A VR-BASED TRAINING PROGRAM FOR CONVEYOR BELT SAFETY

SUBMITTED: June 2007
REVISED: January 2008
PUBLISHED: July 2008
EDITOR: B-C Björk

Jason Lucas, Graduate Research Assistant,
Department of Building Construction, Virginia Tech, Blacksburg, Virginia, USA;
jlucas06@vt.edu

Walid Thabet, Associate Professor,
Department of Building Construction, Virginia Tech, Blacksburg, Virginia, USA;
thabet@vt.edu

Poonam Worlikar, Graduate Research Assistant,
Department of Building Construction, Virginia Tech, Blacksburg, Virginia, USA;
worlikar@vt.edu

SUMMARY: *The mining industry is characterized by the need for high volume of production which has forced its adoption of large and fast moving equipment for transporting bulk material. Belt conveyors have attained a dominant position in transferring material due to such inherent advantages as their economy of operation, reliability, versatility, and practically unlimited range of capabilities. With all of these factors comes an inherent danger. From 1995 to 2007 there have been a total of 534 equipment related fatal accidents in the United States as recorded by the Mine Safety and Health Administration, 50 of which are conveyor belt related. Most accidents around belt conveyors are caused by human error, improper maintenance procedures, lack of effective training or lack of awareness of possible hazards.*

To counteract this high number of accidents, virtual reality (VR) is being looked at as an alternative to current safety training programs. The structure and program being proposed consists of 4 steps in creating a two phased program. This paper discusses the step by step structure of creating a safety training program for belt conveyors and the first phase of implantation of the program. The first phase includes an instructional-based phase that allows for the presentation of the information compiled for the areas of training that were determined within the structure of the program. This paper will discuss the framework used in developing the VR safety training application, the first phase of the prototype development, how the data has been retrieved and organized, and how industry feedback was gathered and used to develop the application.

KEYWORDS*: virtual reality, safety training, conveyor belts*

1. INTRODUCTION

The mining industry is characterized by the need for high volume of production which has forced its adoption of large and fast moving equipment for transporting bulk material. Belt conveyors have attained a dominant position in transferring material due to such inherent advantages as their economy of operation, reliability, versatility, and practically unlimited range of capabilities.

Belt conveyors come in various configurations; however, the basic components of the conveyors are the same. They can be level or inclined and are usually set up in a series of multiple conveyor runs. With the basic operation of a belt conveyor, the material is loaded onto the belt near a tail pulley and unloaded near a head pulley (or drive end). Between the head and tail pulleys are a series of idlers and pulleys to keep the tension and alignment of the belt and to help prevent excessive wear (Fig. 1). Belt conveyors run continuously without loss of time for the loading and unloading, scheduling, and dispatching that haul trucks and other equipment require. They typically run at 600 feet per minute and only need to be stopped for maintenance. Belt conveyors also often offer the lowest transport, maintenance, power, and labor cost per ton of material moved with a larger capacity to operation time ratio than other material moving equipment (Swinderman 2002).

