positive reaction to the proposed training. Regarding organization, practically all respondents valued the trainer preparedness, their responsiveness, and time allocated for each one of the portions of the training positively. Regarding content, most of the respondents found the classroom session relevant to their current activities, presented in a reasonable amount of time and well organized. Practically all the participants of the training valued the contents, quality, and organization of the hands-on portion of the training positively. Despite valuing the specifics of the classroom session positively, the most preferred portion of the training was the hands-on session with the exercises executed in the simulated mine. About 80% of the respondents would like to experience more reduced visibility exercises with the scoop located in different positions inside the simulated mine.

Table 6 compiles the comments provided by the respondents showing their reactions and opinions to the content presented in the classroom and hands-on session of the training.

Table 6. Level 1. Participant Reaction. Transcription of comments provided by the respondents.

Group #	Participant #	Comments (transcribed from the Comments section of the questionnaires)
2	2	*Who the responsibility will fall on with wearing of equipment for the PDS. Will it be individual or operator?*
	4	*Other than the proximity material the classroom session cut or cut down some (more hands-on, less classroom)*
	8	*I feel the cameras on the scoops will lessen the chance of an accident due to lack of visibility*
3	1	*L1-Q14: More about...New Tech.*
	2	*L1-Q14: More about…Fatalities with respect to equipment.*
	5	*Smaller boxes (detecting) to carry. Q: If a scoop operator does not see a miner who does not have the proximity box, you need a shutoff button that another operator could activate in case of an emergency.*
	6	*L1-Q13: Liked all. There should be a deactivating button on the pad that could stop the scoop from a distance in case of immediate danger.*
	8	*Make the PADS smaller, make the buttons bigger because of gloves.*
4	3	*Camera needs (to be) placed facing behind operator, guard needs (to be) installed as to what is more commonly found on scoops, and blind spots need to be more defined.*
	8	*Cameras are a good idea, need a remote camera or longer extension on camera cord so it can be moved to front or rear. Prox. sensor I believe it needs more design, it will probably be left in dinner hole. L1-Q16: Camera Ok, Prox. sensor not good.*
	9	*L1-Q14: More about… work scenarios*
5	1	*Very informative presentation. My only concern is the practicality of this law and its observance by the miners themselves. Many will not care to carry another item on their belt. I am also concerned about the large costs of this proximity sensor. But overall. I feel these detectors will drastically reduce miner's injuries and fatalities.*
	4	*This training was very helpful and clear.*
	5	*Good class, would be beneficial if we got to drive the scoop around and feel the warning and danger zones.*
	6	*Future of protection, great to gain exposure to new systems revolutionizing the industry and saving lives.*
	7	*Class was a bit long. Hands-on activity was best part.*
	8	*Very good training.*
6	2	*L1-Q13 Other: Technology is not advanced enough. The technology isn't advanced enough yet. Has problems in screen heading with proximity. Almost hurt a miner operator at our mine when proximity kicked in while tramming miner and caused miner to roll back towards him.*
	5	*I agree with canopies in scoops, but the protective grid limits the sight line of the operator. Thus, it causes the need of some prox. system. I think the visibility issue can be solved by re-thinking the grid in the operator's deck.*
	6	*L1-Q14 More about: Laws; L1-Q15: More about: offside visual*
	7	*L1-Q13 Other: length; L1-Q15 Other: hydraulics while people in proximity*
	10	*L1-Q14 More about: the faults*
	14	*This training is exceptionally useful and insightful in [the] area of safety. This is the first time I am coming across it and is highly recommended to any functioning mine for implementation.*

Note. Level 1 (L1) Questionnaire: Participant reaction. Q# is the question number within L1.

5.1.2. Results: Level 2 – Perceived Learning

Responses to the set of questions corresponding to perceived learning after completing the training are summarized in Table 7. Here also, as presented previously in Table 1, responses are organized in groups and presented in graphical summaries. Responses to questions related to changes in knowledge are illustrated in Figure 14. Responses to questions related to changes in attitude and behavioral intent are illustrated in Figure 15. Figure 16 summarizes the results of responses that demonstrate a basic understanding of the newly acquired knowledge.

Respondents of questions related to changes in knowledge were allowed to select multiple options for questions #1 and #2 in order to capture most of the changes that the participants experienced in their knowledge during the training sessions. A similar approach was adopted for questions related to changes in attitude and behavioral intent (Q#3, Q#4 and Q#10).

Questions that evaluate demonstrated skills and abilities, or demonstrated understanding (Q#5 to Q#9, Q#11 and Q#12), included one correct answer and two or three incorrect ones. Based on their newly acquired skills or understanding, the respondents picked only one response. However, during the analysis of the results of this particular set of questions, it was found that some of the respondents picked all possible answers (possibly because they did not know what to answer). Since it is not possible to know what the actual preference of the respondent was, a neutral approach was implemented for the analysis. Respondents who chose multiple answers instead one were not included in the computations. This correction was implemented in questions #5, #6, #10 and #12.

For this particular question, only 56 effective responses out of 68 participants were considered for the analysis. In the case of question #6, two responses were not included. For questions #10 and #12, only one response was excluded for each one of them.

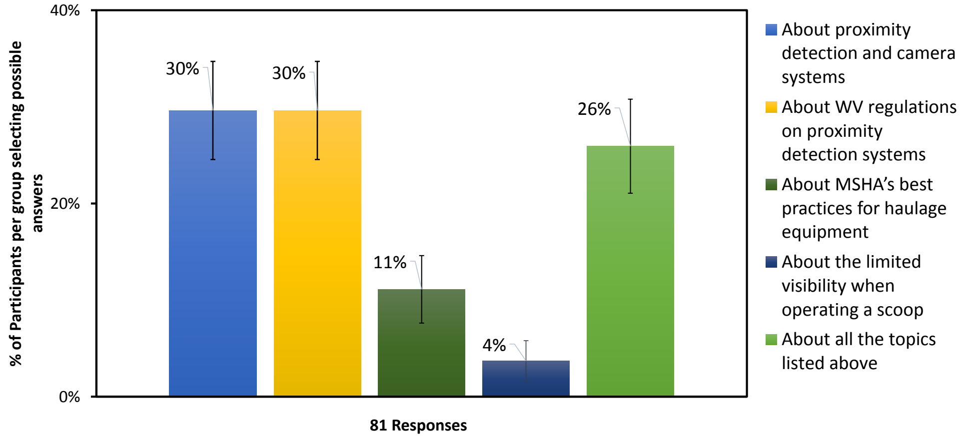
Results corresponding to changes in knowledge (Figure 14) indicate that 26% of the respondents learned about all the topics presented during the training sessions. Equal percentages of respondents (30%) indicated that proximity detection and camera systems or the WV regulations for these systems were new for them (Q#1). When the trainees were asked about the most valuable thing learned during the training sessions, 37% selected the availability of proximity detection technology while equal percentages (29%) selected the limitations of the proximity detection technology or the risk of accidents because of lack of visibility (Q#2).

Looking at the results corresponding to changes in attitude and behavioral intent (Figure 15), 37% of the respondents will use the information learned during the training to implement changes in their work, while about half (51%) of the respondents indicated that they will use the information to some extent for the same purpose, and 12% will not use the learnings to implement changes in their work (Q#3). Among those who will implement some change in attitude or behavior, 28% of the respondents manifested they will increase their personal alertness when working around haulage equipment, and 60% will share the new knowledge with their peers (Q#4). Additionally, a combined 94% of the respondents considered that the inclusion of proximity or cameras in haulage equipment can often or always improve the safety of miners working around this type of machinery (Q#10).

Table 7. Level 2. Perceived Leaning. Global Results.

	Questions	Multiple Choice Answers	n	% of Responses	Margin of Error	Categ.
1	What have you learned in this pilot training that you did not know when you walked in the door?	About proximity detection and camera systems	81	30%	±5.1%	Changes in knowledge
		About the limited visibility when operating a scoop		4%	±2.1%	
		About MSHA's best practices for haulage equipment		11%	±3.5%	
		About WV regulations on proximity detection systems		30%	±5.1%	
		About all the topics listed above		26%	±4.9%	
2	What is the most valuable thing you have learned today?	Risk of accidents because of lack of visibility	73	29%	±5.3%	
		Availability of technology for proximity detection		37%	±5.7%	
		Limitations on the visibility of scoop operators		5%	±2.7%	
		Limitations of the proximity detection technology		29%	±5.3%	
3	Will you use the information you learned in this training to implement changes in your work?	Yes	68	37%	±5.8%	Changes in attitude, behavioral intent
		To some extent		51%	±6.1%	
		No		12%	±3.9%	
4	If yes, what changes will you implement?	Increment my personal alertness about working around scoops and haulage equipment	65	28%	±5.6%	
		Share the knowledge acquired here with my fellow miners		60%	±6.1%	
		Suggest my coworkers taking this training course		12%	±4.1%	
10	Do you think that the inclusion of proximity detection or camera systems in haulage equipment can improve the safety of miners working near this type of machinery?	No	67	6%	±2.9%	
		Often		52%	±6.1%	
		Yes, always		42%	±6.0%	
5	The following technology creates the warning and danger zones:	The cameras installed in the scoop	56	11%	±4.1%	Demonstrated Understanding
		The proximity detection system installed in the scoop		80%	±5.3%	
		The hydraulic system of the scoop		9%	±3.8%	
6	When a miner approaches the danger zone of a scoop equipped with an active proximity detection system, the machine will:	Continue moving	66	0%	±0.0%	
		Reduce its tramming speed		30%	±5.7%	
		Stop immediately		70%	±5.7%	
7	In a scoop equipped with a camera system, can the scoop operator always see who is working around the machine?	No	68	60%	±5.9%	
		Often		38%	±5.9%	
		Yes, always		1%	±1.5%	
8	Considering the exercises performed in the simulated mine, which level of reduction of visibility was the most challenging for you as a miner walking around the scoop?	Level 1: Bucket unloaded + operator's guard removed	65	3%	±2.1%	
		Level 2: Bucket loaded + operator's guard removed		12%	±4.1%	
		Level 3: Bucket unloaded + operator's guard in place		11%	±3.8%	
		Level 4: Bucket loaded + operator's guard in place		74%	±5.5%	
9	Also, as a scoop driver, can you estimate the percentage of how much your visibility is reduced by the presence of the simulated protective guard?	About 10%	67	9%	±3.5%	
		About 25%		28%	±5.5%	
		About 50%		40%	±6.0%	
		About 75%		22%	±5.1%	
11	MSHA recommends that a miner would never position himself in an area or location where equipment operator cannot readily see him.	TRUE	68	90%	±3.7%	
		FALSE		10%	±3.7%	
12	Pre-operational checks of proximity detection and camera systems are:	Required by law	68	9%	±3.4%	
		Important for proper functionality while working		6%	±2.9%	
		Part of the Safe Work Instructions		6%	±2.9%	
		All of the above		78%	±5.0%	
		None of the above		1%	±1.5%	

L2-Q#1. What have you learned in this pilot training that you did not know when you walked in the door?



L2-Q#2. What is the most valuable thing you have learned today?

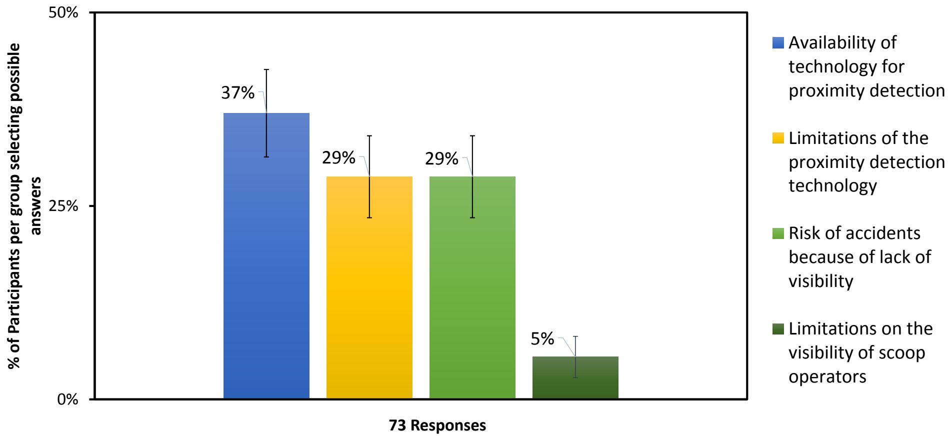
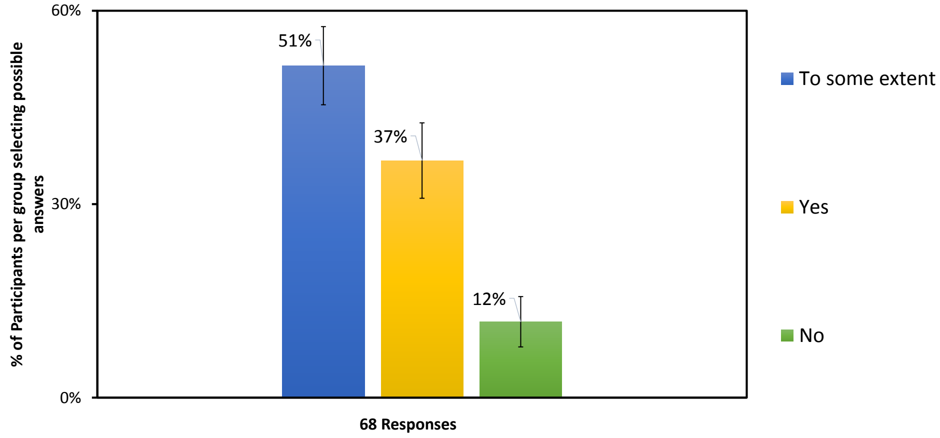
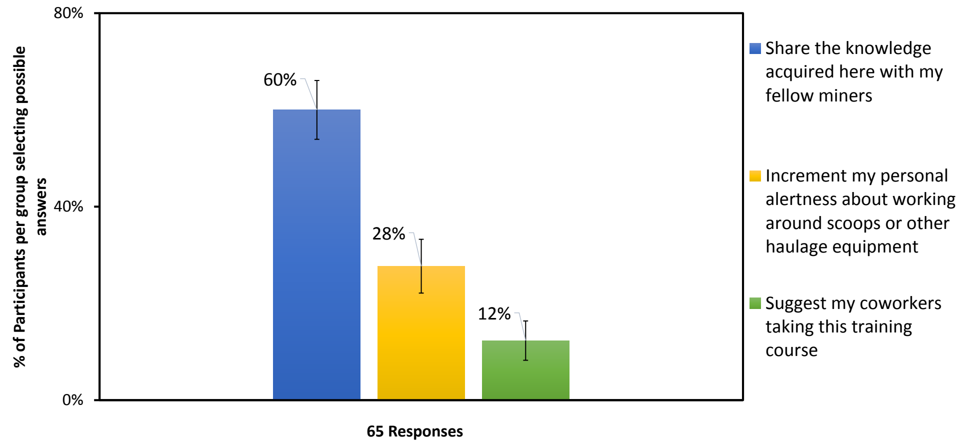


Figure 14. Level 2, Perceived Learning, Questions #1, #2, Changes in Knowledge.

L2-Q#3. Will you use the information you learned in this training to implement changes in your work?



L2-Q#4. If yes, what changes will you implement?



L2-Q#10. Do you think that the inclusion of proximity detection or camera systems in haulage equipment can improve the safety of miners working near this type of machinery?

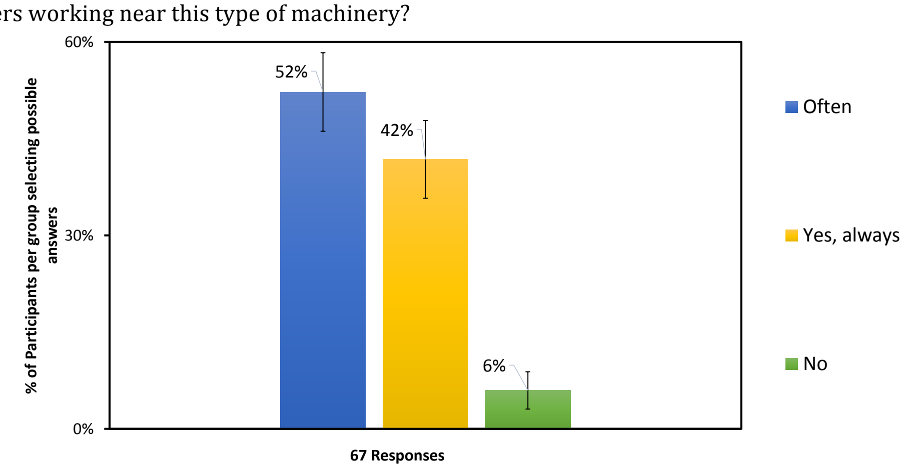


Figure 15. Level 2, Perceived Learning, Questions #3, #4, #10, Changes in Attitude, Behavioral Intent.

Several questions were asked to evaluate the understanding of the materials taught during the training sessions (Figures 16(a), 16(b) and 16(c)).

Results show that for question #5, 80% were correct in answering that the warning and danger zone were created by the proximity detection system installed in the scoop.

For question #6, 70% were correct in responding that when a miner enters the danger zone of a scoop equipped with an active proximity detection system, the machine should stop immediately while the remaining 30% incorrectly indicated that the machine will reduce its tramming speed, which occurs when the miner enters the warning zone of the proximity detection system.

For question #7, 60% agreed that the operator of a scoop equipped with a camera system will not always see who is working around the machine while 38% indicated that the operator will often see who is working around said machine.

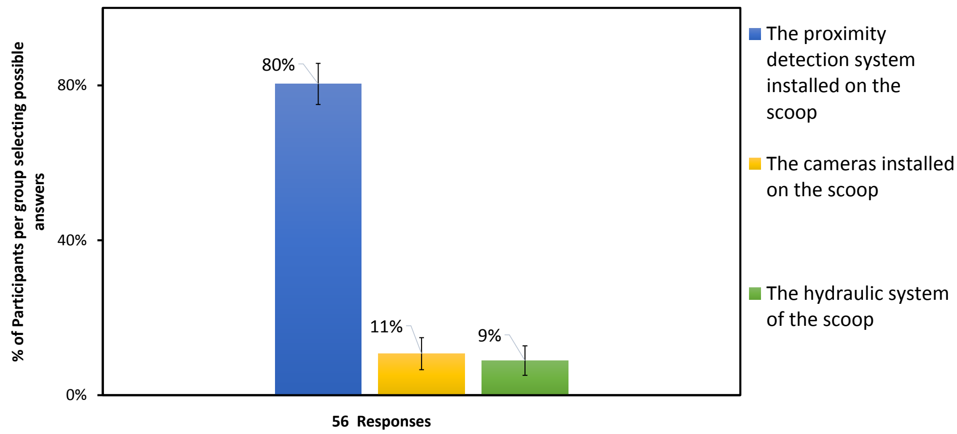
For question #8, 74% agreed that a miner working around a scoop with a load on the bucket and a safety guard installed in the operator's compartment is the most challenging scenario in terms of visibility since the driver may not detect of their presence around the machine.

For question #9, considering the level of reduction of visibility due to the presence of the protective guard from the perspective of the scoop operator, 40% of the respondents indicated that the visibility is reduced about 50% while 28% estimated a reduction in the visibility of about 25%. Combining these two results, 68% estimated that the reduction of visibility produced by the protective guard is in the range of 25 to 50%, which is similar to the range estimated by comparing the surface area covered by the presence of the protective guard with respect to the surface area of the field of view available for the scoop operator without the presence of the guard.

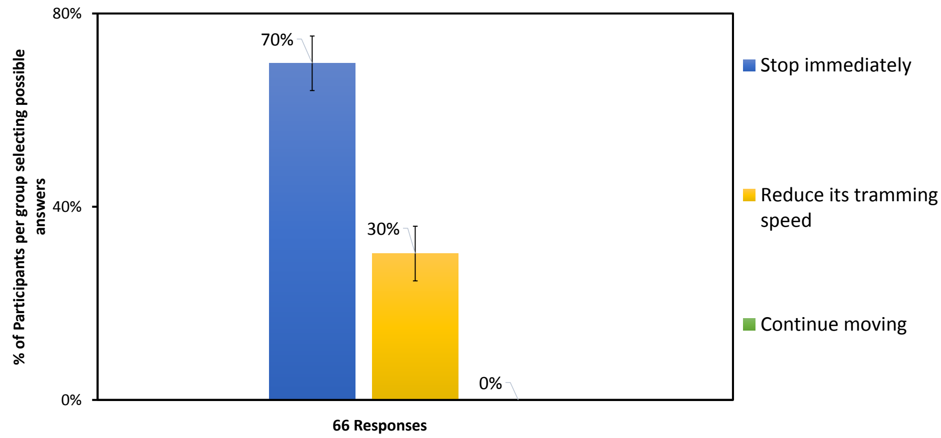
For question #11, 90% of the respondents agreed with the MSHA recommendation about not putting themselves in a position where the scoop operator cannot readily see them.

Finally, for question #12, 74% of the respondents agreed that pre-operational checks are important for proper functionality of proximity and camera system while in operation, also part of the Safe Work Instruction as well as required by the new regulations for implementation of proximity detection systems.

L2-Q#5. The following technology creates the warning and danger zones:



L2-Q#6. When a miner approaches the danger zone of a scoop equipped with an active proximity detection system, the machine will:



L2-Q#7. In a scoop equipped with a camera system, can the scoop operator always see who is working around the machine?