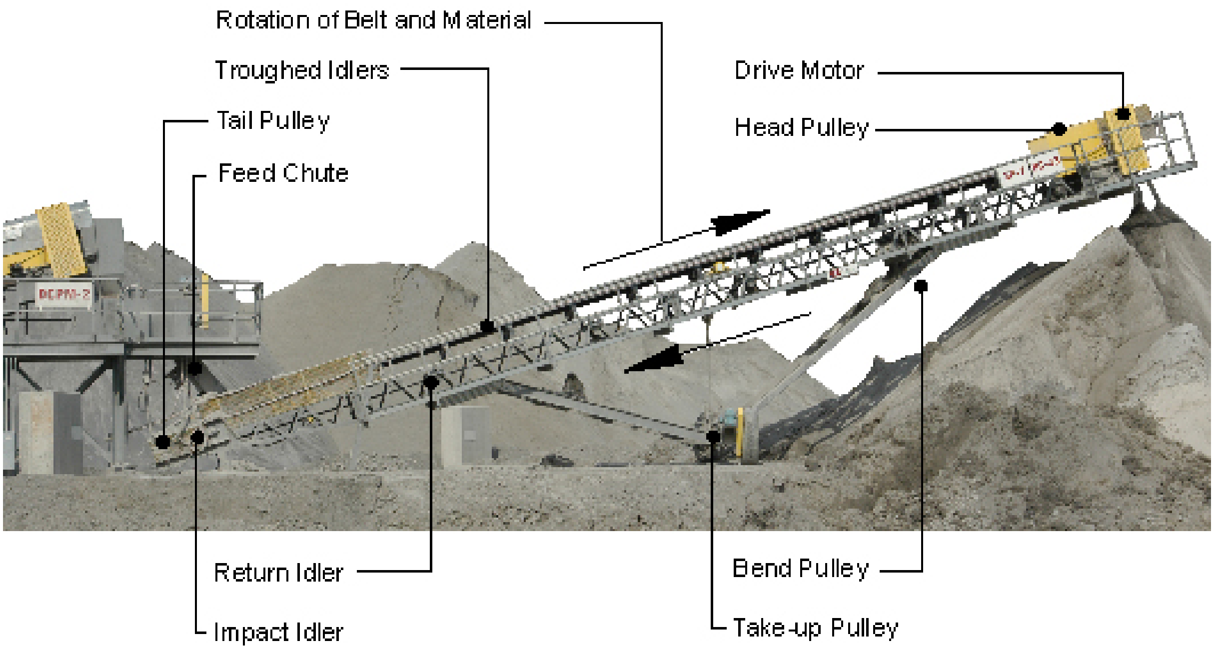


Fig. 1: Conveyor Belt Components.

By their very nature, belt conveyors are inherently dangerous as a work environment. Due to the continuous moving parts and high rate of materials transported, the forces applied by conveyor belts are significant and potentially dangerous. Conveyors also feature many “pinch” points with large amounts of mechanical energy. As the name suggests, pinch points form areas between the moving conveyor parts (e.g. cylinders) and belt where miners can get entangled or pulled during performing maintenance tasks. As a result, they have a high rate of injury. Nevertheless, belt conveyors have become “part of the landscape; they are not seen as hazards, but rather as a fact of life” (Goldbeck, 2003). It is imperative to be aware of the power of a conveyor while performing operations and maintenance as it has potential to injure or kill an untrained or unaware individual.

Most of the accidents around belt conveyors are caused by human error, improper maintenance procedures, lack of effective training or lack of awareness of possible hazards. In the Code of Federal Regulations (CFR) Part 46 and 48, the Mine Safety and Health Administration of the United States Department of Labor (MSHA) require training for all miners (Goldbeck, 2003). Newly trained workers must receive 24 hrs of specified training. An additional 8 hrs of refresher training is specified each 12 months. No specific training on belt conveyors is mentioned. Based on the number of conveyor related accidents and fatalities (MSHA 2007), it is evident that current required training that are based on standard audio-visual methods, are not achieving their goal. More rigorous and structured training programs oriented towards identifying conveyor belts’ problems and hazards need to be devised and implemented. Virtual reality (VR) provides the opportunity to develop interactive virtual training applications that are comparable to real life simulations but could be more cost effective. Interactive VR applications designed for safety training can provide better cognitive learning tools by allowing trainees to actively participate and experience in near-reality sense the hazards associated with working around conveyor belts and to virtually practice performing tasks without the dangers of a working belt. A large amount of scholarly work investigating the use of VR for safety training exists (Delabbio, et. al. 2007, Ruff, 2001, Stothard, et. al., 2004, Orr, et. al., in press, Schafrik, et. al., 2003, Hollands, et. al., 2002, and Dezelic, et. al., 2005). However, no published work was found that explores the benefits of VR to improve safety training of conveyor belts.

A VR-based training program is proposed for safety training around belt conveyors. The proposed program comprises of two interactive phases; an instructional-based phase, and a task-based phase. The instructional-based phase is a guided walkthrough simulation intended to familiarize the trainee with the working environment around a conveyor belt, the conveyor belt components, and to alert the user of the maintenance tasks and related hazards of the moving components. The second phase of the study involves task-based training. Simulations of various problem scenarios will be developed to test the user’s ability on resolving problems while immersed in the VR environment. Information related to the task can be accessed from within the simulation and the trainee’s ability to identify and remedy risks can be quantified. Consequences of poor decision-making or risk-taking behaviours while interacting with the environment will be demonstrated to the user. Quantifying the trainee’s ability to identify and remedy risks will allow for enhancing the cognitive learning process of users and help track the effectiveness of the training program. The goals of the research is to offer a VR application that train the user at their own pace through first person interactions while tracking their process and performance while giving them direct consequences to actions taken and finally to offer an aid to the industry that they would view as a valuable supplement to current training material.

This paper discusses the requirements of the proposed training program and presents in detail the steps that are being suggested to use in order to develop a comprehensive training program as well as the developed instructional-based phase of the prototype. Needed data on belt components, maintenance and safety issues were acquired through site visits, examination of documented case studies, and literature on current training practices. A digital 3D model of a conveyor belt is created from images taken during various site visits and from manufactures' catalogues. The 3D model was developed using Autodesk's AutoCAD™ and 3D Studio MAX™. The model was imported into Right Hemisphere's Deep Creator ™ and linked to safety training data to develop the instructional-based prototype. Interviews with industry professionals involved in the operation and maintenance of belt conveyors is used to provide feedback on the prototype development and to revise the prototype for its completeness and accuracy. The limitations of this research are recognized as a VR program can only offer a supplement for advanced training before on-the-job training and that it can not fully replace the experience gained through one-on-one interaction with an expert who works within the real environment day in and day out. The intention of this research is to not replace all other training, but to add a valuable aid to supplement current training practices.

2. EXISTING CONDITIONS

2.1 CONVEYOR BELT ACCIDENT ANALYSIS

Between 1995-2007 there have been a total of 534 fatal accidents in the surface mining that are equipment related, out of which 50 cases were associated with conveyor belts (MSHA, 2007). We analysed the 50 cases to identify the reasons for the accidents, and determine the type of maintenance tasks performed and their location around the belt when the accident occurred. A summary review of our analysis is provided in Table 3 in appendix A. The 50 reported injuries were grouped into four categories based on the cause of the accident; entanglement, collapse of structure, belt components or loose material (suffocating or crushing the victim), falling from heights, and miscellaneous. Within each accident category, we identified the type of maintenance task that was being performed when the accident occurred, and the belt assembly that contributed to the fatal injury. Figure 2 provides a summary statistical analysis of the 50 cases showing distribution by accident category, by maintenance task category being performed while the accident occurred, by critical belt assembly contributing to the accident, and by year the accident occurred.

Analysis results by accident category (Fig. 2b) show that the most common reported cause of accident around conveyors is due to entanglement between the victim's body parts, or his tools (e.g. shovels) and the conveyor assembly. This accounted for 28 (56%) of the 50 fatalities reported. Few of the entanglement incidents occurred due ignoring proper work attire. A second critical cause of fatal accidents included collapse of structures, belt assembly, or loose material falling off the conveyor, either crushing, or suffocating the victim. This contributed to a total of 12 fatalities (24%). Falling from height mainly off the elevated structures along the conveyor, or while crossing the conveyor where there is no crosswalk, resulted into 5 fatalities (10%). Other various reasons contributed to 5 fatalities (10%). Theses included burning, run over by service equipment and victim being crushed by belt assembly.