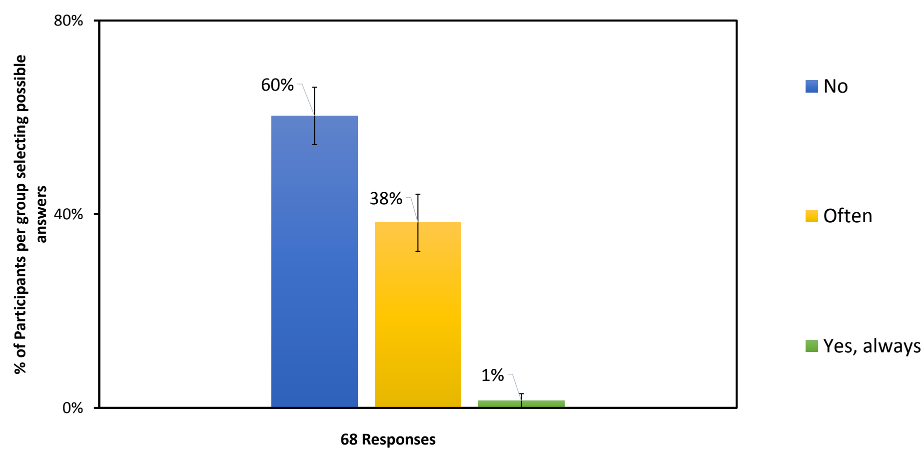
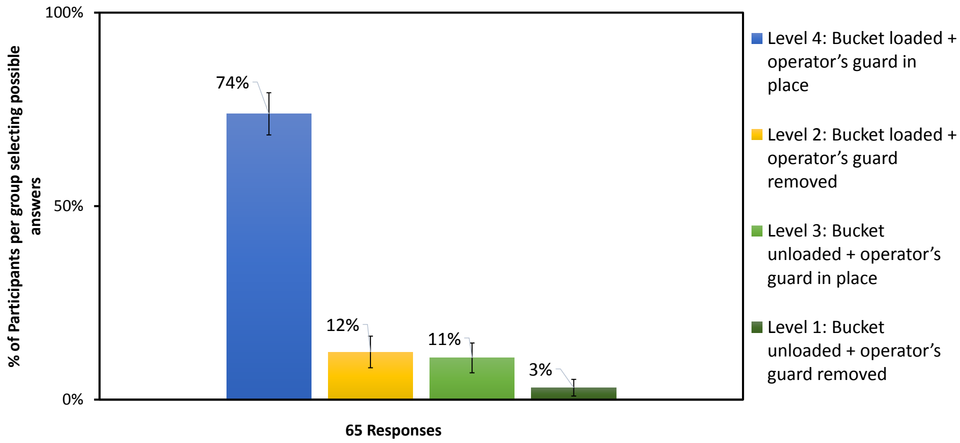
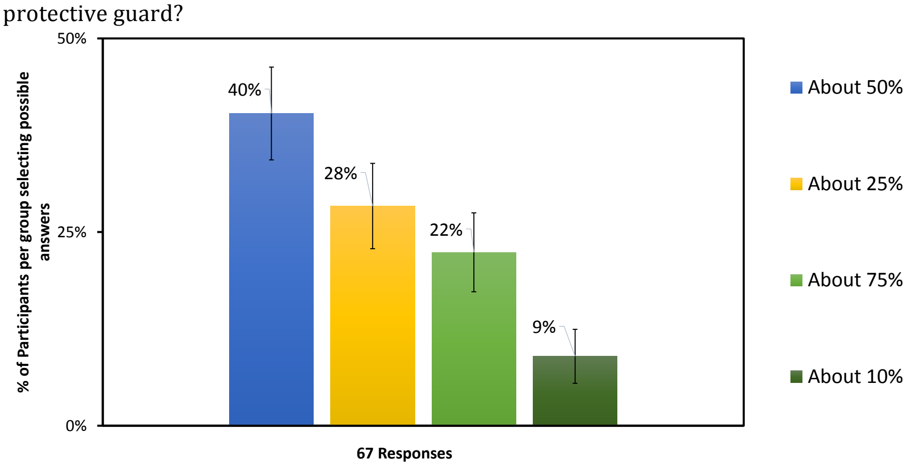


Figure 16(a). Level 2, Perceived Learning, Questions #5, #6, #7, Demonstrated Understanding.

L2-Q#8. Considering the exercises performed in the simulated mine, which level of reduction of visibility was the most challenging for you as a miner walking around the scoop?



L2-Q#9. Also, as a scoop driver, can you estimate the percentage of how much your visibility is reduced by the presence of the simulated protective guard?



L2-Q#11. MSHA recommends that a miner would never position himself in an area or location where equipment operator cannot readily see him.

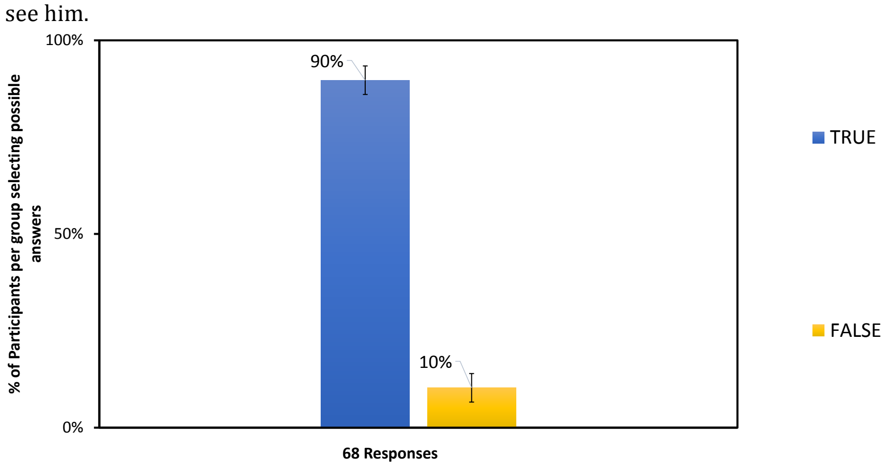


Figure 16(b). Level 2, Perceived Learning, Questions #8, #9, #11, Demonstrated Understanding.

L2-Q#12. Pre-operational checks of proximity detection and camera systems are:

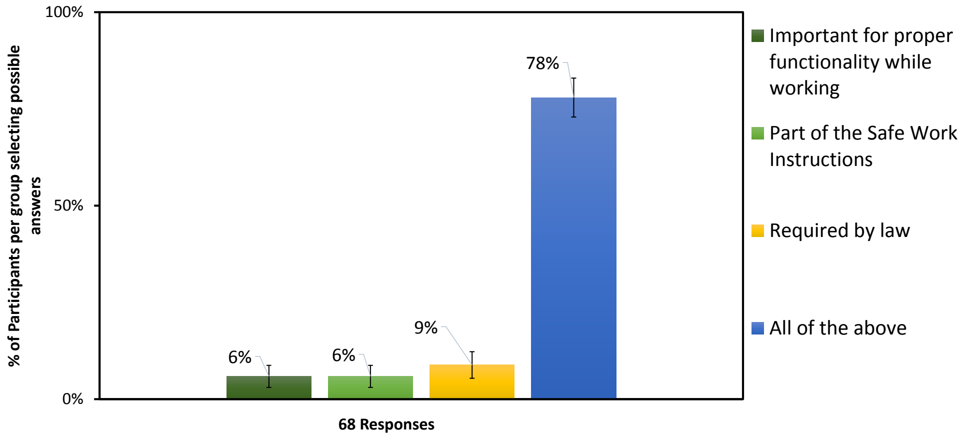


Figure 16(c). Level 2, Perceived Learning, Question #12, Demonstrated Understanding.

An overview of the results obtained from the evaluation of changes in knowledge indicates that the proposed training increased the knowledge of the trainees in different facets such as the availability of proximity detection and camera system, existing regulations about the systems, and their limitations as well as the risk of accidents due to the lack of proper visibility when working around haulage equipment.

Looking at the potential changes in attitude, nearly 9 out of 10 participants manifested intention of implementing changes in their current activities as a result of their new knowledge or were willing to share this new knowledge with their peers. A similar proportion believed that the implementation of proximity detection and camera system can often or always improve the safety of miners working around haulage equipment.

A measure of the effectiveness of the proposed training program is provided by the results obtained from the responses related to the understanding of the training materials. Overall, 7 to 9 out of 10 respondents provided correct answers when asked about basic functionality and particularities of proximity detection and camera systems. These results indicate that there is room for improvement to increase the effectiveness of the proposed training. Some of the factors that might be considered for increasing the effectiveness include:

(a) The time allocated for delivering and assimilation of specific topics, either in the classroom or the hands-on session of the training. Both the classroom and hands-on sessions were delivered in a relatively short period (2 hours in total for both sessions). It is believed that a full implementation of the proposed training program will require adjustments in the time allocated for each one of the training modules in order to allow trainees more time for assimilation of new knowledge.

(b) The instructional style of the trainers could have influenced the effectiveness of the proposed training. Here again, a full implementation of the training program will be required to put more emphasis on the collaborative interaction in an atmosphere where students and instructors support each other both in and out of the formal learning within a climate of cooperative communication in order to maximize the effectiveness of the training experience.

5.2. Research Tasks for Stage 3 (Outcome Research)

5.2.1. Research design

The research design comprised the following steps:

a) Identification of the problem and justification of its selection.

As pointed out earlier, machine mounted cameras and proximity detection systems can improve the ability of equipment operators to know when individuals may be in harm's way. However, without proper training, there may be a tendency for operators to rely too much on this technology. Neither represents a failsafe system.

The implementation of realistic experiential training is necessary to convey the dangers presented by mobile equipment, the limitations of any technological aids, and best safety practices followed by everyone to reduce the number of accidents involving mobile equipment significantly.

b) Review of previous literature dealing with the problem area.

As described in Section 2.2, between 2000 and 2010 nearly 800 miners were injured and 16 killed in accidents involving shuttle cars and scoops in underground coal mines [4]. Many nonfatal accidents also involved mobile underground coal mining equipment. Most of these accidents occurred because the equipment operator was not aware of the presence of personnel near the mining equipment.

In 2010, MSHA introduced an initiative titled ''Safety Practices around Shuttle Cars and Scoops in Underground Coal Mines''. Under this initiative, MSHA started a safety campaign to raise the mining industry's awareness of pinning, crushing, or striking hazards associated with mobile mining machines. This initiative included training programs and best practices to encourage mine operators to train underground coal miners to exercise caution when working around mobile machines [5]. Even with the introduction of this initiative and shared experience among companies across different states, 41 pinning, crushing, or striking accidents involving coal hauling machines and scoops have occurred since 2010. Among these 41 incidents, 23 involved coal hauling machines and 18 involved scoops. Moreover, a total of three fatalities occurred in 2013, one involving a scoop and two involving coal hauling machines. One fatality occurred in 2014 involving a scoop [6]. Further investigation of the accidents determined that proximity detection systems could have prevented these accidents. Recent evaluations made by MSHA of accident reports involving coal hauling machines and scoops indicated that the implementation of proximity detection systems could have prevented 42 fatalities and 179 injuries between 1984 and 2014 [6].

However, the reduction of accidents involving haulage equipment with the implementation of the proximity detection systems will not be immediate. A transition period in which miners will need new training to operate and work nearby machines equipped with proximity detection systems will be necessary. The experience accumulated in the past years by mine operators, manufacturers, and regulators support the perception that machinery equipped with proximity detection systems provide an additional layer of safety that complements the basic rules and recommended best safety practices. Miners working with and around machinery equipped with proximity detection systems will require additional training to handle different machine operating procedures, machine positions, and movements, as well as new visual and audible signals coming from the wearable components of the proximity systems. Furthermore, safe work instructions will need modifications to account for the modifications and updates required for the functionality of proximity detection systems installed in the machinery. Therefore, the adoption of proximity detection systems will require new task and equipment training on the proper functioning of the proximity detection system before requiring miners to operate or work in the vicinity of a machine equipped with a proximity detection system [3].

Also, as pointed out earlier in this report, some of the fundamental questions for the success of the implementation of a new technology for improving safety is how the workers are trained and how they learn to deal with the new situations and the environment. Camm and Cullen [17] noted that "for a significant proportion of workers, most formal training has taken place in a school in grades K-12. For many, memories of school and sitting in a classroom are memories of boredom and tedious exercises with little relevance to real life. The idea of sitting through a lecture with a test at the end does not stir pleasant emotions. Most of the models we have for teaching are based on teaching school children. When we consider the experiences most blue-collar workers had in school, it is no surprise that their reaction to these traditional learning settings tends toward ambivalence, reluctance, or even hostility. Yet, this is still the most common approach used for training adults in a work setting". In this context, Camm and Cullen [17] emphasized that traditionally, students were raised to do "seatwork" when they were in the classroom, with most or all of the class time spent with the instructor in front of the room lecturing to the students.

With these considerations, Kowalski and Vaught [18] pointed out that it is very important to understand and integrate principles of adult learning in the training efforts of miners. They also emphasize that the implementation of a more effective and efficient training methods should pay attention to the miner population itself and how their individuals learn and respond to information. Kowalski and Vaught [18] suggested that there is no one theory or one best theory of adult learning. They also indicate that those theories that recognize that adult learners come to the learning situation from a particular environment and with a personal history seem most appropriate. With these considerations, Caudron [20] suggested that adult trainers should take into consideration that the training experience should include collaborative interaction, an atmosphere where learners and instructors support each other both in and out of the formal learning within a climate of cooperative communication. According to Kowalski and Vaught [18], it is important for the trainer to understand how adults learn to plan an appropriate and effective training.

Considering how adults acquire knowledge, Ference and Vockell [21] pointed out that adults respond best to learning that is active and experienced-based. Adults like interactive learning and learning that can relate to the basis of their experiences. Therefore, examples and illustrations included in training materials should be relevant to the trainees. This expertise needs to be recognized and may be used to meet the learning goal. They are real-life centered and prefer problems, examples, and descriptions of the real world.

Furthermore, practice is an important part of the learning process. Most importantly, how the practice is done makes a significant difference. Simon [22] found that in the long term, integrated practice led to better learning than did block practice. The same study found that "people is often poor assessors of what they have learned". In this regard, Kowalski and Vaught [18] pointed out that this is not serious in some cases, but in others, such as machinery operations or putting on an emergency breathing apparatus, the consequences can be very serious.

c) Specification of the hypothesis central to the problem selected.

Originally, the central hypotheses of this work consisted of two main parts:

I. Providing the necessary information on safety technology and demonstration in a simulated mine environment will aid in technology adoption;
II. Trainees will prefer experiential training over typical classroom instructional methods.

However, due to the enactment of state and federal regulations requiring the implementation of proximity detection and enhanced visibility systems on haulage equipment, part I of the hypothesis is no longer valid because mining operators are now mandated to adopt the technology in different phases during the upcoming years.

At the state level, effective July 1, 2014, the West Virginia new rule entitled "Rules Governing Proximity Detection Systems and Haulage Safety" [28] is governing the implementation of proximity detection systems to place-change continuous mining machines, as well as proximity detection systems, cameras, or other approved alternatives to scoops and other diesel/battery powered section haulage equipment.

Similarly, at the federal level, on January 15, 2015, the Mine Safety and Health Administration (MSHA) announced the release of the final version of a new rule entitled "Proximity Detection Systems for Continuous Mining Machines in Underground Coal Mines" [29]. This new rule is intended to strengthen protections for miners in the working section of underground coal mines by reducing the potential for pinning, crushing, or striking accidents associated with place-changing continuous mining machines. The rule took effect on March 16, 2015. It is noteworthy to mention that the federal rule is compatible with the state rule but only covers continuous miners. A separate rule is under preparation and evaluation for other types of underground equipment used in coal mines. On September 2, 2015, MSHA published for comment a proposed rule for proximity detection systems on underground coal hauling machines and scoops used in coal mining. In the proposal, MSHA also requested comments on the application of the proposed requirements to underground metal and nonmetal mines. The comment period will close on Dec. 1, 2015, and MSHA will hold public hearings to allow the public to present their views on the proposed rule [30].

Considering that the adoption of proximity detection technology is mandatory at state and federal levels, and the schedule of implementation is already specified in the rule, the efforts to accelerate the adoption of the technology originally proposed in this work would be without purpose or at best any results would be biased. However, the actual times of adoption might vary widely from mine-to-mine and, therefore, the need for new or enhanced training. For this reason, all the efforts were focused on developing training and evaluation materials to collect supporting data to validate or disprove part (II) of the original hypothesis of this project.

d) Description of the data that will be necessary for an adequate test of the hypothesis.

Testing the hypothesis required the creation of a training curriculum comprised of two parts: One that involves the implementation of classroom instructional methods and one that requires the implementation of training based on an experiential setting. Trainees were exposed to both types of training. At the end of the training sessions, trainees completed questionnaires that measured separate variables including questions about a person's preferences, behavior, and facts. Questions were grouped into two sets. Set 1 evaluated their reactions to both types of training, classroom and experiential; while Set 2 evaluated their perceived learning. The questionnaires were designed to be closed-ended. A select number of possible answers were given from which the respondent can choose his answer. Basic demographic information of the participants was collected as well to try to understand the differences in reactions and learning based on age, previous experience, and level of education. Set 1 included three questions created to evaluate the preference of the trainees regarding the materials delivered during the training sessions.

e) Description of the methods of analysis applied to the data.

The data collected from the questionnaires will be analyzed in quantitative terms considering univariate and bivariate analysis. The data analysis involved two major steps:

- Data preparation involves inspection of data for completeness and consistency; data transform; coding and data entry; and developing and documenting a database structure that integrates the different measures. Different features available in MS Excel and JMP were used to organize and analyze the data.
- Descriptive statistics for describing basic features of the collected data in the form of summaries and graphs. This type of analysis provided descriptive statistics that helped to measure the distribution and frequency of responses obtained from the questionnaires. This type of analysis is implemented to a single variable at the time. Correlation between variables was analyzed as well.

5.2.2. Selection of Sample Size

The sample size was estimated considering the following criteria:

1. Total population working in underground coal mining in West Virginia as reported on December 2014.
2. Approximate total number of mobile equipment in use in West Virginia as reported on November 2013.
3. Approximate total number of mobile equipment in use in West Virginia as reported on November 2013.
4. Total number of underground mobile equipment in use in the US as reported on January 2014.
5. Approximate number of underground haulage equipment in use in the US as reported on January 2014.
6. A confidence level of 95%. This confidence level represents how often the true percentage of the population who would pick an answer lies within the confidence interval.
7. Two confidence intervals 5% and 10% were considered. These values led to approximate standard errors of ±2.5% and ±5%, respectively. The confidence interval is also called the margin of error and typically the wider the confidence interval, the more certain that the

whole population answers would be within that range [31]. Table 8 summarizes the considerations for calculating the sample size.

Table 8. Summary of criteria used to determine the sample size.

Location and Date	Criteria	Source	Population (N)	Confidence Level	Confidence Interval	Standard Error	Sample size (n)
WV 12/2014	Total Number of employees in underground coal mining	WV OMHST web page	14,073	95%	5%	± 2.5%	374
					10%	± 5%	96
WV 11/2013	Approximate total number of mobile equipment	WV OMHST data	1,800	95%	5%	± 2.5%	317
					10%	± 5%	92
WV 11/2013	Approximate total number of mobile equipment with PDS/Cams	WV OMHST data	150	95%	5%	± 2.5%	108
					10%	± 5%	59
US 01/2014	Total number of mobile equipment with PDS	MSHA Reports	399	95%	5%	± 2.5%	196
					10%	± 5%	78
US 01/2014	Approximate total number of haulage equipment with PDS	MSHA Reports	88	95%	5%	± 2.5%	71
					10%	± 5%	46
						Max	374
						Min	46
						Average	**144**
						Median	**94**

The selection of the populations summarized in Table 8 corresponds to the potential number of people that will be working around or operating mobile equipment. If the entire population of employees in underground coal mining working in WV is considered, the sample size should be around 374 and 96 for confidence intervals of 5% and 10%, respectively. However, it is very likely that only a fraction of the nearly 14,000 underground employees is truly exposed to or have some interaction with mobile equipment, but that fraction is not readily available.

One way to estimate the number of people interacting with or operating mobile equipment (including continuous miners, shuttle cars, scoops, roof bolters and other) is considering the approximate total number of mobile equipment in use in WV. From a total of about 1,800 units, the sample sizes should be around 317 and 92 for confidence intervals of 5% and 10%, respectively.

However, if the number of machinery with proximity detection systems installed is considered, either at national or state levels, the sample size ranges from 71 to 196 for a confidence interval of 5%, while, for a confidence interval of 10%, the sample size ranged from 46 to 78.

Overall, and considering both confidence intervals, sample sizes ranged from a minimum of 46 to a maximum of 374, with an average of 144 and a median of 94, as summarized in Table 8. Considering that this project is focused on mobile haulage equipment in use in WV, that the majority of the participants of the training sessions were recruited from operating mines in WV, and also assuming a wider confidence interval (10%), a sample size within a range of 60 to 95 was targeted.

This research was carried out during 2014 and part of 2015 in which the WV and national coal mining industry experienced a considerable downturn that affected the operation of several mining companies. This downturn influenced the availability of volunteers willing to take the training materials developed under this project. Despite this limitation, the final number of participants of the training sessions was 68. This number is within the target range, but closer to the lower limit for predicting meaningful results.