Four categories of maintenance tasks were identified from the cases:

- Cleaning around and under the belt and equipment to remove spilled debris accumulated on belt components or built-up on the floor under the belt. Cleaning was frequently done using small tools (e.g. shovel) or sometimes by hand.
- Installation and repair. This involved maintenance work for installing new or repair existing parts of the belt assembly (e.g. replace broken chain for belt drive motor) or the surrounding structure.
- Belt alignment
- Other. This included miscellaneous maintenance tasks such as inspection work, maintenance of large service equipment (e.g. loader) near the belt, and material sampling.

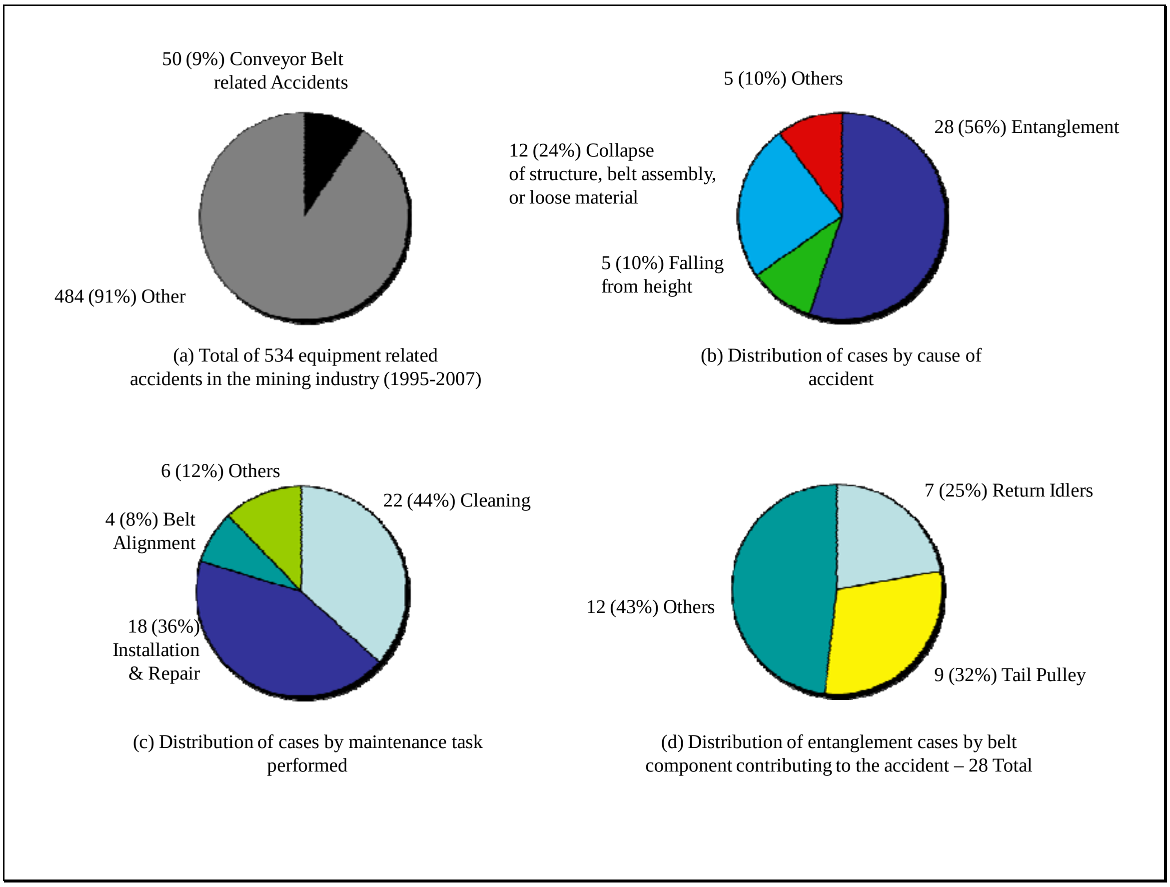


Fig. 2: Statistical analysis of belt-related fatal accidents reported by MSHA between 1995-2007

Distribution of accidents by maintenance task category (Fig. 2c) indicated that cleaning of spillage and debris on and around the energized belt was the highest reported work performed when the accident occurred – 22 of the 50 accidents reported or 44%. Of these 22 accidents, 14 (73%) were a result of entanglement, and 7 (27%) occurred due to falling loose material and components crushing or suffocating the victim. Maintenance work involving installation and repair of the belt assembly or the surrounding structure contributed to 18 of 49 fatal accidents (36%). Four accidents (8%) occurred during maintenance work involving belt alignment. The remaining 6 out of 49 accidents (12%) occurred during performing other miscellaneous tasks.

Fatal accidents due to entanglement were analyzed to determine critical belt component contributing to the accident. Figure 2d shows distribution of accident by belt component involved. It is realized that the most critical parts of the conveyor assembly contributing to accidents by entanglement are return idlers, tail pulleys, and the conveyor belt itself. In total, 28 fatalities have occurred due to entanglement. 14 of these accidents were a result of getting entangled between an unguarded tail pulley (8 cases or 29%) or an unguarded return idler (6 cases or 22%) and the energized belt. An additional 14 accidents (48%) occurred as a result various other belt components and assemblies including head pulleys, drive pulleys, bend pulleys, take-up pulleys, power rollers and drive motor rollers. Most of these accidents could have been avoided by de-energizing of the belt and proper lock-out and tag-out procedures.

Figure 3 shows the distribution of accident categories by year from 1995 to 2007. Except for 2003, the average number of fatalities per year reported was 4-5 accidents. The lowest number of accidents occurring per year was 3, and the highest was 8.

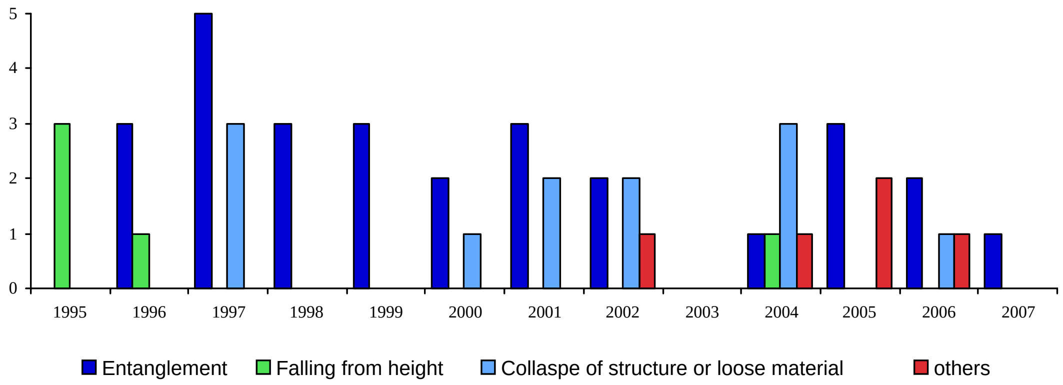


Fig. 3: Distribution of belt-related fatal accidents by year

Conveyor belt injuries were also reported by Goldbeck (2003) in surface areas of metallic/non-metallic mines in the use. He reported that between 1996 and 2000 there were 459 reported injuries ranging from fatalities to injuries with restricted work activities. Of these 459 reported accidents, 13 were fatalities and another 22 were reported as permanent disabilities. 42% of reported accidents occurred when the injured worker was performing direct belt maintenance. Another 39% occurred while the subject was cleaning and shovelling around the conveyors. 290 of the 459 injuries and 10 of 13 fatalities have occurred due to working around moving conveyor belts and due to getting caught between the moving conveyor belt and a pulley (Goldbeck 2003).