5.2.3. Implementation of Controlled Trials

As presented in the previous sections, the training modules were carried out in six sessions with a total of 68 participants. Each session was attended by a different number of volunteer participants as summarized in Table 4. The majority of the volunteers (59/68 or 87%) exposed to the training materials were part of the WV Mine Foreman/Fireboss Certification offered at the WVU Academy for Mine Training and Energy Technologies. The remaining were WVU Mining Engineering students (9/68 or 13%) with no experience working in underground coal mining.

5.2.4. Results

The responses to the following three questions taken from the participant's reaction questionnaire (Level 1) were analyzed to verify the validity of the hypothesis of this work:

Question # 5: Were the hands-on exercises useful to complement the content presented during the classroom session?

Question #12: What did you like best about this (pilot) training?

Question #13: What did you dislike about this (pilot) training?

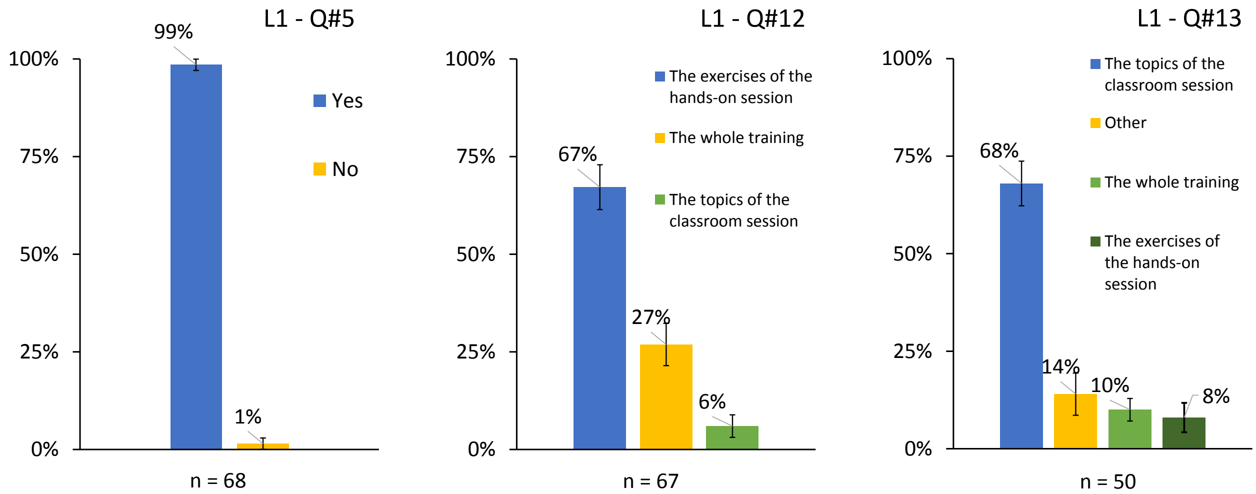
Each of these questions included multiple possible answers from which the respondents chose. Responses to these questions are summarized in Table 5 for all the respondents. Appendix 5 summarizes the responses corresponding to each group that participated in this study.

Figure 17 presents a graphical summary of all the responses to each of the questions. Note that all 68 participants responded to question #5, while questions #12 and #13 were responded to by 67 and 50 participants, respectively.

Since the number of participants and the characteristics of each group were not the same, some fluctuation in the responses is to be expected. Figure 18 presents a graphical summary of the responses organized by group and individual responses to the questions per group.

The demographic characteristics of each group in terms of age, years of experience in the mining industry, and the highest level of education achieved by the participants are summarized in Figure 19.

Finally, the relationship between responses to questions #5, #12, #13 and demographic information is presented in Figure 20 which presents the data in a color scale that allows the identification of predominant responses for the different categories of demographic information.



L1-Q#5. Were the hands-on exercises useful to complement the content presented during the classroom session?
L1-Q#12. What did you like best about this pilot training?
L1-Q#13. What did you dislike about this pilot training?

(a) (b) (c)

Figure 17. Summary of all responses to Questions #5, #12 and #13.

5.2.5. Data Analysis

Since the main hypothesis of this work is to demonstrate the preference of trainees for experiential training rather than typical classroom instructional methods, Figure 17 provides some evidence extracted from the results of the training efforts developed in this project. Figure 17 summarizes the distribution of responses to questions #5, #12 and #13, presented previously.

Results summarized in Figure 17(a) indicate that 99% of the respondents agreed that the hands-on session was useful to complement the content presented during the classroom session. All 68 participants answered this question with only one participant responding negatively.

When the trainees were asked what they liked best about the training (Figure 17(b)), 67% of the respondents chose the exercises of the hands-on session, while 27% of the respondents chose the entire training. Only 6% of the respondents selected the topics of the classroom session. Only one participant did not answer this question. Moreover, when the trainees were asked what they disliked about the training sessions (Figure 17(c)), 68% of the respondents indicated the topics of the classroom session, followed by a 14% of respondents who selected other reasons (not explicitly specified). Nearly 10% of the respondents disliked the whole training, and only 8% disliked the exercises of the hands-on session. It is noteworthy that for this particular question, only 50 of the 68 participants selected one of the possible answers. Despite the missing answers from 18 of the participants, the tendency indicates that the classroom session was the most disliked part of the proposed training and confirms that the trainees preferred experiential training that includes hands-on activities instead of the classical classroom setting.

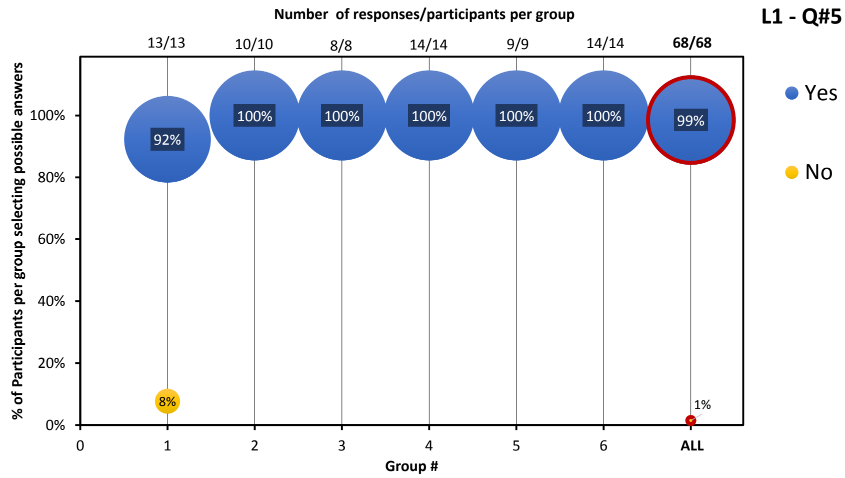
A more detailed look at the distribution of responses to questions #5, #12 and #13 for each group is presented in Figure 18. As mentioned previously, and as illustrated in Figure 18(a), practically all the respondents of each group agreed on the usefulness of the exercises of the hands-on session. Figure 18(b) illustrates the preference of the different groups regarding the most liked portion of the training. Once again, the exercises of the hands-on session were consistently selected by the majority of the respondents, followed by those who liked the entire training. Only Group #1 seemed to prefer the hands-on exercises or the topics of the classroom session equally, and only a few participants of 3 groups (#1, #2 and #6) liked the classroom sessions.

Figure 18(c) shows the variability of responses related to what part of the training was disliked the most. Unlike the results illustrated in Figures 18(a) and 18(b), results summarized in Figure 18(c) displays more fluctuation in the responses. While it is clear that most of the respondents seemed to dislike the topics of the classroom session, the percentages vary considerably among groups. It is speculated that the fluctuations in the percentages are influenced by the way in which the question was posed and the proposed multiple choice answers, which in turn influenced the number of responses with respect to the number of participants. In this regard, a total of 18 out of 68 (~27%) participants avoided selecting one of the proposed answers to the question. Only 73% of the total number of participants responded to this particular question. With these considerations, it is recognized that perhaps the most disliked portion of the training might have been not just the topics of the classroom session, but the whole classroom setting itself.

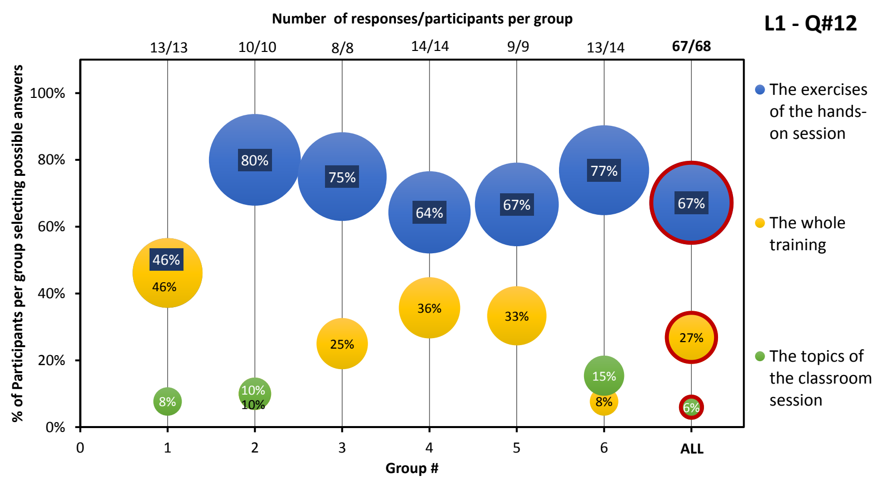
Three demographic aspects of the participants are summarized in Figure 19. The age distributions corresponding to each group is summarized in Figure 19(a). Results show that each group of trainees included different proportions of age groups. Trainees of Groups 1 to 3 included three age groups, 25-34, 35-44 and 45-54, while Group 4 included the same three age groups plus a proportion of younger people in the range of 18-24 years of age. Group 5 included mostly younger people in the range 18-24 years of age. This group consisted of WVU mining engineering students as summarized in Table 4. Group 6 included participants mostly within the ranges of 25-34 and 35-44. Overall, 78% of the trainees were in the range of 25 to 54 years of age, while the remaining 22% consisted of relatively younger participants in the range of 18 to 24 years of age.

In terms of experience in the coal mining industry (Figure 19(b)), 43% of the respondents indicated having between 1 to 5 years of experience, while 26% indicated having 5 to 10 years of experience. These two groups constituted 69% of the responses. The remaining 31% is distributed among those with 10 to 20 years of experience (16%), those with less than one year of experience (12% and all of them in Group 5), and those with more than 20 years of experience (3%). The group of respondents with less than one year of experience can be considered apprentice miners since they have little or no experience in underground coal mining operations.

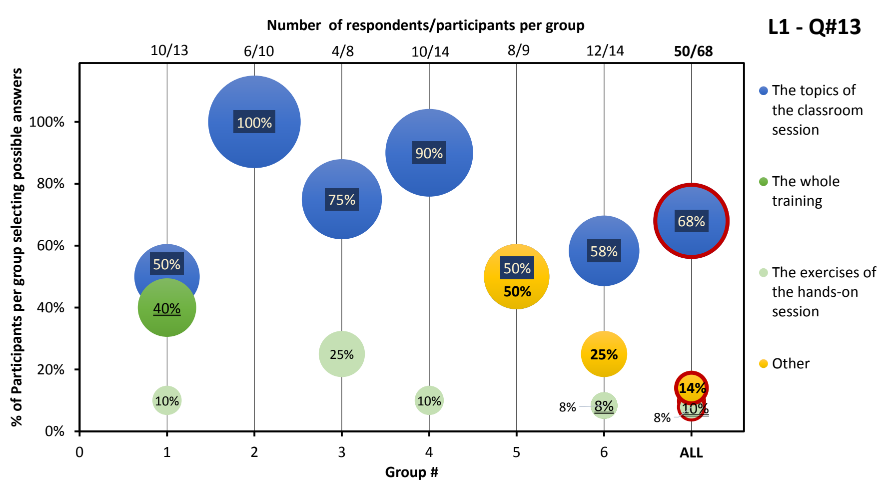
Figure 19(c) illustrates the education distribution per group of participants. Considering the highest level of education attained by all the participants, a combined 77% of the respondents were high school graduates, some of them with college experience, but no degrees. The remaining 33% indicated having either associate's degrees (10%), bachelor's degrees (10%) or graduate or professional degrees (3%). Figure 19(c) also illustrates the education distribution per group of participants; in this figure, except for Group 5, all the other groups included volunteers with diverse levels of education.



(a) L1-Q#5. Were the hands-on exercises useful to complement the content presented during the classroom session?

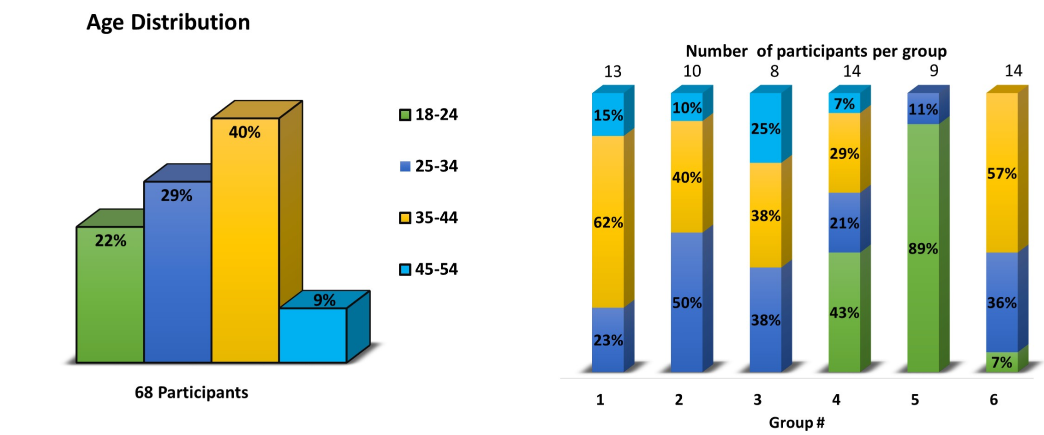


(b) L1-Q#12. What did you like best about this pilot training?

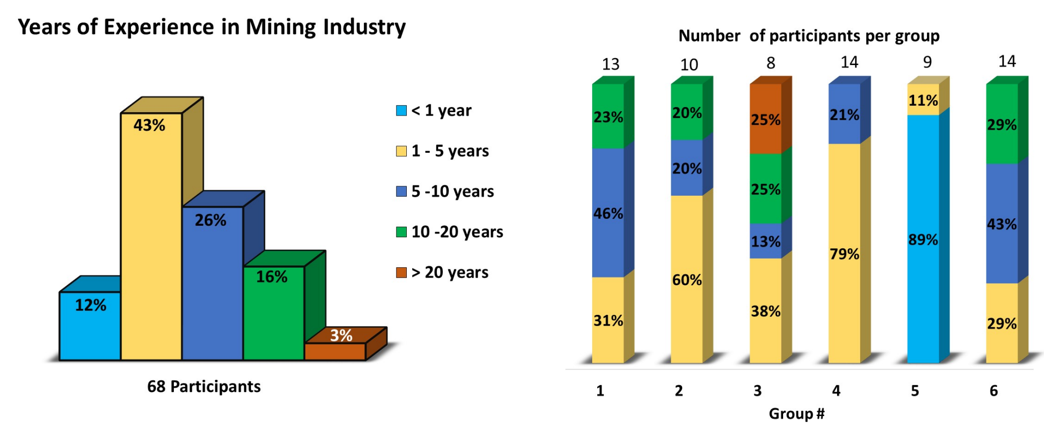


(c) L1-Q#13. What did you dislike about this pilot training?

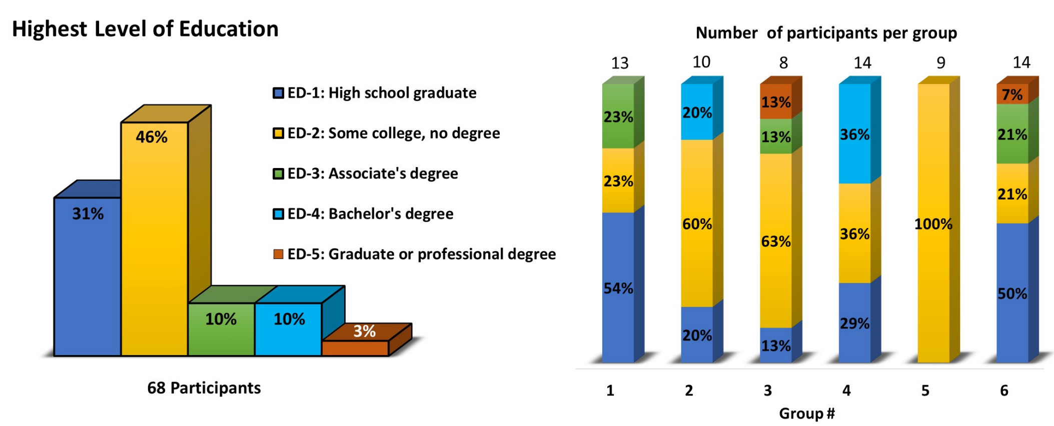
Figure 18. Summary of all responses to questions #5, #12 and #13 organized by group.



(a)

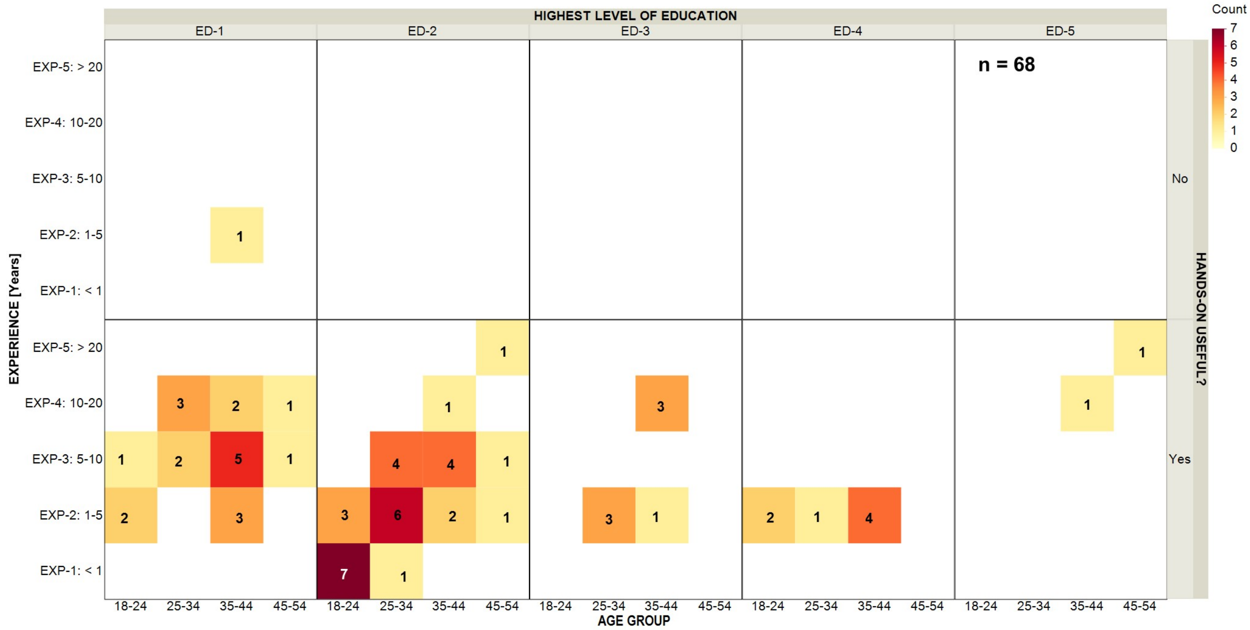


(b)

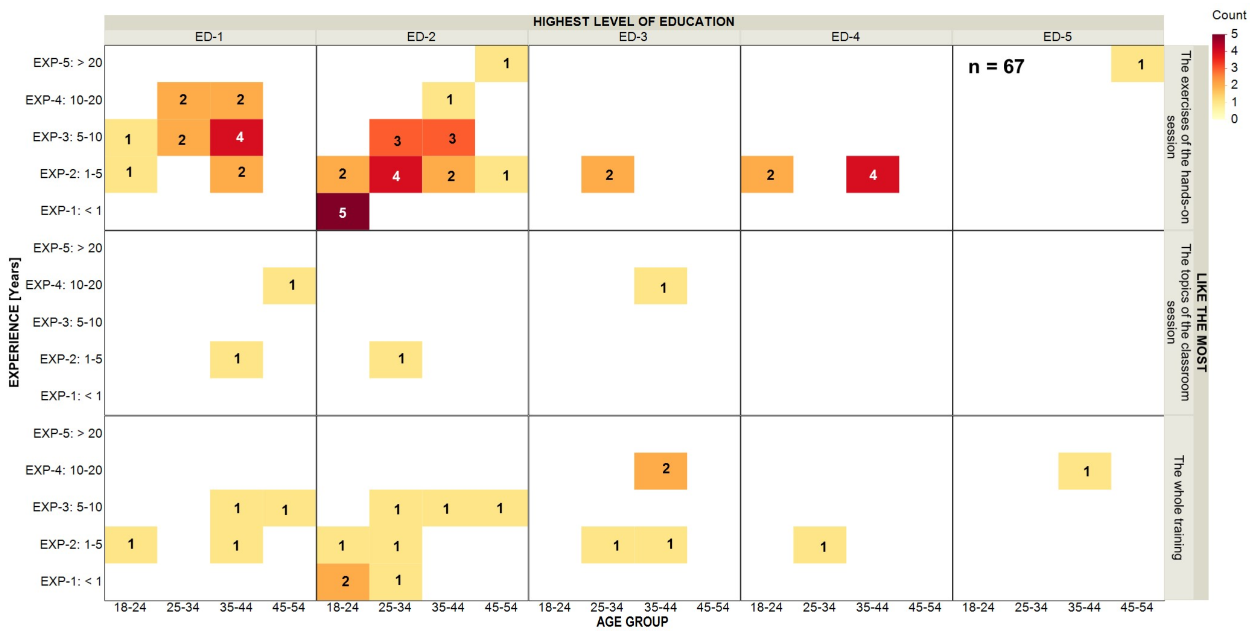


(c)