2.2 Need for a Saftey Training program for belt Conveyors

The average cost of a fatality in a mine is estimated $1.02 million (figure originally published in 1986, would equal $1.94 million in 2007 according to the U.S. Bureau of Labor Statistics inflation value (U.S. Bureau of Labor Statistics, 2007) and was calculated by considering medical expenses, worker's compensation, accident investigation, loss of family income, and lost production value. Permanent disability accidents of less severity were estimated at $237,000 and each lost-time accident resulted in an average of $5,000 (Goldbeck, 2003). A well structured training program that covers areas of proper maintenance, proper working habits, proper work attire, and hazards and safety recognition can save on injuries and fatalities. The cost for developing the program is a small price to pay compared to the cost of preventable accidents and the loss of human life.

Recognizing the need for conveyor safety standards during the 1940s, the American Society of Mechanical Engineers (ASME) issued safety standards through the American National Standards Institute (ANSI) for conveyors and related equipment (Schultz, 2003.). This was later modified to B20 in 1972 (a specification-based standard) and then to B20.1 in 1976 (a performance-based standard). The Occupational Safety and Health Administration within the United States Department of Labor (OSHA) was founded in the 1970's and started preparation of its own conveyor safety standards (20CFR, Part 1910.186). To date, OSHA has not adopted any conveyor safety standards and seldom become involved with conveyor safety inspections which remain MSHA's responsibility.

According to Schultz (2003), conveyor safety operations and training are not adequately addressed by the ANSI standards or OSHA regulations. They place responsibility on the owner to limit job assignments to "certified," "competent," and "qualified" employees. When it comes to conveyor belt safety training, training materials as videos or text information is minimal as prepared by ANSI Conveyor Safety Standards, OSHA, or by any of the safety engineering professional associations. These associations have some general safety guidelines, but do not place requirements or suggest a training program structure or specific training guidelines (Schultz, 2002 and Schultz, 2003), leaving the responsibility of developing a successful training program to the owner/operator of belt conveyor.

MSHA requires 24 hours of training in part 46 and 48 of the Code of Federal Regulations (CFR). MSHA requires that the first 4 hours of training be given before the new employee starts work withthe remaining twenty hours performed within the first sixty days of work (Goldbeck, 2003). Since it is up to the operator of the conveyor belt system to structure their training programs, there are some essential elements that should be included. These essential elements include establishing learning objectives, preparing a course outline, allocating proper time, recognizing the level of training required (knowing who your audience is), documenting the training that take places, and evaluating the class/session effectiveness and making proper modifications (Shultz, 2003).

In order to help reduce accidents with a comprehensive safety training program, it is important to include certain areas of training. Goldbeck (2003) proposed four categorizes of training areas: general safety practices, guidance for performing maintenance and inspection, information about conveyor and belt conditions, and procedures for belt tracking. General safety practices include using the proper safety equipment, hardhats and glasses, to wear proper clothing and hair that is not loose or too long, and making sure that the each employee is aware of emergency stop button or cord locations. Guidance for performing maintenance and inspections includes making sure the conveyor is properly locked out and tagged out when performing maintenance tasks, performing maintenance tasks properly, and making sure any connected equipment is properly placed out of service and blocking, if necessary, is used. The employee also needs to be trained on belt conditions and be able to recognize impact and heat damage, belt cupping and cambering, or damage to belt splices. The training also needs to include general conveyor system conditions, such as to make sure idlers are properly working and having the ability to recognize spillage sources. Lastly, Goldbeck explains belt tracking as a science of manipulating conveyor belt components to get the belt to run on the center of the structure. The improper adjustment of components when tracking the belt can lead to serious injury (Goldbeck, 2003).