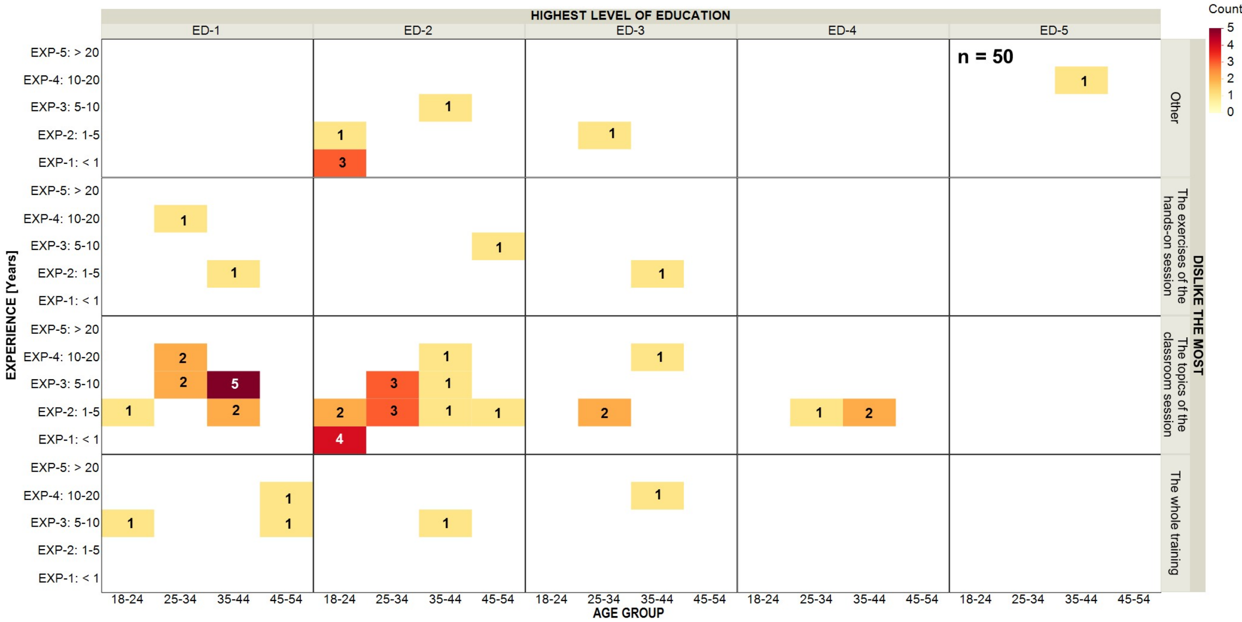
Figure 19. Summary of demographic information: global results (left) and by group (right).


HIGHEST LEVEL OF EDUCATION
ED-1
ED-2
ED-3
ED-4
ED-5
n = 68
Count
EXPERIENCE [Years]
EXP-5: > 20
EXP-4: 10-20
EXP-3: 5-10
EXP-2: 1-5
EXP-1: < 1
HANDS-ON USEFUL?
No
Yes
AGE GROUP
18-24
25-34
35-44
45-54

(a)


HIGHEST LEVEL OF EDUCATION
ED-1
ED-2
ED-3
ED-4
ED-5
n = 67
Count
EXPERIENCE [Years]
EXP-5: > 20
EXP-4: 10-20
EXP-3: 5-10
EXP-2: 1-5
EXP-1: < 1
LIKE THE MOST
The exercises of the hands-on session
The topics of the classroom session
The whole training
AGE GROUP
18-24
25-34
35-44
45-54

(b)



(c)

Figure 20. Summary of responses as function of demographic information: (a) Question #5; (b) Question #12; (c) Question #13.

The relationship between modifying variables (Table 3.c) and dependent variables (Table 3.d) is illustrated in Figure 20. The modifying variables are represented by the demographic information (age, experience and education). The dependent variables are represented by the responses to questions #5, #12, and #13. Figure 20 summarizes the individual count of responses organized in a color map (commonly known as "heat map"). This data representation highlights the predominant answers per demographic characteristic under consideration. Figures 20(a), 20(b) and 20(c) show the distribution of responses to questions #5, #12 and #13, respectively.

Looking at the overall distribution of the responses to all three questions, it is seen that about 75% to 80% of the responses are concentrated in two levels of education (ED-1: high school graduate, and ED-2: Some college with no degree). Within these two groups, responses for each of the questions are grouped predominantly into two levels of experience: those with less than one year of experience and those with 5 to 10 years of experience. Moreover, looking at the predominant responses ("yes" for question #5, "the exercises of the hands-on session" for question #12, and "the topics of the classroom session" for question #13), it is seen that relatively younger and less experienced respondents, with education level ED-2, found the hands-on session useful, are more inclined to like doing exercises during the hands-on session and more likely to dislike having a classroom session as part of the training. A similar tendency in the distribution of responses is seen for relatively older trainees (35-44 years of age), with education level ED-1 and more experience in the coal mining industry (5-10 years). These results seem encouraging in terms of improving the safety of relatively younger and less experienced miners. A study conducted by Groves et al. [32] that analyzed fatalities and injuries involving mining equipment found that younger employees had an elevated risk of injury and also that a large majority of incidents involved workers with less than 5 years of experience.

In summary, the data presented in Figures 17 to 20 provides clear evidence that trainees preferred experiential training that included hands-on activities instead of learning through the classical classroom setting. These results are in agreement with observations made by Ference and Vockell [21] who pointed out that adults respond best to learning that is active and experienced-based. The results obtained in this work are also in agreement with the observations made by Kowalski and Vaught [18] who recognized that traditional lectures are not appropriate for adult learners today since they are more likely to forget lecture material than material gained through experience, especially within the miner's community.

5.3. Summary of Accomplishments

As stated in Section 3.3 of this report, the main objective of this research was to create and provide the research-based experiential training necessary to improve the safe operation of shuttle cars and scoops in underground coal mines. With this main objective in mind, the specific aims of this work included:

1. Development of training curriculum, including the creation of key components of a training curriculum based on experience and limitations observed by equipment operators and management of currently operating mines.
2. Execution of a pilot training program, which included training exercises at the simulated mine facility, and demonstrations of mine safety technology for public and private organizations.
3. Assessment of impact and effectiveness of the training effort to provide evidence that the training conducted as part of this effort has been effective.
4. Validation of hypothesis. Based on the training exercises conducted, generation of supporting data to validate or disprove the project hypothesis that providing the necessary information on safety technology and demonstration in a simulated mine environment will aid in technology adoption and that trainees will prefer experiential training over typical classroom instructional methods.

Attaining specific aim #1 included the following accomplishments:

- (a) Contacted and worked with three coal mining companies to learn about their experience with the implementation of proximity and camera systems, current training procedures, and recommendations for developing enhanced training programs to improve the safe operation of shuttle cars and scoops in underground coal mines. Safety managers and current scoop operators were surveyed to gather information on current practices as summarized in Appendix 2-A.
- (b) Contacted and worked with four companies currently offering MSHA approved proximity detection and camera systems. This effort included learning about the basic characteristics and functionality of their products as summarized in Appendix 2-B.
- (c) Within the framework of the TIER model and in conjunction with the ADDIE instructional model, developed a preliminary training curriculum that included components offered in the classroom and hands-on sessions.
- (d) This preliminary training curriculum was presented to representatives of coal mining companies currently operating in West Virginia to get feedback and observations for implementation. The recommendations were incorporated in the proposed curriculum in

preparation for implementation, and the resulting training materials are compiled in Appendix 3.

Attaining specific aim #2 included the following accomplishments:

(a) Delivered updated training program to 68 volunteers recruited from the WV Mine Foreman/Fireboss Certification class as well as WVU mining engineering students. The volunteers were exposed to the training program in six groups of 8 to 14 participants per group, as described in Section 4 of this report.
(b) As part of the training program, each group participated in a one-hour classroom session followed by a one-hour hands-on session conducted in the simulated mine of the WVU Training Academy and utilized a battery-powered scoop equipped with a proximity detection system and a camera system procured as part of this project.

Attaining specific aim #3 included the following accomplishments:

(a) After completing the training sessions, each group of volunteers was subjected to two levels of evaluation to assess the effectiveness of the training program: Level 1, Participant Reaction and Level 2, Perceived Learning. Two sets of questions were prepared for each level to gather information concerning aspects of the classroom and hands-on sessions, preparedness and training organization, participant satisfaction, changes in knowledge, changes in attitude and behavioral intent and demonstrated an understanding of the training materials. Basic demographic information of the participants of the training was collected as well. The questionnaires implemented for each level are compiled in Appendix 4.
(b) Data collected during the evaluations was compiled and systematized in tabular and graphical forms to quantify results and identify behaviors and tendencies as described in Section 4 of this report and compiled in Appendix 5.
(c) Responses to questionnaires distributed after the training sessions and completed by the participants allowed the determination of the degree of effectiveness of the proposed training as well as the identification of areas of improvement for wider implementation of the proposed training program.

Attaining specific aim #4 included the following accomplishments:

(a) Part of the original hypothesis resulted modified by the promulgation of state and federal regulations that mandate the implementation of proximity detection systems in underground coal mining equipment including continuous miners, shuttle cars, and scoops among others. Since the implementation of proximity detection technology became mandatory at the state level in 2014 and federal level in 2015, only the part of the hypothesis concerning the preference of the trainees on the type of training was evaluated.
(b) Further analysis of selected questions incorporated in the questionnaires utilized as assessment tools of the effectiveness of the proposed training curriculum allowed confirmation of the trainees' preference for experiential learning rather than for traditional classroom settings as described and summarized in Section 4 of this report.
(c) The relationship between preferences and demographic information was evaluated as well.

The sum of accomplishments detailed above allowed reaching the ultimate objective of creating and delivering a training program of research-based experiential training necessary to improve the safe operation of scoops in underground coal mines. It is believed that with minor adjustments, the proposed training curriculum is ready for wider implementation and can complement the training required by the recently promulgated rules requiring the implementation of proximity detection technology.

6.0 DISSEMINATION EFFORTS AND HIGHLIGHTS

The following is a list of the dissemination efforts carried out during the development of this project:

1. On January 31, 2014, the Principal Investigator participated of the West Virginia Coal Association Mining Symposium held at the Charleston Civic Center, Charleston, WV. In that event, the PI delivered a presentation titled "Proximity Detection Technology" in which part of the objectives and activities planned for this research project were presented to representatives of coal mining companies and the general audience.

2. On May 23, 2014, a preliminary training curriculum was presented to the startup committee formed by representatives of three mining companies currently operating in WV who agreed to participate in this study. The startup committee was integrated by safety managers and scoop operators with different levels of experience. The presentation of the pilot training curriculum took place in a meeting at the WVU Academy for Mine Training and Energy Technologies. During this event, the Principal Investigator and the research team introduced the startup committee to the objectives and contents of the proposed training curriculum. During and after the presentation, the committee provided observations and feedback that were incorporated in the proposed training curriculum before initial implementation.

3. On October 23, 2015, a preliminary compilation of work and results obtained under this research project were presented at the 2015 Joint Fall Meeting of the West Virginia Coal Mining Institute and the Central Appalachian Section of SME held at White Sulphur Springs, WV. The PI delivered the presentation titled "Proximity Detection System: Latest Developments on Training and Technology Demonstration".

4. On November 6, 2015, an overview of the research efforts and preliminary results were presented at the Statler College of Engineering and Mineral Resources of West Virginia University as part of the "Mining Engineering Graduate Seminar", organized by the Department of Mining Engineering. Collaborators of the PI delivered the presentation titled "Proximity Detection System: Latest Developments on Training and Technology Demonstration".

5. An abstract and a conference paper based on the final results included in this report will be generated for submission to the SME Minnesota Conference 2016. Abstracts for consideration are due on November 16, 2015.

As part of the dissemination plan, the following activities will be completed upon approval of the final report:

1. The final versions of the presentations delivered at the different events listed above as well as the publication generated as part of this project will be posted on the departmental website.

2. All the training materials developed as part of this project will be posted on the departmental website.

7.0 CONCLUSIONS AND IMPACT ASSESSMENT

7.1. Conclusions

Based on the observations and results obtained from development of this project, the following conclusions can be drawn:

A. Considering the reaction of the trainees to the proposed training materials:

1. The volunteers exposed to the materials developed as part of this research project manifested a positive reaction to the proposed training approach consisting of a combination of classroom and hands-on sessions. Nearly 9 out of 10 participants valued the preparedness and responsiveness of trainers as well as the time allocated for each one of the portions of the training positively.
2. Regarding the content delivered in the classroom sessions, about 9 out of 10 respondents found the classroom session relevant or very relevant to their current activities. However, despite valuing the specifics of the classroom session positively, the most preferred portion of the training was the hands-on session with the exercises executed in the simulated mine. Practically all the participants of the training valued the contents, quality, and organization of the hands-on portion of the training positively.

B. Considering the changes in knowledge of the trainees after being exposed to proposed training materials:

1. The contents of the training materials increased the knowledge of the trainees in different facets such as the availability of proximity detection and camera system, existing regulations about the systems, their limitations as well as the risk of accidents due to the lack of proper visibility when working around haulage equipment.
2. Taking into account potential changes in attitude after being exposed to the training materials, nearly 9 out of 10 participants manifested intentions of implementing changes in their current activities as a result of their new knowledge or were willing to share the new knowledge with their peers.
3. A measure of the effectiveness of the proposed training program is provided by the results obtained from the responses related to the understanding of the training materials. Overall, 7 to 9 out of 10 participants responded correctly when asked about basic functionality and particularities of proximity detection and camera systems. These results indicate that there is room for improvement to increase the effectiveness of the proposed training.

C. Considering the preference of trainees regarding classroom vs. experiential training settings:

1. Trainees clearly preferred experiential training that included hands-on activities instead of learning through the classical classroom setting.
2. This result is in line with previous observations reported in the literature that pointed out that adults respond best to learning that is active and experience-based and that also recognized that traditional lectures are not appropriate for adult learners today, since they are more likely to forget lecture material than material gained through experience, especially within the miner's community.

7.2. Impact Assessment

The immediate impact of the results of this research work include:

1. A total of 68 volunteer trainees were exposed to the training curriculum developed under this project. All these volunteers took part of the classroom and hands-on sessions designed to expose them to proximity detection and enhanced visibility technology.

2. All of the trainees experienced the functionality of this technology installed on a battery-powered scoop within an environment of reduced visibility created in the simulated mine at WVU. The implementation of a functioning battery-powered scoop equipped with the proximity detection system and cameras provided an element of realism that was not previously achievable in the simulated mine.

3. All the participants expressed their reactions to the training materials, demonstrated their perceived learning and made their observations about the implementation of proximity detection technology in underground coal mining operations.

The implementation of a plan for evaluation of mid to long term impacts of the work developed in this project would include:

1. Further dissemination of the training materials created in this project and encouragement to different mine operators for the adoption and implementation of this material as part of their normal training procedures.

2. Extended implementation of the training curriculum will allow collecting additional data on reactions and perceived learning that will allow identification of other particularities not captured by the sample sized used in this research as well as refinements of the training approach. It is believed that a key measure of the success and impact of further implementation of the training materials in the mid to long terms would be significant reduction of safety incidents involving lack of visibility, a considerable increase in the awareness of the risks of working around haulage equipment by miners and machinery operators, and most importantly, a significant reduction or elimination of the fatalities related to reduced visibility or unawareness of the surroundings in underground coal mining.

3. Continuous communication and interaction between the WVU research team and safety managers of mining companies who decide to adopt the training materials in order to identify improvements and new areas of concern. This interaction will allow adjusting the training materials and operating procedures as the needs of miners evolve with the purpose of maximizing the impact.

8.0 RECOMMENDATIONS FOR FUTURE WORK

Some recommendations for future work include:

1. Considering some of the comments received from the trainees that participated in this study, a plausible future work to expand the usefulness of the training developed in this research work comprises the inclusion of additional reduced visibility exercises executed with the scoop in the simulated mine. Similarly, several trainees manifested either verbally or in the responses to the questionnaires, their interest in experiencing the functionally of the proximity detection system when the scoop is located in other positions in the simulated mine. It is believed that this addition will expand the number of possible scenarios that either machine operators or miners working around the machine would experience in actual coal mining operations.

2. Another aspect for consideration is the development of training exercises to account for directional activation of the proximity detection system. In the work carried out in this research project, all the electromagnetic generators of the proximity system were active regardless of the direction of tramming of the scoop. For this particular type of machinery, this configuration can be very limiting in terms of productivity. A new approach currently being tested in the industry in conjunction with proximity manufacturers is to activate the electromagnetic generators as a function of the direction of tramming. The proximity detection system installed on the scoop acquired as part of this project can be reconfigured to recreate directional activation of the electromagnetic generators. Additional exercises with this new configuration can be carried out in the simulated mine.

3. The approach implemented in this project for developing a training program specifically for scoop operators and people working nearby this type of equipment can be also applied to shuttle cars. This particular type of haulage equipment has its particularities regarding size, operation, speed and reduction of the operator's visibility in normal operating conditions. The implementation of proximity detection systems, now required by the WV (and soon by MSHA) regulations, adds another element for consideration in the implementation of training programs.

4. This work would also benefit from the future full implementation of Stage 4 of the TIER model that includes longitudinal studies in the actual work environment. This activity will allow further evaluation of the intended and unintended impacts of the training on the trainees, as well as additional evaluations of the effectiveness of the proposed training approach.

5. Finally, considering the recent promulgation of state and federal rules regulating the implementation of the proximity detection systems for different types of underground coal mining machinery, additional efforts should be spent in further understanding advantages, limitations and interaction of the different measures. The requirement of implementation of proximity detection or camera systems, in combination with additional reflective clothing and marking of hazardous work sites, provides a set of layers of protection that can increase miner's safety. However, none of these measures are completely failsafe individually, and further emphasis on training workers to not rely on only one safety measure is needed.

ACKNOWLEDGMENTS

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. under grant AFC113-16-2R371. The support from the Alpha Foundation is very much appreciated.

Several persons contributed as members of the startup committee providing input or collaborating in the development and execution of this study.

The research team is thankful to representatives of mining companies with operations in West Virginia and surrounding areas, including: Gary Dixon (Mepco), Kevin Hatfield (Mepco), Steven Simms (Mepco), Kris Lilly (Red Bone), Charlie Lilly (Red Bone), Kevin Rakes (Dana), Aaron Price (Patriot Coal), Todd Moore (Consol Energy), Terry Hudson (Patriot Coal), and to the 59 volunteers who agreed to take the training sessions developed as part of this project.

The technical support and information provided by Mike Dunmire (Strata), Neil Glaze (Strata), David Clardy (Matrix), Aric Pryor (Matrix), Harry Dushac (Nautilus/United Central Industrial Supply), Larry Rowley (Mining Controls Inc. MCI), Charles W. Lilly (CAI Industries) and Randy Riddle (CAI Industries) is very much appreciated.

The research team also wants to thank David Chirdon (MSHA) for providing historical data on accidents and installation of proximity detection systems in the US. The comments and details on state regulations provided by the WV Office of Miners Health, Safety and Training through Director Eugene White and deputy directors Greg Norman and John Kinder are much appreciated.

Thanks also to Professor Vladislav Kecojevic and the 9 Mining Engineering students of the WVU Mining Engineering Department who volunteered to take the training sessions developed as part of this project.

Finally, the research team is thankful for the efforts and assistance provided by Thomas Hall, Joshua Caldwell, George Rannenberg and Joshua Brady of the Department of Mining and Industrial Extension at WVU.

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10.0 APPENDICES

APPENDIX 1. ADDIE MODEL

The Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional design model is a framework traditionally used by instructional designers and training developers. There are various adaptations and variations of the ADDIE model, but it consists of five cyclical phases—Analysis, Design, Development, Implementation, and Evaluation interrelated as illustrated in Figure 1.

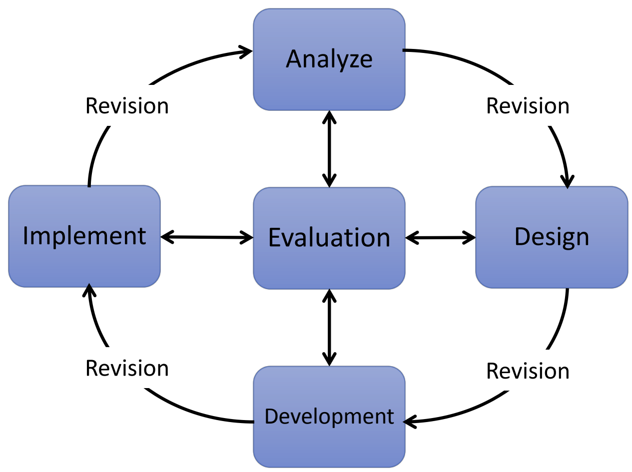

Figure 1. Schematic of ADDIE model, current conceptual scheme [3].

The ADDIE model was originally developed by Florida State University with the purpose of explaining, "...the processes involved in the formulation of an instructional systems development (ISD) program for military interservice training that will adequately train individuals to do a particular job and which can also be applied to any interservice curriculum development activity." [Ref]. The different phases of this model typically include:

1. ***Analysis Phase:*** In the analysis phase, the instructional problem is clarified, the instructional goals and objectives are established, and the learning environment and learner's existing knowledge and skills are identified.

2. ***Design Phase:*** The design phase deals with learning objectives, assessment instruments, exercises, content, subject matter analysis, and lesson planning and media selection. The design phase should be systematic and specific, where Systematic means a logical, orderly method of identifying, developing and evaluating a set of planned strategies targeted for attaining the project's goals; and Specific means each element of the instructional design plan must be executed with attention to details.

3. ***Development Phase:*** In the development phase, instructional designers and developers create and assemble content assets blueprinted in the design phase. In this phase, the designers create storyboards and graphics. Initial trials are implemented to debug materials and procedures.

The project is reviewed and revised according to feedback provided by experts and results from preliminary trials.

4. ***Implementation Phase:*** During the implementation phase, a procedure for training the facilitators and the students is developed. The facilitators' training typically covers the course curriculum, learning outcomes, method of delivery, and testing procedures.

5. ***Evaluation phase:*** The evaluation phase consists of two parts: formative and summative. Formative evaluation is present in each stage of the ADDIE process as shown schematically in Figure 2. The Summative evaluation consists of tests designed for domain specific criterion-related referenced items and providing opportunities for feedback from the users that were identified. Evaluation can be both formative, normally done to impact the process as it is happening, and summative, typically completed immediately after training is conducted to evaluate the extent to which students enjoyed and believed they received valuable learning. This phase can also be conducted over the course of weeks or months after training.

Figure 2 illustrate the schematically the relationship between the evaluation phase and the other four phases of the ADDIE model.

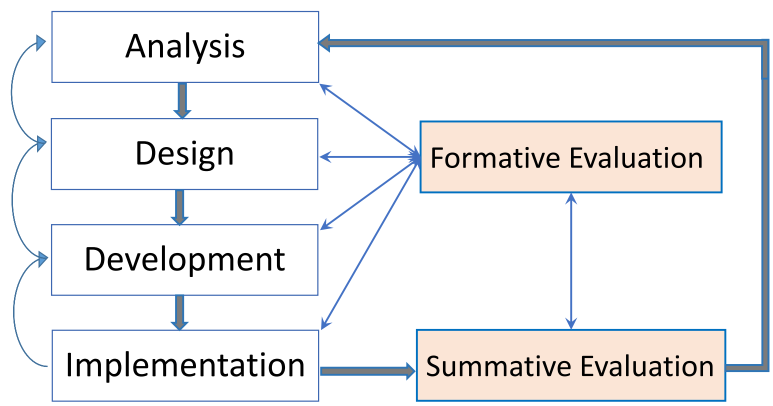

Figure 2. ADDIE Model. Evaluation phase. Adapted from original diagram created by Steven J. McGriff, Instructional Systems, College of Education, Penn State University [3].

In this project, the four levels of training evaluation proposed by Kirkpatrick were implemented as part of the evaluation phase. Kirkpatrick's four-level model is considered an industry standard across the HR and training communities. The four levels of Kirkpatrick's evaluation model essentially measure:

Reactions. Examines how the students felt about the learning experience, what they thought and felt about the training.

Learning. Measures the resulting increase in knowledge or capabilities after the training has been taken.

Behavior. Measures how the training has been implemented on the job, measuring the extent of applied training in the day to day responsibilities.

Results. Evaluates the effects of the training on the business or the performance of the trainee.

All these measures are recommended for full and meaningful evaluation of training in organizations, although their application broadly increases in complexity and usually cost. These four indicators are typically arranged in levels from 1 to 4. Typically, Level 1 is quick and very easy to obtain and analyze. Level 2 is relatively simple to set up and offers a clear-cut for quantifiable skills, but is less easy to implement for complex learning. Level 3 is a short to midterm evaluation that requires measurement of behavior change and typically requires cooperation and skill of line-managers. Level 4 is a mid to long-term evaluation implemented at the organization level and requires management reporting and departmental assessments. Table A1-1 provides an overview of the evaluation levels (adapted from [26]).

Table A1-1. Kirkpatrick's four-level evaluation model.

Level	Evaluation type (what is measured)	Evaluation description and characteristics	Examples of evaluation tools and methods	Relevance and practicability
1	Reaction	Reaction evaluation is how the delegates felt about the training or learning experience.	Feedback forms or surveys. Verbal reactions, post-training surveys or questionnaires.	Quick and very easy to obtain. Not expensive to gather or to analyze.
2	Learning	Learning evaluation is the measurement of the increase in knowledge - before and after.	Typically assessments or tests before and after the training. Interview or observation can also be used.	Relatively simple to set up; clear-cut for quantifiable skills. Less easy for complex learning.
3	Behavior	Behavior evaluation is the extent of applied learning back on the job - implementation.	Observation and interview over time are required to assess change, the relevance of change, and sustainability of change.	Measurement of behavior change typically requires cooperation and skill of line-managers.
4	Results	Results evaluation is the effect on the business or environment by the trainee.	Measures are already in place via normal management systems and reporting - the challenge is to relate to the trainee.	Individually not difficult. The process must attribute clear accountabilities.

APPENDIX 2-A. PROXIMITY DETECTION SYSTEMS AVAILABLE IN THE U.S.

Summary of basic features offered by manufacturers of proximity detection systems currently approved by MSHA for use in the US.

Questions		**Strata**
#	Survey Date	3/7/2014
1	What is the underlying technology of the proposed system? (Magnetic, RF, others)	*Electromagnetic.*
2	Has the proposed system received MSHA approval? When?	*Yes. February 2006*
3	How many units of the proposed system are currently installed in the US?	*120*
4	How many units of the proposed system are currently installed worldwide excluding the US?	*1000*
5	Are there limitations on the number of Personal Wearable Devices that can be worn?	*We have tested with 25-50 PADs around the machine at one time*
6	Has the proposed system shown parasitic coupling or interference issues with metal straps, pizza pans, wire mesh or similar elements usually installed in underground coal or other mines?	*Yes, we have seen the fields grow to a known distance at a repeatable distance.*
7	Is the proposed system integrated to other tracking, communication or other systems in the US? If not, are there plans for integration with other systems?	*Yes we are looking at integrating Strata's current communications system (Commtrac).*
8	Has the proposed system been tested in low-seam coal mines (less than 40 inches)?	*Yes.*
9	How often does the proposed system need to be serviced, recalibrated, and/or maintained?	*At a minimum, Strata recommend checking the machine zone sizes on a monthly basis.*
10	What are the typical installation and troubleshooting times for continuous miners, shuttle cars, scoops and other similar equipment?	*Troubleshooting times have never been documented. We have a display POD to reduce troubleshooting times. With having reasonable access to the machine and mine personnel CM ~ 48 hours, SC ~ 48 hours, Scoops ~ 48 hours, Loaders ~48. Rebuild Shop installation time is around half the time.*
11	What is the price range of the proposed system (assume a 4 generator system with 12 person wearable devices or provide detail for your response)?	*Less than $80,000*

Questions		**Matrix**
#	Survey Date	3/13/2014
1	What is the underlying technology of the proposed system? (Magnetic, RF, others)	*The Matrix IntelliZone and Joy SmartZone Gen2 systems use multiple sensing technologies with software-generated X, Y coordinate derivation, which allows software-defined sharp-angle warning and stop zones, as well as dynamic, cooperative, and operator zones.*
2	Has the proposed system received MSHA approval? When?	*Yes, July 2013.*
3	How many units of the proposed system are currently installed in the US?	*Matrix M3-1000 & SmartZone Gen 1 – 225+ . Matrix IntelliZone & SmartZone Gen 2 – 10+ (depending on date of publication)*
4	How many units of the proposed system are currently installed worldwide excluding the US?	*1-5, depending on the date of publication.*
5	Are there limitations on the number of Personal Wearable Devices that can be worn?	*Currently, the maximum recommended IntelliZone PWDs ("Locators") in close proximity to an IntelliZone system is 25.*
6	Has the proposed system shown parasitic coupling or interference issues with metal straps, pizza pans, wire mesh or similar elements usually installed in underground coal or other mines?	*Matrix IntelliZone uses multiple sensing technologies and a proprietary, software-defined Environment Correction Factor (ECF) algorithm to provide dynamic correction for changing underground mine environmental factors such as wire mesh. Without the ECF, magnetic systems are susceptible to interference.*
7	Is the proposed system integrated to other tracking, communication or other systems in the US? If not, are there plans for integration with other systems?	*The Matrix IntelliZone system includes the capabilities to communicate with the Matrix MX3 tracking, communication, atmospheric monitoring, data transfer and automation control system.*
8	Has the proposed system been tested in low-seam coal mines (less than 40 inches)?	*Yes, depending on the date of publication.*
9	How often does the proposed system need to be serviced, recalibrated, and/or maintained?	*We anticipate that US Federal rule will require PWD's (or Locators) and each system should be checked for correct operation before each shift.*
10	What are the typical installation and troubleshooting times for continuous miners, shuttle cars, scoops and other similar equipment?	*Installation and troubleshooting times vary greatly depending on the location of the equipment (surface or underground, in disassembly due to rebuild, etc), the mine seam height and other mine conditions, the year and technology of the equipment, etc. A simple answer is not feasible. Please ask your readers to consult the manufacturer with their specific conditions.*
11	What is the price range of the proposed system (assume a 4 generator system with 12 person wearable devices or provide detail for your response)?	*The price range depends on a large number of factors not easily contained in a simple table. Please ask your readers to consult the manufacturer with their specific needs.*

Questions		Nautilus
#	Survey Date	3/25/2014
1	What is the underlying technology of the proposed system? (Magnetic, RF, others)	*Magnetic.*
2	Has the proposed system received MSHA approval? When?	*The first approval was received in 2007 and the second approval was received in 2009.*
3	How many units of the proposed system are currently installed in the US?	*None that I know of at this time. AT Massey had four systems and was going to install the systems on all mining machines in WV. The acquisition by Alpha Natural Resources stopped the Nautilus program. The installed systems were disconnected from operation at that time.*
4	How many units of the proposed system are currently installed worldwide excluding the US?	*Hundreds mainly in Canada, Australia, and New Zealand. Nautilus sells through distribution in those countries, so it is difficult to know where these systems go. I do remember the BHP has been using these systems in Australia since the early 2000's. Nautilus won a national safety award from BHP in 2005 as a significant safety system. I think this is still on their website?*
5	Are there limitations on the number of Personal Wearable Devices that can be worn?	*255 per mine*
6	Has the proposed system shown parasitic coupling or interference issues with metal straps, pizza pans, wire mesh or similar elements usually installed in underground coal or other mines?	*Because the Nautilus system uses a magnetic approach, no parasitic coupling or interference has been noticed.*
7	Is the proposed system integrated to other tracking, communication or other systems in the US? If not, are there plans for integration with other systems?	*The US approved version is not integrated with any other functions. International models have tracking and communication options available with proximity.*
8	Has the proposed system been tested in low-seam coal mines (less than 40 inches)?	*No.*
9	How often does the proposed system need to be serviced, recalibrated, and/or maintained?	*The system does not require servicing, calibration or maintenance unless damage has occurred. The PDD's, radiators and logic units are all sealed. Bad components are just replaced if damage occurs. Nautilus has a testing and programming device called the "LITTLE GENIUS". It can troubleshoot the system and also reprogram the system operation, as well as modify the "warning" and "alarm" zones by a wireless connection. Nautilus recommends testing for proper operation prior to each use of the machine.*
10	What are the typical installation and troubleshooting times for continuous miners, shuttle cars, scoops and other similar equipment?	*I have been involved in two installations underground. It took about 1 shift to prepare and install mechanical items, brackets, etc, another shift to finish cable installation and testing. This was in high coal, 6+ feet. These mining machines were already in use. Cutting and welding was required to mount hardware. Most mines want to have this done by the OEM or rebuild shops. We have conducted tests on shuttle cars and scoops, but they were not permanently installed. I estimate the same time as that for a mining machine. The Nautilus system is approved "INTRINSICALLY SAFE (IS)". Radiators are relatively small as a result. The cables only carry "IS" energy.*
11	What is the price range of the proposed system (assume a 4 generator system with 12 person wearable devices or provide detail for your response)?	*The estimated cost for the above request would be around $108,000. Another $4300 is needed for the test and programming items. One set of tests and programming items would be enough for an entire mine of machines. However, additional test units would most likely be purchased in large mines with multiple sections.*

APPENDIX 2-B. PRE-STARTUP SURVEY SUMMARY

Comments on the level of satisfaction with the implementation of Proximity Detection System or Cameras in underground coal mining equipment.

Participant ID	Level of Satisfaction	Comments
AC11	6-9: Somewhat satisfied	*The cameras have been a great enhancement to safety, and we have had very little problems with installation or maintaining them. The proximity on our CM has been hard to keep calibrated and caused a bit of trouble for our operators.*
AC12	6-9: Somewhat satisfied	*Our current PDS on our continuous miner works well in non-screened areas of the mine. However, in screened entries the PDS shuts the miner down when the continuous miner operator is located at a significant distance from the machine. The cameras on our shuttle cars and scoops are operating adequately and the operators like them.*
PC11	6-9: Somewhat satisfied	*We have 2 prox. systems in miners. We have issues with Strata. Joy System has not given us the results that Strata has.*
UC11	6-9: Somewhat satisfied	*Difficulty of setting functional zones. It takes a lot of trial and error.*
CE11	6-9: Somewhat satisfied	*Too slow!*
CE12	6-9: Somewhat satisfied	*Concerned that miners will get a false sense of security.*

Testimonials and other comments

Participant ID	Testimonials
AC11	*I have heard several shuttle car operators speak of different incidents of the camera's helping eliminate what could have been a bad situation when tramming through check curtains and around blind corners.*
AC12	*Our shuttle car operators have told me that they like the camera systems on the shuttle cars. They said it improves safety and improves their ability to drive safer.*
PC11	*With prox. on miners the operator is removed further from the machine and out of the dust.*
CE11	*Detrimental on loaders and possibly on scoops. Beneficial on shuttle cars and ram cars.*
CE12	*It forces the face employees towards the face while cutting corners.*

Summary of responses from scoop operators to questions related to training and experience (48 participants).

Questions	Multiple choice answers	Number of selections	Total # of responses	Percentages of selected answers	
		i	n	Partial	Total
1. How many years of experience do you have in operating scoops?	Less than 1 year	9	48	19%	100%
	More than 1 year but less than 5 years	23		48%	
	More than 5 years	16		33%	
2. How did you get trained?	Safe Work Instructions (SWI) only	4	47	9%	100%
	SWI + Period of practice	15		32%	
	SWI + Demonstration + Period of practice	28		60%	
3. For how long?	Less than 1 day	13	48	27%	100%
	More than 1 day, but less than 1 week	16		33%	
	Between 1 week and 1 month	10		21%	
	More than a month	9		19%	
4. What were the biggest challenges in the process of learning to run scoops?	The size of the machine	6	53	11%	100%
	The position of the driver	1		2%	
	The extent of visibility in the mine	28		53%	
	Turning maneuvers	13		25%	
	Other	5		9%	
5. How long did it take you to feel "comfortable" operating the machine?	Less than 1 day	7	48	15%	100%
	More than 1 day, but less than 1 week	19		40%	
	Between 1 week and 1 month	18		38%	
	More than 1 month	4		8%	
6. How many blind spots can you identify or recognize while operating the machine?	More than 1 but less than 3	19	47	40%	100%
	More than 3 but less than 5	21		45%	
	More than 5	7		15%	
7. Does the light of your cap lamp affect the operation?	Yes	21	48	44%	100%
	No	27		56%	
8. What maneuvers do you think are the most challenging in terms of visibility?	Going forward	4	51	8%	100%
	Going backward	14		27%	
	Turning left or right	33		65%	
9. Do you run scoops that include a protective grid or guard in the operator's compartment?	Yes	40	49	82%	100%
	No	9		18%	
10. Have you operated scoops without any protective grid?	Yes	33	48	69%	100%
	No	15		31%	
11. Can you estimate the percentage of how much your visibility is reduced with the presence of protective guard?	About 10%	6	48	13%	100%
	About 25%	22		46%	
	About 50%	15		31%	
	About 75%	5		10%	
12. Were you involved in any "near miss" or safety incident because of the reduced or lack of visibility?	No	41	47	87%	100%
	Yes	6		13%	

APPENDIX 3. SYLLABUS AND INSTRUCTION MATERIALS

Training on Proximity Detection Systems and Camera Systems

Instructor(s):	Extension Agents, Research Faculty
Location:	WVU Training Facilities at Doll's Run, WV
Duration:	2.0 to 2.5 hours
Format:	Training format is organized into two modules. Module 1 includes a lecture with room for trainee discussion. Module 2 includes demonstrations and hands-on exercises in a simulated mine setting and using actual mining equipment.
Training objective:	Enhance training of miners by exposing them to the most current safety technology installed on a battery scoop. The exposure will provide to the trainees the opportunity to experience the functionality of the safety technology in a situation of limited visibility provided by a simulated mine environment.
Instructional Outcomes:	Upon completion of this training class, the trainee should be able to: 1. Recognize the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine. 2. Understand the basics of the operation of haulage equipment equipped with proximity detection and camera systems. 3. Understand the advantages and limitations of proximity detection or camera systems. 4. Experience the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine.
Training Outline:	See Tables A3-1 and A3-2.

Table A3-1: Detailed Training Plan - Proximity Detection and Camera Systems.

Module 1					
Part	Subject	Specific Objectives	Teaching Methods	Course Material	Evaluation Method
1-1	GENERAL OVERVIEW OF TOPICS. FAMILIARITY WITH UNDERGROUND HAULAGE EQUIPMENT FOR COAL MINING	The trainee will identify typical haulage equipment normally used in underground coal mining operations.	Lecture and discussion complemented with Q&A	Handouts, graphics, audio, text, and videos	Questions in common format such as multiple-choice, true/false, matching, and others
1-2	SYNOPSIS OF MSHA RECOMMENDED SAFETY PRACTICES AROUND SHUTTLE CARS AND SCOOPS IN UNDERGROUND COAL MINES	The trainee will recognize potential hazards associated with operating and working around shuttle cars and scoops.	Lecture and discussion complemented with Q&A	Handouts, graphics, audio, text, and videos	Questions in common format such as multiple-choice, true/false, matching, and others
1-3	OVERVIEW OF PROXIMITY DETECTION SYSTEMS	The trainee will recognize and identify typical components of proximity detection systems, including their function and location in a piece of haulage equipment. The trainee will understand the advantages and limitations of the proximity detection system.	Lecture and discussion complemented with Q&A	Handouts, graphics, audio, text, and videos	Questions in common format such as multiple-choice, true/false, matching, and others
1-4	OVERVIEW OF CAMERA SYSTEMS	The trainee will recognize and identify typical components of camera systems, including their function and location in a piece of haulage equipment. The trainee will understand the advantages and limitations of the camera system.	Lecture and discussion complemented with Q&A	Handouts, graphics, audio, text, and videos	Questions in common format such as multiple-choice, true/false, matching, and others
1-5	SYNOPSIS OF WV AND FEDERAL REGULATIONS ON PROXIMITY DETECTION SYSTEMS	The trainee will be informed of the latest state and federal regulations concerning the implementation of proximity detection and camera systems in underground mining equipment.	Lecture and discussion complemented with Q&A	Handouts, graphics, audio, text, and videos	Questions in common format such as multiple-choice, true/false, matching, and others

Table A3-2: Detailed Training Plan - Proximity Detection and Camera Systems.

Module 2					
Part	Subject	Specific Objectives	Teaching Methods	Course Material	Evaluation Method
2-1	OVERVIEW OF SIMULATED MINE AND SIMULATION EXERCISES	The trainee will be familiarized with the environment provided by the simulated mine where training exercises will take place.	Demonstration complemented with Q&A	Handouts and hands-on activities in the simulated mine	Questions in common format such as multiple-choice, true/false, matching, and others
2-2	SCOOP CONFIGURATION WITH PROXIMITY DETECTION AND CAMERA SYSTEMS	The trainee will identify typical components of proximity detection and camera systems, including their function and location in a battery scoop.	Demonstration and discussion complemented with Q&A	Handouts and hands-on activities in the simulated mine	Questions in common format such as multiple-choice, true/false, matching, and others
2-3	EXPERIENTIAL LEARNING	The trainee will experience the functionality of proximity detection and camera system. The trainee will experience reduced visibility as operator of a battery scoop or as a miner working around a battery scoop.	Demonstration and discussion complemented with Q&A	Demonstration and Hands-on experience in the simulated mine and using an actual battery scoop	Questions in common format such as multiple-choice, true/false, matching, and others

Appendix 3-A. Instructional Materials for Classroom Session

ENHANCED MOBILE EQUIPMENT EXPERIENTIAL LEARNING AND SAFETY TECHNOLOGY DEMONSTRATION

MODULE I

Classroom Session

B. Statler College of Engineering and Mineral Resources
Department of Mining and Industrial Extension
West Virginia University

1

ACKNOWLEDGMENTS AND DISCLAIMERS

- The following training material was developed and/or compiled by the Department of Mining and Industrial Extension at West Virginia University (WVU).
- The authors wish to acknowledge the Alpha Foundation for the Improvement of Mine Safety and Health as funding source.
- The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the Alpha Foundation, its Directors and staff.
- Any mention of company or product does not constitute an endorsement of the Alpha Foundation or WVU.

2

OUTLINE OF MODULE I

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

3

TRAINING OBJECTIVE

Enhance training of miners by exposing them to the most current safety technology installed on a battery scoop. The exposure will provide to the trainees the opportunity to experience the functionality of the safety technology in a situation of limited visibility provided by a simulated mine environment.

TARGET AUDIENCE

Apprentice miner or mine foreman student with or without scoop experience.

4

LEARNING OUTCOMES

Upon completion of the training, the trainee will be able to:

1. Recognize the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine.
2. Understand the basics of the operation of haulage equipment equipped with proximity detection and camera systems.
3. Understand the advantages and limitations of proximity detection or camera systems.
4. Experience the challenges of the operation of scoops in confined spaces and poor visibility typical in a working mine.

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OUTLINE

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

6

Battery-Powered Scoops

CAI Industries

- CAI 488 Battery Scoop

GE Fairchild

- GE Fairchild Battery Scoop

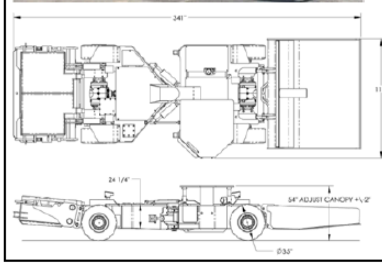
Caterpillar

- Cat Battery Scoop

7

CAI 488 Battery Scoop

CAI 488 BATTERY SCOOP
CAI INDUSTRIES



Specifications	
Max Steer Angle	40 Degrees Each Direction
Min Inside Turn Radius	42 1/2' Nominal
Min Outside Turn Radius	88' Nominal
Max Bucket Tilt Up Angle	16.5 Degrees
Max Bucket Tilt Down Angle	26 Degrees
Approx. Bucket Capacity	110 CuFt

Standard Features
John Deere 1200 Series Inboard Planetary Axles
On Demand Diff lock
Inboard Wet Service Brakes
Heavy Duty Driveshaft Assemblies
Ground Base Battery Lift
3 Post Adjustable Certified Canopy
10" Extended Cab
50hp Tram Motor
Customer Choice of Electronic Drive
1 1/2" Thick Structural Main Frame Plates
Optional Equipment Available to meet your mines specific needs

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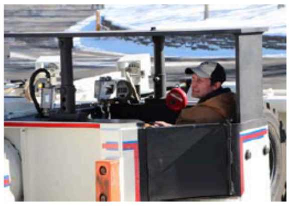
Operator's compartment



WITHOUT OPERATOR'S PROTECTIVE GRID

WITH OPERATOR'S PROTECTIVE GRID

Typical Uses of Battery Scoops

For mining operations

1. Coal haulage
2. Cleaning of working zone
3. Other…

For support operations

1. Transportation of mine supplies
2. Support for rock dusting operations
3. Other…

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OUTLINE

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

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SAFETY PRACTICES AROUND SHUTTLE CARS AND SCOOPS IN UNDERGROUND COAL MINES

WATCH OUT!!

Condensed version of the document available on line at: http://www.msha.gov/focuson/watchout/Hitby%20SHUTTLECARS.pdf

12

The MSHA initiative has been developed to make miners aware of the hazards associated with operating and working around shuttle cars and scoops.

Please remember, you can prevent these types of accidents and fatalities.

Condensed version of the document available on line at:
http://www.msha.gov/focuson/watchout/Hitby%20SHUTTLECARS.pdf

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MSHA Recommended Best Practices

- For Shuttle Car and Scoop Operators
- For Miners
- For Mine Owners, Superintendents, or Supervisors

Full document available online at:
http://www.msha.gov/focuson/watchout/Hitby%20SHUTTLECARS.pdf

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MSHA's Recommended Do's and Don'ts

VISIBILITY	• Always wear reflective clothing to increase your chances of being seen by equipment operators. • Always maintain clear visibility with all personnel in your vicinity when operating mobile equipment.
COMMUNICATION	• Always instruct equipment operators to sound warning bells and horns when the operator's visibility could be obstructed at curtains or when making tight turns, or when changing directions.
POSITION	• Always maintain a safe distance between yourself and any equipment that is moving. • Always walk behind moving mobile equipment when traveling in the same entry.
OPERATION	• Always do pre-operational checks to identify any hazards that may affect the safe operation of the equipment before it is placed into service. • Always, when operating a scoop, assure supplies and materials in the bucket, without obstructing operator visibility.

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MSHA's Recommended Do's and Don'ts

VISIBILITY	• Never in any circumstances assume that an equipment operator sees you and is stopping for you.
COMMUNICATION	• Never ignore warning bells and horns when approaching curtains or when making tight turns, or when changing directions.
POSITION	• Never position yourself in an area or location where equipment operators cannot readily see you.
OPERATION	• Do not operate a scoop without conducting a pre-op check, including brakes.

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OUTLINE

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. **Examples of Accidents**
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

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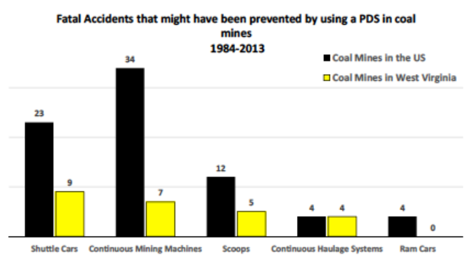
WAYS TO BE CRUSHED

1. **UNANTICIPATED MOVEMENT OF THE MACHINE** - either by equipment malfunction, the victim moving the machine differently than intended, or by someone else starting or moving the machine differently than intended

OR

2. **LACK OR REDUCED VISIBILITY** - the operator did not see the victim or did not realize that the victim was located in a hazardous location

ACCIDENT TRENDS



Source: MSHA Analysis by Chirdon, et al. (2014)

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ACCIDENT TRENDS

Nearly 800 miners have been injured and 16 killed in accidents from 01/2000-09/2010 involving shuttle cars and scoops in underground coal mines.

Fatal Accident – 2008

In February 2008, a surveyor with 8 years of total experience was fatally injured while surveying in an active underground mining section. The victim was struck by a loaded shuttle car as it traveled through a run-through check curtain.

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Fatal Accident – 2008

In May 2008, a general inside laborer with four weeks experience was fatally injured when he was struck by a battery powered scoop. The victim was assisting two other miners repair a haul road.

The victim was traveling on foot and was being followed by the scoop and a diesel road grader. While in route, the scoop operator struck the victim causing fatal injuries.

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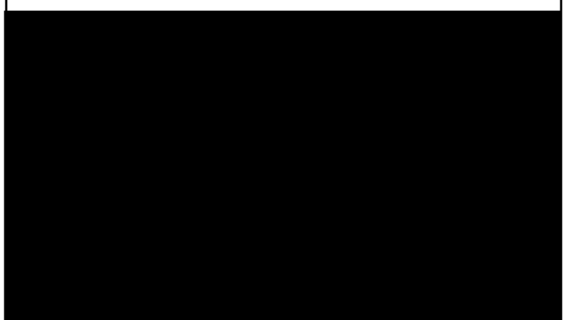
VISIBILITY VIDEO



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RISK CONTROL MEASURES

Traditional Control Measures:

- Reflective & high visibility clothing
- Advocating deep cuts to limit exposure
- Training
- Strobes marking stationary work areas

Focus of this training session:

- Implementation of Proximity Detection Systems
- Implementation of cameras to improve visibility

OUTLINE

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PROXIMITY DETECTION SYSTEMS (PDS)

Technology developed for detecting the presence of miners within a certain distance.

Programmable to send a warning signal and stop the equipment on which it's installed when a certain area close to the system is breached.

If a miner approaches the machinery it is installed upon, the system will send a warning signal (visual or audible)

If the miner gets closer, the equipment will shut down.

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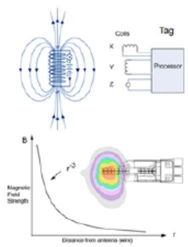
PROXIMITY DETECTION SYSTEMS (PDS)

Underlying technology:

- Current commercial systems are based on electromagnetic technology.
- Require wearable tags.

Objective of the technology:

- Detect individuals in dangerous positions around operating machinery.
- Alert machine operator.
- Alert individuals.
- Interlock – stop and/or disable the machine when needed.



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PROXIMITY DETECTION SYSTEMS*

Strata
- HazardAvert
- HazardAlarm

Matrix/Joy
- M3-1000 Proximity Detection System
- IntelliZone Proximity Detection
- IntelliZoneHD and IntelliZoneLT
- IntelliZoneLT

Nautilus#
- Nautilus Buddy-188SSF
- Nautilus Coal-Buddy
- Nautilus Haultruck-Buddy
- Nautilus Cap-Lamp-Buddy

* MSHA Approved; # Not currently in use in the US.

INSTALLATION NUMBERS IN THE U.S.

January, 2014

Manufacturer	CMs	Shuttle Cars	Haulers	Scoops	Loaders	MBCs	Roof Bolting Machines	Feeder / Breaker	Misc.	Total
Matrix Design Group M3-1000 at Alliance Coal Company	76									76
Matrix Design Group Intellizone at Alliance Coal Company	2									2
Matrix Design Group M3-1000	7									7
Joy Smartzone Gen 1	135									135
Joy Smartzone Gen 2	2		1							3
Strata HazardAvert	72	34	12	33	19	0	1	1	4	176
Total	294	34	13	33	19	0	1	1	4	399

September, 2014

Manufacturer	CMs	Shuttle Cars	Haulers	Scoops	Loaders	MBCs	Roof Bolting Machines	Feeder / Breaker	Misc.	Total
Matrix Design Group M3-1000 at Alliance Coal Company	66									66
Matrix Design Group Intellizone at Alliance Coal Company	34	4								38
Matrix Design Group M3-1000	9									9
Matrix Design Group Intellizone	8									8
Joy Smartzone Gen 1	146									146
Joy Smartzone Gen 2	49	1	2							52
Strata HazardAvert	82	45	13	42	22	0	1	1	4	210
Total	394	50	16	42	22	0	1	1	4	529

STRATA WORLDWIDE

HazardAvert

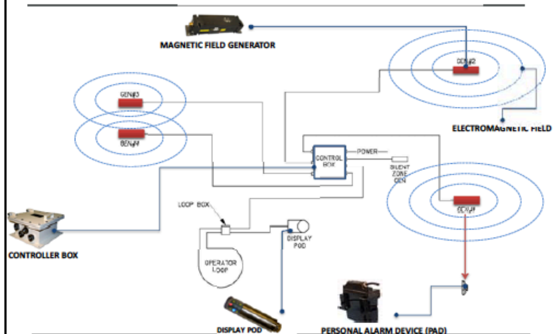
Strata Proximity Detection
Short Training Tutorial

KEY FEATURES OF HAZARDAVERT

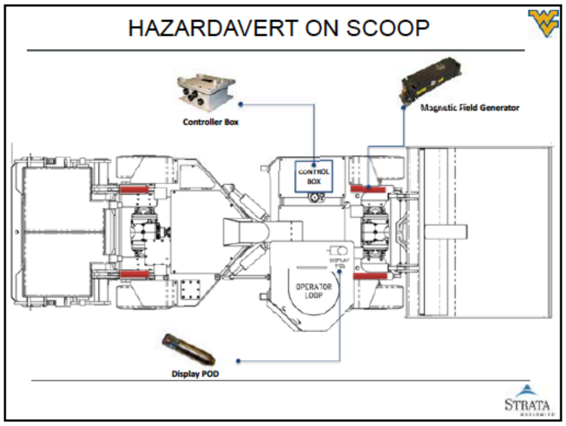
- A driver aid to help reduce crushing or pinching accidents.
- Pedestrian aid to advise when vehicle is too close for comfort.
- Creates a virtual “protection” bubble around vehicle.
- Operational in a mine-wide application
- Can be interfaced on multiple OEM machines
- Multiple miners and multiple pieces of equipment in the same working section

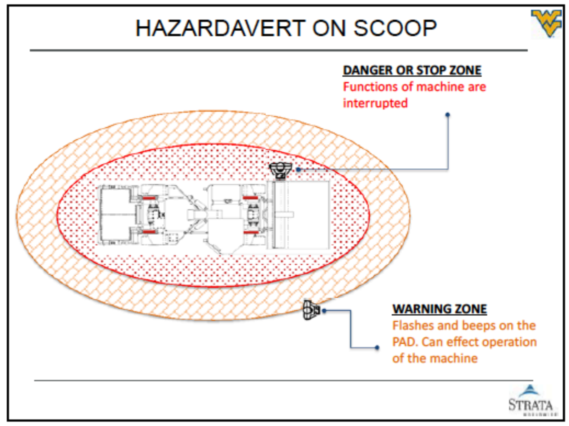
STRATA

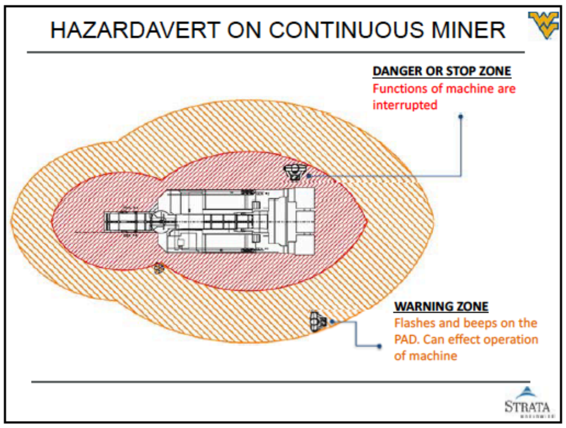
HAZARDAVERT SYSTEM OVERVIEW

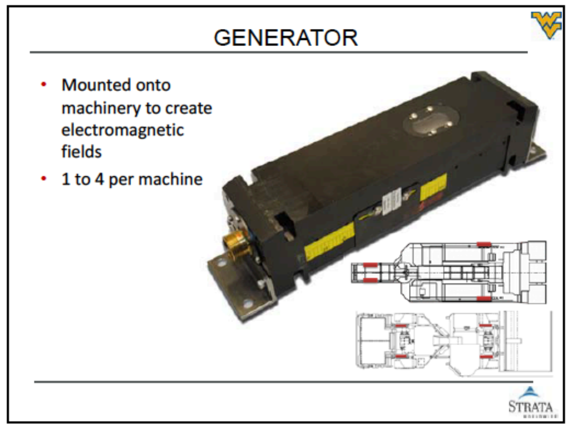


STRATA


HAZARDAVERT ON SCOOP
Controller Box
Magnetic Field Generator
CONTROL BOX
OPERATOR LOOP
Display POD
STRATA


HAZARDAVERT ON SCOOP
DANGER OR STOP ZONE
Functions of machine are interrupted
WARNING ZONE
Flashes and beeps on the PAD. Can effect operation of the machine
STRATA


HAZARDAVERT ON CONTINUOUS MINER
DANGER OR STOP ZONE
Functions of machine are interrupted
WARNING ZONE
Flashes and beeps on the PAD. Can effect operation of machine
STRATA

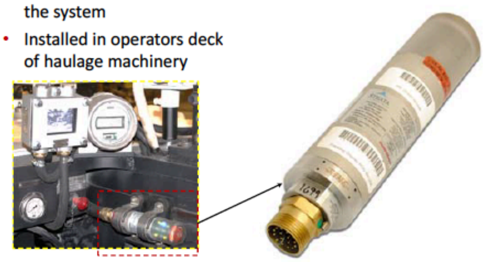

GENERATOR
• Mounted onto machinery to create electromagnetic fields
• 1 to 4 per machine
STRATA

QUICK CONNECT CABLING

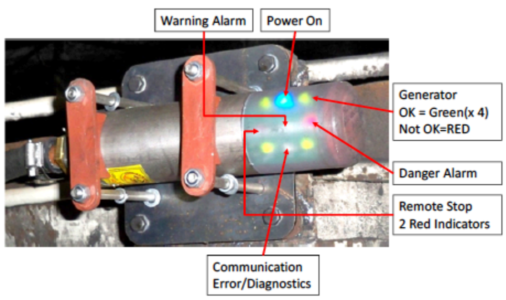
- Connects generators to central control box. Carries power and data.

DISPLAY POD

- Sequence of LEDs that show the operator the status of the system
- Installed in operators deck of haulage machinery

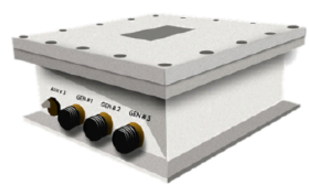


DISPLAY POD WITH INDICATORS



CONTROL BOX

- Holds the controller board
- Bulkheads for Quick Connect Cabling



PERSONAL ALARM DEVICE (PAD)

- Receives the signal from the generator
- Worn by personnel

Miner wearing HazardAvert PAD

REMOTE STOP: PRESSING ANY TWO BUTTONS SIMULTANEOUSLY WILL SHUTDOWN ANY EQUIPMENT RECEIVING SIGNAL

STRATA

SUMMARY OF SYSTEM OPERATION

- **Generators create a magnetic field around the vehicle**
- **Pad detects the magnetic field**
- **Warning signals or danger signals are given to pedestrian and operator:**
  - **Warning Zone (WZ): pad produces a brief series of 4 beeps and 4 led flashes. Scoop speed is reduced to low**
  - **Danger Zone (DZ): pad produces continuous beep and constant led. Hydraulic function is interrupted, tramming is interrupted, machine stops**

STRATA

PROXIMITY IN USE (VIDEO #2)

STRATA

CHECK-OUT STATION: HARDWARE

Overview of Checkout Station

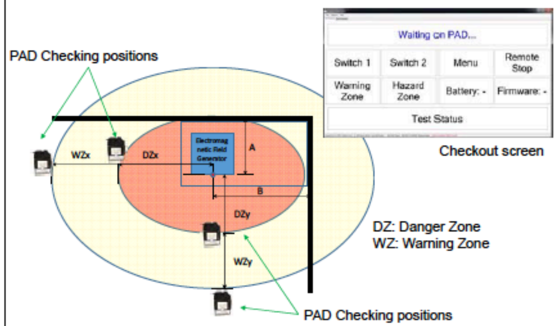
Charging Station for PADs

Magnetic Field Generator Box

STRATA

HAZARDAVERT PADS IN CHARGING STATIONS

CHECK-OUT STATION: SOFTWARE



OUTLINE

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CAMERA SYSTEMS

Readily available technology installed in different pieces of equipment to enhance the visibility of operators.

Provide enhanced visibility specially in blind spots.

Depending on the type of equipment, one or two cameras can be installed.

Different systems:
Low light cameras, Thermal cameras, Infrared cameras.

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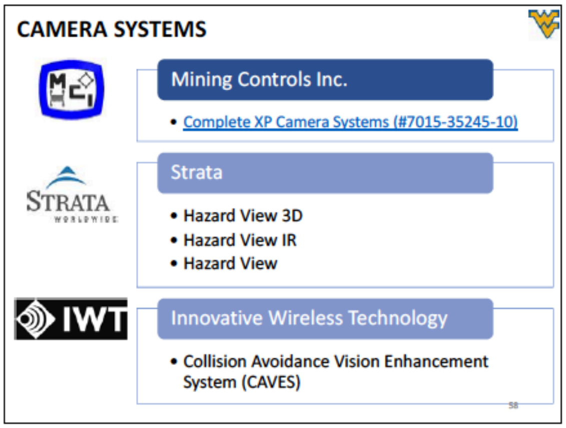
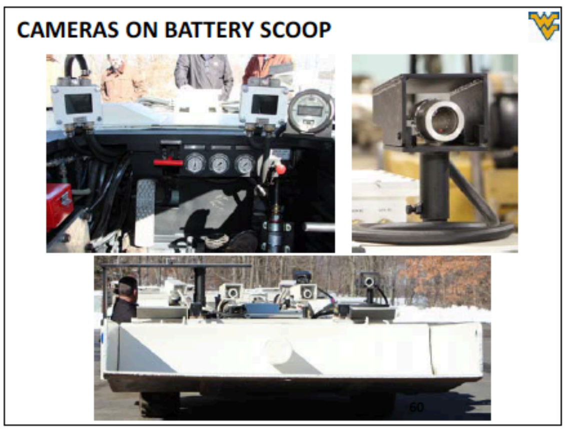
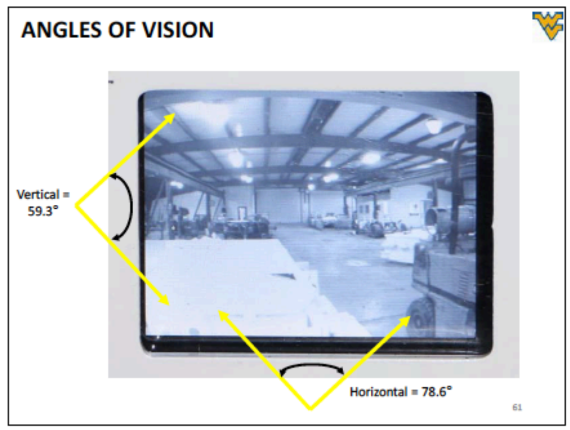
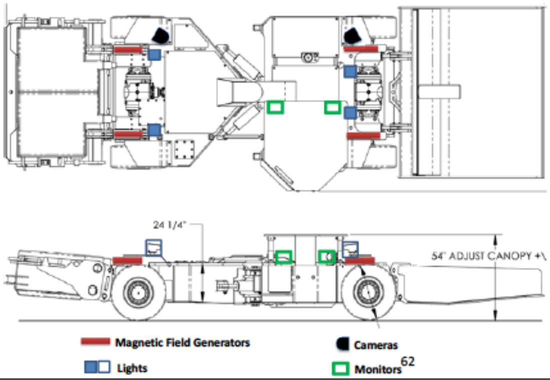

CAMERA SYSTEMS
Mining Controls Inc.
• Complete XP Camera Systems (#7015-35245-10)
STRATA WORLDWIDE
Strata
• Hazard View 3D
• Hazard View IR
• Hazard View
IWT
Innovative Wireless Technology
• Collision Avoidance Vision Enhancement System (CAVES)
58


CAMERAS ON SCOOP
- Two low light cameras
- Front and back
- Two monitors in operator's compartment
- Repositionable
- Angles of vision:
H = 78.6 deg.
V = 59.3 deg.
5.000
5.094
4.000
3.634
1 1/8" - 12 Threads
Typ. 2 Places
RESOLUTION = 600 TV LINES
AUTO GAIN & 10-BIT DSP
MIN. ILLUMINATION = 0.0003 Lux @ F1.2
IRIS CONTROL = AUTO
LENS = 3.6 mm
POWER = 12V DC @ 120mA
MODEL 35400 CERT. XP-3844-1
P/N 7015-35400-41
4" LCD Monitor With XP Enclosure
For One Camera
12V DC 0.400 AMPS.
59


CAMERAS ON BATTERY SCOOP
60


ANGLES OF VISION
Vertical = 59.3°
Horizontal = 78.6°
61

CAMERAS ON BATTERY SCOOP



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SUMMARY OF CAMERA SYSTEM

- Low-light cameras installed on scoop
- Installed in front and back of the scoop
- Two monitors in the operator's compartment
- Currently placed at standard positions on scoop
- Angles of vision:
  - Horizontal = 78.6°
  - Vertical = 59.3°
- Placed within protective cases
- No recording

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OUTLINE

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

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Safe Work Instructions (SWI) Typical Content

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Strata Recommended Pre Operational Check List

1. A visual inspection of all proximity hardware for signs of damage (If so please alert your Supervisor to take appropriate action).
2. Machine power ON
3. Communication Check
4. Turning on the Magnetic fields
5. Checking the Warning Zone
6. Checking the Danger Zone

STRATA

OUTLINE

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

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<u>REMEMBER</u>: The currently approved WV and Federal laws on the following topics will always take precedence over the slides in this presentation.

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Rules Governing Proximity Detection Systems and Haulage Safety Generally

West Virginia Board of Coal Mine Health and Safety

Tittle 37, Series 57

July 1, 2014

71

MSHA's Final Rule on Proximity Detection Systems for Continuous Mining Machines in Underground Coal Mines

Published January 15, 2015

http://www.msha.gov/regs/fedreg/final/2015/proximity-detection/

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WV vs. FEDERAL REGULATIONS

	West Virginia	Federal
Office	West Virginia Board of Coal Mine Health and Safety	Mine Safety and Health Administration - MSHA
Effective Date	July 1, 2014	March 16, 2015
Equipment Covered	- Continuous Miners - Scoops - Shuttle cars - Diesel-or battery-powered section haulage equipment	- Continuous Miners only
Compliance Dates	- January 1, 2015 for new CMMs - July 1, 2015 for rebuilt CMMs - July 1, 2017 for existing CMMs and other haulage equipment	- September 16, 2016 for New CMMs - March 16, 2018 for Old CMMs

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West Virginia vs. MSHA Requirements

MSHA's final rule is compatible with West Virginia's proximity detection requirements for continuous mining machines (CMM).

Compliance Dates

West Virginia	MSHA
• January 1, 2015 (6 months) for new CMMs • July 1, 2015 (12 months) for rebuilt CMMs • July 1, 2017 (36 months) for existing CMMs	• November 16, 2015 (8 months) for new CMMs • September 16, 2016 (18 months) for CMMs equipped with PDS • March 16, 2018 (36 months) for existing CMMs

Table presented by MSHA at the 42nd, WVCA Coal Mining Symposium, January 28-30, 2015

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Stopping Machine, Warnings, and Signals

West Virginia	MSHA
• Stop the equipment at intervals established for the mine to prevent contact. • Provide an audible or visual warning.	• Stop before contacting a miner. • Provide an audible and visual warning on the miner-wearable component and a visual warning on the machine. • Provide a visual signal on the machine that indicates the machine-mounted components are functioning properly.
• Prevent movement if the system is not functioning properly. • Movement is permitted to relocate the equipment from an unsafe location during malfunction for repair or emergencies.	• Prevent movement if the system is not functioning properly. • Allows movement if the system provides an audible or visual warning signal as the machine is relocated from an unsafe location for repairs.
• Install PDS and maintain by a trained person.	• Install PDS and maintain by a trained person.

Table presented by MSHA at the 42nd, WVCA Coal Mining Symposium, January 28-30, 2015

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Checking

West Virginia	MSHA
• Test machine-mounted and miner-wearable components at the beginning of each shift or prior to any initial operation.	• Check machine-mounted components to verify that they are intact, functioning properly and take action to correct defects— • At the beginning of each shift • Immediately prior to operation • Within 1 hour of a shift change • Check miner-wearable components at the beginning of each shift.

Recordkeeping

West Virginia	MSHA
• Record malfunctions and corrections.	• A Certified person must record initials, date, and time of the check, defects and corrective actions.

Table presented by MSHA at the 42nd, WVCA Coal Mining Symposium, January 28-30, 2015

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MSHA Approved Proximity Detection Systems

- The following systems have been approved by MSHA to meet the "permissibility" requirements in Title 30 CFR Part 18.
  - Strata Mining Products HazardAvert® System
  - Nautilus
  - Matrix Design Group, Gen 1
  - Matrix Design Group, Gen 2

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END OF MODULE I

1. Objective and Learning Outcomes
2. Selection of Equipment
3. MSHA Recommended Safety Practices
4. Examples of Accidents
5. Proximity Detection Systems (PDS)
6. Camera Systems
7. Safe Work Instructions (SWI)
8. WV Regulations and Federal Regulations

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Appendix 3-B. Instructional Materials for Hands-on Session

ENHANCED MOBILE EQUIPMENT EXPERIENTIAL LEARNING AND SAFETY TECHNOLOGY DEMONSTRATION

MODULE II

Hands-on Session in Simulated Mine

B. Statler College of Engineering and Mineral Resources
Department of Mining and Industrial Extension
West Virginia University

ACKNOWLEDGMENTS AND DISCLAIMERS

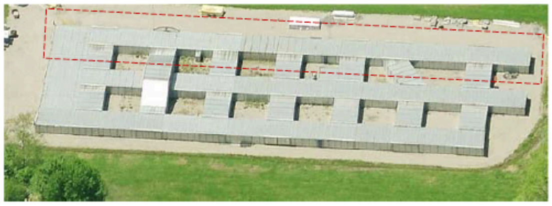
- The following training material was developed and/or compiled by the Department of Mining and Industrial Extension at West Virginia University (WVU).
- The authors wish to acknowledge the Alpha Foundation for the Improvement of Mine Safety and Health as funding source.
- The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the Alpha Foundation, its Directors and staff.
- Any mention of company or product does not constitute an endorsement of the Alpha Foundation or WVU.

OUTLINE OF MODULE II

1. Objective of Module II

Experience different scenarios of reduced visibility combined with use of proximity detection system and cameras installed on a battery-powered scoop.

2. Simulated Mine



- Demonstration in main entry #1

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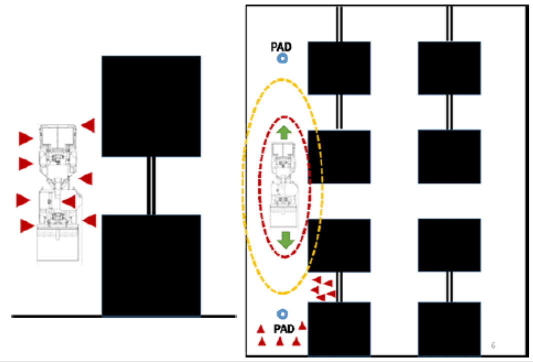
3. Position of Scoop in Simulated Mine



6

4. Scoop operator's compartment

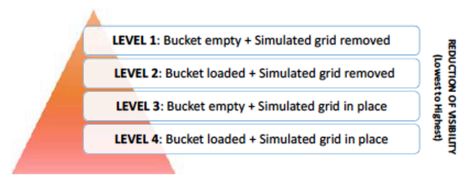
START WITH SIMULATED PROTECTIVE GRID

FINISH WITHOUT PROTECTIVE GRID

7

5. Reduction of Visibility

VISUAL OBSTACLES ↓ →	Scoop without simulated operator's guard	Scoop with simulated operator's guard
Bucket unloaded	X	X
Bucket loaded	X	X



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6. Summary of Experiential Learning

Training Main Objective: Experience different scenarios of reduced visibility combined with use of proximity detection system and cameras installed on a battery-powered scoop.

Exercise #	Sub-Objective(s)	Procedure(s)/Setup	Duration
#1	○ Identify new components on scoop (PDS and Cameras)	○ Instructors show PDS/Cameras components installed on scoop: generators, controller box, POD, cameras and monitors	10-15 min
#2	○ Experience the functionality of PDS	○ Cameras ON, PDS ON ○ Cockpit with simulated protective grid installed ○ Scoop bucket loaded ○ Participants standing in a crosscut	20 min
#3	○ Experience reduced visibility when visual obstructions are in the bucket	○ Cameras ON, PDS OFF ○ Cockpit with simulated protective grid in place and then removed ○ Scoop bucket loaded ○ One group member (driver) sitting in the cabin while other group members walk around the scoop	20 min

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7. Exit Questionnaires

In order to assess the effectiveness of this pilot training we need your feedback.

Level 1: Participant Reaction
Level 2: Perceived Learning

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APPENDIX 4. QUESTIONNAIRES

LEVEL 1: PARTICIPANT REACTION

1. How useful was the content of the classroom session to the work you currently perform?	Not useful Useful Very useful
2. How was the quality of the topics presented in the classroom session?	Not good Good Excellent
3. Were the instructors familiarized with the topics presented in the classroom session?	No Yes
4. Were the videos useful to enhance some of the topics presented in the classroom session?	No Yes
5. Were the hands-on exercises useful to complement the content presented during the classroom session?	No Yes
6. How relevant was the content of the hands-on session to the work you currently perform?	Not relevant Relevant Very relevant
7. How was the quality of the exercises implemented in the hands-on session?	Not good Good Excellent
8. Were the instructors knowledgeable of the material presented in the hands-on session?	No Yes
9. Were the instructors responsive to questions that arose during both sessions?	No Yes
10. Do you feel that the time for each session was sufficient?	No Yes
11. Was the sequence of presentation of training materials appropriate?	No Yes
12. What did you <u>like best</u> about this pilot training?	The topics of the classroom session The exercises of the hands-on session The entire training
13. What did you <u>dislike</u> about this pilot training?	The classroom session The hands-on session The entire training Other:__________
14. What other topics would you like us to include in the contents of the classroom session?	More about MSHA's best practices More about proximity detection or cameras More about regulations More about __________
15. What other topics or exercises would you like us to include in the contents of the hands-on session?	More reduced visibility exercises More about scoop operation Other positions of the scoop in the crosscut More about __________
16. What was your overall impression of this proposed pilot training?	Not good Good Excellent

LEVEL 2: PERCEIVED LEARNING

1.	What have you learned in this pilot training that you did not know when you walked in the door?	About proximity detection and camera systems About the limited visibility when operating a scoop About MSHA's best practices for haulage equipment About WV regulations on proximity detection systems About all the topics listed above
2.	What is the most valuable thing that you have learned?	Risk of accidents because of lack of visibility Availability of technology for proximity detection Limitations on the visibility of scoop operators Limitations of the proximity detection technology
3.	Will you use the information you learned in this training to implement changes in your work?	Yes To some extent No
4.	If yes, what changes will you implement?	Increment my personal alertness about working around scoops or other haulage equipment Share the knowledge acquired here with my fellow miners Suggest to my coworkers taking this training
5.	The following technology creates the warning and danger zones:	The camera system The proximity detection system The hydraulic system
6.	When a miner approaches the danger zone of a scoop equipped with an active proximity detection system, the machine will:	Continue moving Reduce its tramming speed Stop immediately
7.	In a scoop equipped with a camera system, can the scoop operator always see who is working around the machine?	No Often Yes, always
8.	Considering the exercises performed in the simulated mine, which level of reduction of visibility was the most challenging for you as a miner walking around the scoop?	Level 1: Bucket unloaded + operator's guard removed Level 2: Bucket loaded + operator's guard removed Level 3: Bucket unloaded + operator's guard in place Level 4: Bucket loaded + operator's guard in place
9.	Also, as a scoop driver, can you estimate the percentage of how much your visibility is reduced by the presence of protective guard?	About 10% About 25% About 50% About 75%
10.	Do you feel that the inclusion of proximity detections systems or cameras in haulage equipment can improve the safety of miners working near that machinery?	No Often Yes, always
11.	MSHA recommends that a miner would never position himself in an area or location where equipment operator cannot readily see him.	True False
12.	Pre-operational checks of proximity detection and camera systems are:	Required by the law Important for proper functionality while working Part of the Safe Work Instructions All of the above None of the above

Additional Suggestions, Observations or Comments:

____

____

____

____

____

DEMOGRAPHIC INFORMATION

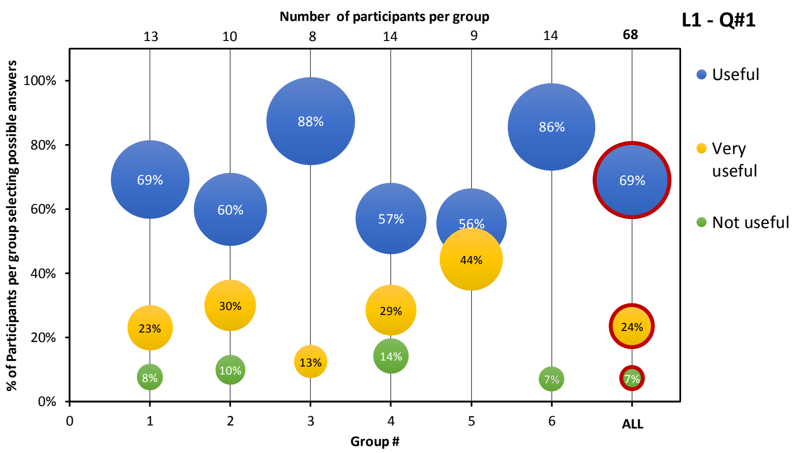
1. What's your age?	18-24 25-34 35-44 45-54 55-64 65 and older
2. How many years have you worked in the mining industry?	Less than 1 year Between 1 and 5 years Between 5 and 10 years Between 10 and 20 years More than 20 years
3. What is the highest degree or level of education you have completed?	Less than high school High school graduate (includes equivalency) Some college, no degree Associate's degree Bachelor's degree Graduate or professional degree Ph.D., Law or Medical Degree

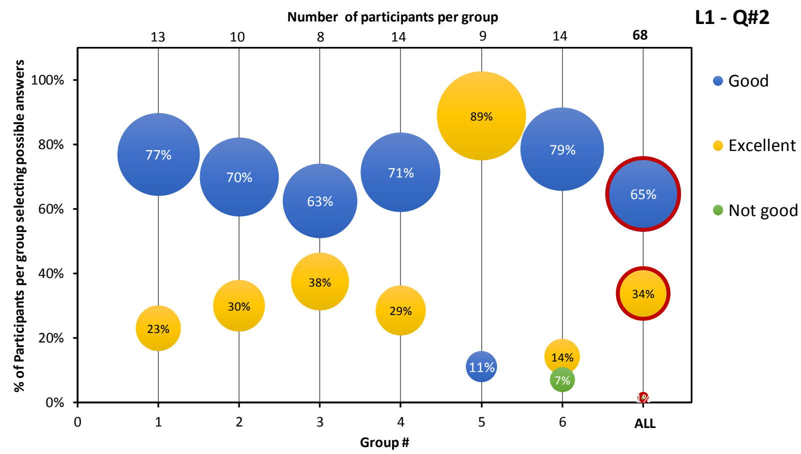
APPENDIX 5. RESPONSES TO QUESTIONNAIRES

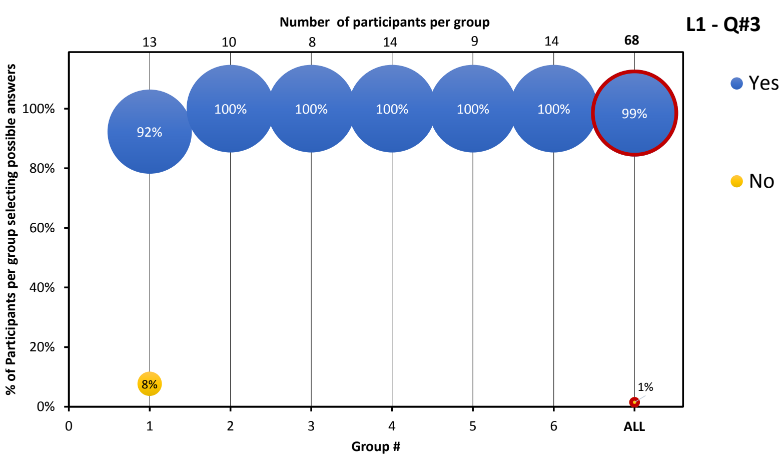
Level 1. Participant Reaction. Responses per group.

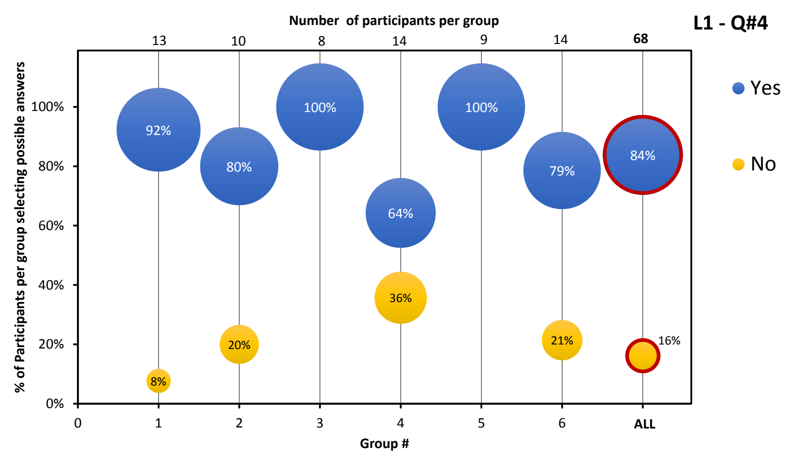
	Questions	Multiple Choice Answers	Group #							Categ.
			1	2	3	4	5	6	All	
			Number of Participants per Group (n)							
			13	10	8	14	9	14	68	
1	How useful was the content of the classroom session to the work you currently perform?	Not useful	8%	10%	0%	14%	0%	7%	7%	Classroom Session
		Useful	69%	60%	88%	57%	56%	86%	69%	
		Very useful	23%	30%	13%	29%	44%	7%	24%	
2	How was the quality of the materials presented in the classroom session?	Not good	0%	0%	0%	0%	0%	7%	1%	
		Good	77%	70%	63%	71%	11%	79%	65%	
		Excellent	23%	30%	38%	29%	89%	14%	34%	
3	Were the instructors familiar with the material presented in the classroom session?	No	8%	0%	0%	0%	0%	0%	1%	
		Yes	92%	100%	100%	100%	100%	100%	99%	
4	Were the videos useful to enhance some of the topics presented in the classroom session?	No	8%	20%	0%	36%	0%	21%	16%	
		Yes	92%	80%	100%	64%	100%	79%	84%	
5	Were the hands-on exercises useful to complement the content presented during the classroom session?	No	8%	0%	0%	0%	0%	0%	1%	Hands-on Session
		Yes	92%	100%	100%	100%	100%	100%	99%	
6	How relevant was the content of the hands-on session to the work you currently perform?	Not relevant	8%	10%	0%	7%	11%	14%	9%	
		Relevant	54%	50%	75%	64%	33%	86%	62%	
		Very relevant	38%	40%	25%	29%	56%	0%	29%	
7	How was the quality of the exercises implemented in the hands-on session?	Not good	0%	0%	0%	0%	0%	7%	1%	
		Good	77%	50%	63%	64%	11%	86%	62%	
		Excellent	23%	50%	38%	36%	89%	7%	37%	
8	Were the instructors knowledgeable of the material presented in the hands-on session?	No	8%	0%	0%	0%	0%	21%	6%	
		Yes	92%	100%	100%	100%	100%	79%	94%	
9	Were the instructors responsive to questions that arose during both sessions?	No	0%	0%	0%	0%	0%	7%	1%	Class Preparedness
		Yes	100%	100%	100%	100%	100%	93%	99%	
10	Do you feel that the time for each session was sufficient?	No	0%	0%	0%	7%	11%	0%	3%	
		Yes	100%	100%	100%	93%	89%	100%	97%	
11	Was the sequence of presentation of training materials appropriate?	No	0%	0%	0%	0%	0%	7%	1%	
		Yes	100%	100%	100%	100%	100%	93%	99%	
12	What did you like best about this pilot training?	The topics of the classroom session	8%	10%	0%	0%	0%	15%	6%	Trainee/Student Satisfaction
		The exercises of the hands-on session	46%	80%	75%	64%	67%	77%	67%	
		The whole training	46%	10%	25%	36%	33%	8%	27%	
13	What did you dislike about this pilot training?	The topics of the classroom session	50%	100%	75%	90%	50%	58%	68%	
		The exercises of the hands-on session	10%	0%	25%	10%	0%	8%	8%	
		The whole training	40%	0%	0%	0%	0%	8%	10%	
		Other	0%	0%	0%	0%	50%	25%	14%	
14	What other topics would you like us to include in the contents of the classroom session?	More about MSHA's best practices	20%	13%	14%	0%	11%	18%	12%	Future Topics/Exercises
		More about proximity detection or cameras	60%	50%	14%	64%	44%	36%	47%	
		More about regulations	20%	38%	43%	29%	11%	27%	27%	
		More about: Other	0%	0%	29%	7%	33%	18%	14%	
15	What other topics or exercises would you like us to include in the contents of the hands-on session?	More reduced visibility exercises	60%	43%	57%	59%	33%	31%	48%	
		More about scoop operation	20%	0%	14%	6%	22%	23%	14%	
		Other positions of the scoop in the mine	20%	43%	29%	35%	33%	31%	32%	
		More about: Other	0%	14%	0%	0%	11%	15%	6%	
16	What was your overall impression of the training?	Not good	0%	0%	0%	14%	0%	14%	6%	Impre ssion
		Good	62%	80%	75%	64%	33%	79%	66%	
		Excellent	38%	20%	25%	21%	67%	7%	28%	

Level 1. Participant Reaction. Responses per group.

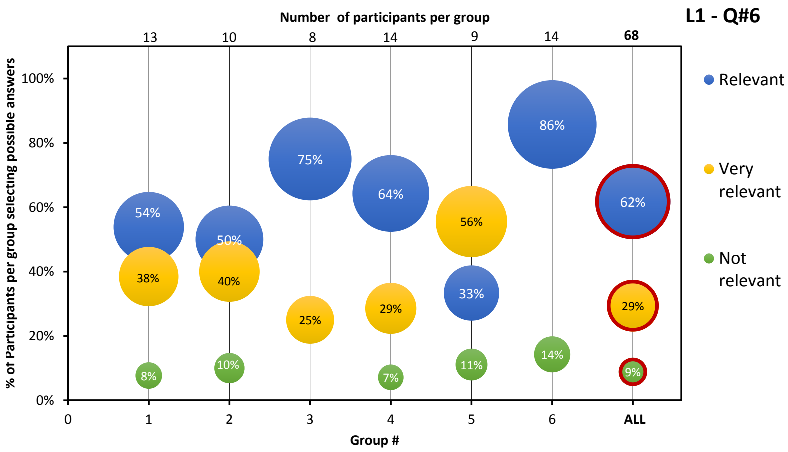


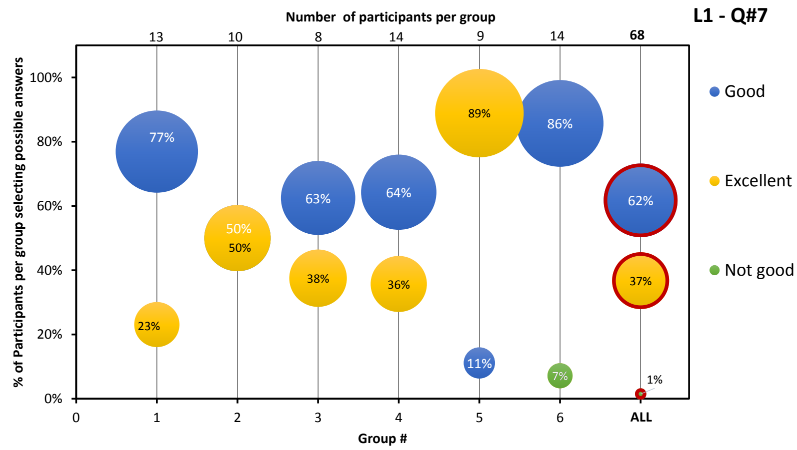


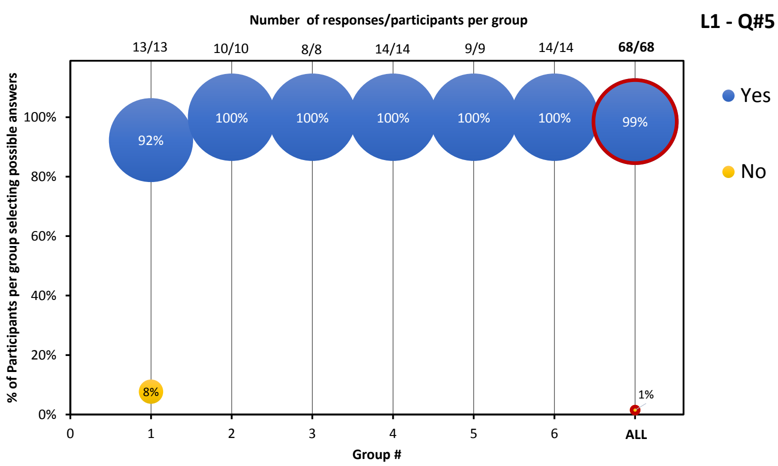


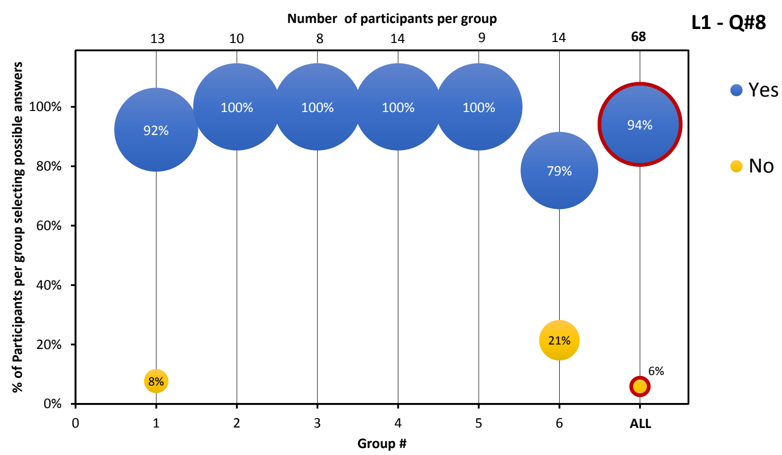


Level 1. Participant Reaction. Responses per group.

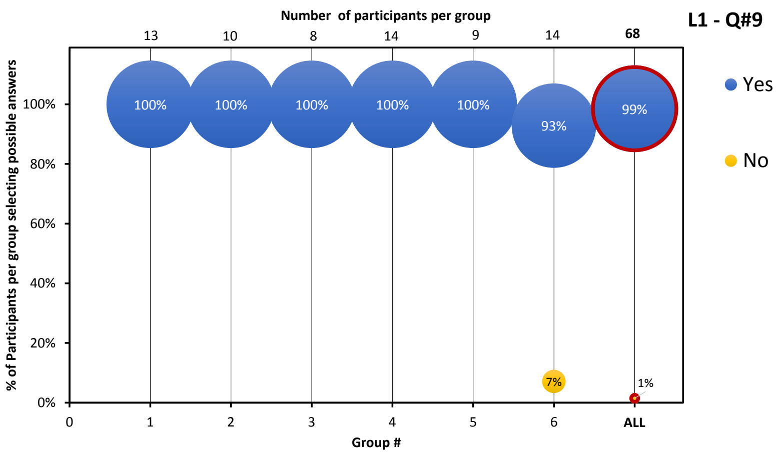


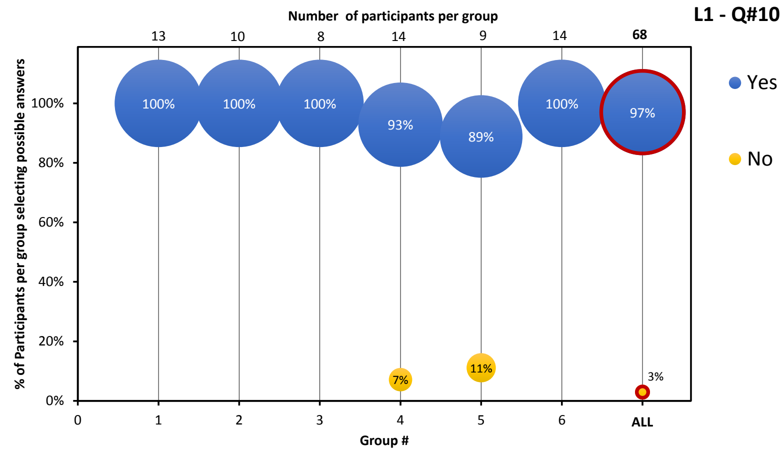


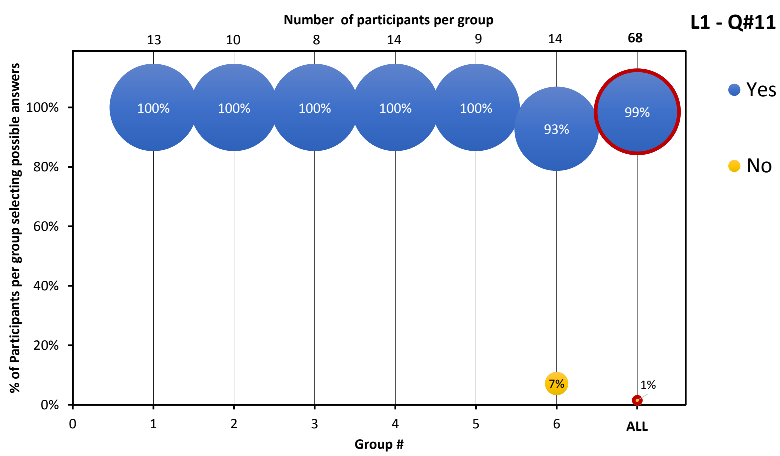


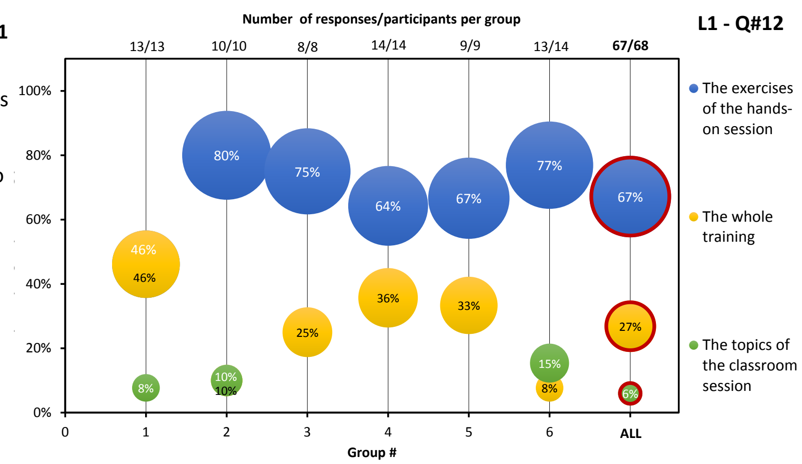


Level 1. Participant Reaction. Responses per group.

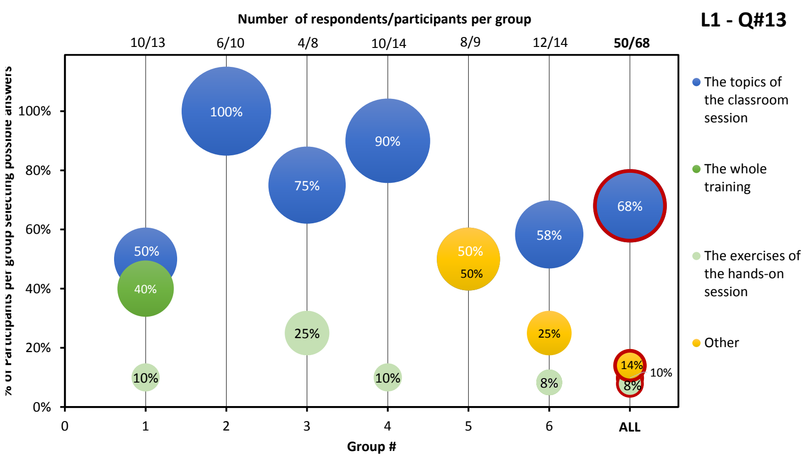


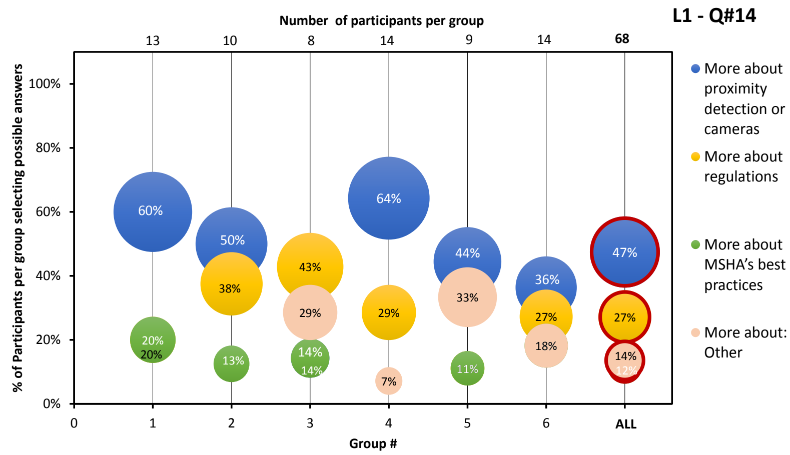


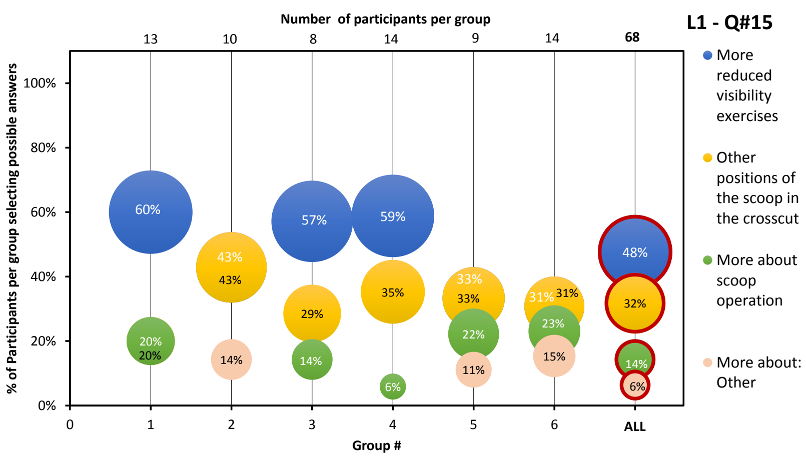


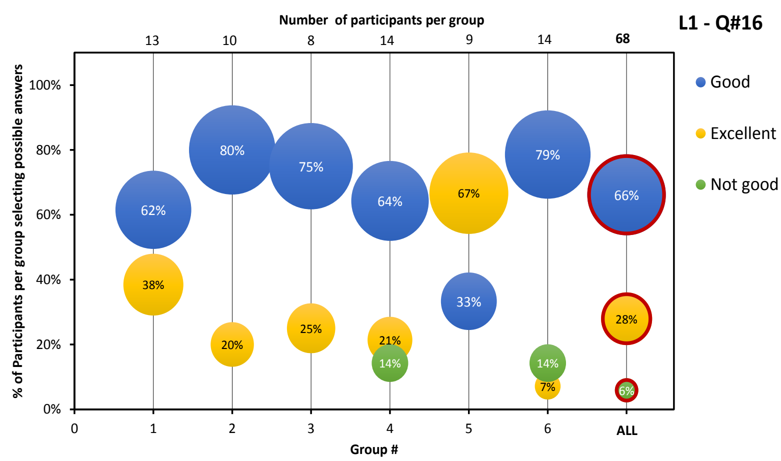


Level 1. Participant Reaction. Responses per group.









Level 2. Perceived Learning. Responses per group.

	Questions	Multiple Choice Answers	Group # 1	2	3	4	5	6	ALL	Categ.
			Number of Participants per Group (n)							
			13	10	8	14	9	14	68	
1	What have you learned in this pilot training that you did not know when you walked in the door?	About proximity detection and camera systems	44%	43%	20%	33%	17%	14%	30%	Changes in knowledge
		About the limited visibility when operating a scoop	13%	0%	10%	0%	0%	0%	4%	
		About MSHA's best practices for haulage equipment	19%	14%	10%	0%	17%	7%	11%	
		About WV regulations on proximity detection systems	6%	21%	50%	13%	25%	71%	30%	
		About all the topics listed above	19%	21%	10%	53%	42%	7%	26%	
2	What is the most valuable thing you have learned today?	Risk of accidents because of lack of visibility	38%	31%	38%	27%	22%	20%	29%	
		Availability of technology for proximity detection	23%	46%	38%	20%	67%	40%	37%	
		Limitations on the visibility of scoop operators	8%	15%	13%	0%	0%	0%	5%	
		Limitations of the proximity detection technology	31%	8%	13%	53%	11%	40%	29%	
5	The following technology creates the warning and danger zones:	The cameras installed in the scoop	17%	33%	11%	29%	10%	7%	19%	Demonstrated Understanding
		The proximity detection system installed in the scoop	58%	60%	78%	65%	90%	79%	70%	
		The hydraulic system of the scoop	25%	7%	11%	6%	0%	14%	10%	
6	When a miner approaches the danger zone of a scoop equipped with an active proximity detection system, the machine will:	Continue moving	0%	8%	0%	0%	0%	0%	1%	
		Reduce its tramming speed	46%	42%	25%	21%	33%	15%	30%	
		Stop immediately	54%	50%	75%	79%	67%	85%	68%	
7	In a scoop equipped with a camera system, can the scoop operator always see who is working around the machine?	No	77%	60%	88%	36%	44%	64%	60%	
		Often	23%	30%	13%	64%	56%	36%	38%	
		Yes, always	0%	10%	0%	0%	0%	0%	1%	
8	Considering the exercises performed in the simulated mine, which level of reduction of visibility was the most challenging for you as a miner walking around the scoop?	Level 1: Bucket unloaded + operator's guard removed	18%	0%	0%	0%	0%	0%	3%	
		Level 2: Bucket loaded + operator's guard removed	18%	0%	25%	0%	13%	21%	12%	
		Level 3: Bucket unloaded + operator's guard in place	45%	0%	25%	0%	0%	0%	11%	
		Level 4: Bucket loaded + operator's guard in place	18%	100 %	50%	100 %	88%	79%	74%	
9	Also, as a scoop driver, can you estimate the percentage of how much your visibility is reduced by the presence of the simulated protective guard?	About 10%	0%	0%	13%	14%	25%	7%	9%	
		About 25%	15%	20%	25%	43%	63%	14%	28%	
		About 50%	38%	60%	63%	29%	13%	43%	40%	
		About 75%	46%	20%	0%	14%	0%	36%	22%	
11	MSHA recommends that a miner would never position himself in an area or location where equipment operator cannot readily see him.	TRUE	92%	90%	75%	86%	100 %	93%	90%	
		FALSE	8%	10%	25%	14%	0%	7%	10%	
12	Pre-operational checks of proximity detection and camera systems are:	Required by law	8%	8%	13%	0%	11%	21%	10%	
		Important for proper functionality while working	0%	17%	0%	0%	11%	14%	7%	
		Part of the Safe Work Instructions	15%	8%	0%	0%	0%	14%	7%	
		All of the above	77%	58%	88%	100 %	78%	50%	74%	
		None of the above	0%	8%	0%	0%	0%	0%	1%	
3	Will you use the information you learned in this training to implement changes in your work?	Yes	54%	30%	38%	21%	56%	29%	37%	Changes in attitude, behavioral intent
		To some extent	38%	70%	63%	71%	22%	43%	51%	
		No	8%	0%	0%	7%	22%	29%	12%	
4	If yes, what changes will you implement?	Increment my personal alertness about working around scoops or other haulage equipment	30%	22%	25%	27%	43%	11%	28%	
		Share the knowledge acquired here with my fellow miners	60%	78%	50%	60%	36%	89%	60%	
		Suggest my coworkers taking this training course	10%	0%	25%	13%	21%	0%	12%	
10	Do you feel that the inclusion of proximity detections systems or cameras in haulage equipment can improve the safety of miners working near that machinery?	No	23%	0%	0%	0%	0%	7%	6%	
		Often	46%	50%	38%	64%	30%	71%	52%	
		Yes, always	31%	50%	63%	36%	70%	21%	42%	

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