Similar training program goals are described by Schultz (2003) who states that traditional safety hierarch priorities are eliminating the hazard or risk, applying safeguarding technology, using warning signs, training and instruction on a regular basis, and prescribing personal protection. Out of these safety priorities the training and instruction on a regular basis and the prescribing personal protection are the primary responsibility of the owner/operator. The training method that Schultz describes includes three steps. The first step is to set safety standards which include establishing performance standards for equipment, systems, personal, and operations and maintenance. It also includes that the design and manufacturing of the conveyor system has to perform to the safety standards when it comes to warning systems and safety factors. The second step is to set training requirements, meaning establish basic training procedures for all employees, and then developing procedures for training of new employees who are statistically involved in more accidents then the more experienced workers. The last step is to have management participation, periodic review, and continued training. This can be accomplished by keeping management involved and advised on all safety training programs and when they are scheduled, the use of monthly operational and maintenance safety review meetings, quarterly operations and maintenance conveyor belt safety review meetings to identify problems or changes which include identification and training of new equipment that can compromise safety and training part-time employees, and lastly keep a permanent record of all safety and health training that takes place by group or individual (Schultz, 2003).

Currently, most training that is taking place is within the MSHA guidelines for training and falls under general training, with very little of the training specifically directed at conveyor belts and conveyor belt safety. Within the industry, the training that focuses on conveyor belts and conveyor belt safety is usually conducted with slideshows and videos. This type of training is very passive and is hard to quantify the amount of knowledge that the employee is gaining through such training. The employees are often then placed with an experienced person for on the job training where they learn how to properly operate, repair, and maintain a conveyor belt system. If this training is incomplete it can lead to accidents that could have been prevented with a better training program. VR is offered as a solution to improve the current training practices of the industry.

VR offers a large variety of possibilities for safety training programs that can offer the owner/operator a cost effective training method with the capability of quantifying or testing the users' knowledge gained through the training program. VR offers the ability to simulate real life events in a digital environment that might be too dangerous to simulate otherwise (Haller, et. al., 1999). VR also offers cost savings within development of specialized programs through RAD (Rapid Application Development) software that requires minimal code programming and offers real time feedback to the designers (Cope, et. al., 2001). VR training also offers specialized training on an individual basis that can be run on a personal computer eliminating the need for large training sessions with groups of people and specialized equipment (Kizil and Joy, In Press).

2.3 Current research

VR has been investigated for training and safety in a wide variety of applications in the mining industry. These safety and training programs include general safety training for hazard recognition and escape planning in underground mining, educational programs based on accident recreation for prevention, proper equipment operations training, and safety design reviews for new equipment and processing layouts.

The safety training programs within the mining industry that utilize VR have focused on a large variety of research goals that are organized in Table 1. Some of the research utilized VR in visualizing information and accident reconstruction, meaning training was conducted by recreating scenes, processes and accidents with VR. One version of information visualization is combined with the trainee being charged with completing a task and is action-reaction training. This shows direct results of actions and shows the effects of a decision. This often consists of recreating what would be likely to happen if the same chain of actions were taken within the real working environment. This is done more as a passive method to let the user know what would happen if the proper procedures are not followed while working within the environment. Similarly, risk analysis training has been explored by giving options to the user and then they would have to judge the risk of the activity and the proper actions to take. Results would be immediately given to the user and consequences are animated within the program.

Table 1: Current Research Focus and Goals

	RESEARCH FOCUS						RESEARCH GOALS										
	VR Training Tool to Create Programs	VR for Equipment Operation	VR Haul Truck Safety Training	VR Health and Safety Activity Simulation	VR Underground Mine Safety Training	VR to Improve Safety Design	Equipment Design Review	Accident Simulations	Information Visualization	Hazard Recognition	Procedure Training	Safety Measures	Customizable Programming	Replace on the Job Training	Action/Reaction Training	Inspection Simulation	Risk Analysis Training
Dellabio, et. al. (2007)						■	■	■	■								
Ruff (2001)					■					■	■	■	■				
Stothard, et. al. (2007)				■							■	■		■			
Orr (In Press)					■				■	■	■	■		■			
Schafrik, et. al. (2003)			■					■	■	■		■			■		
Kizil (In Press)		■						■	■	■						■	■
Hollands, et. al. (2002)	■												■				
Dezelic (2005)		■									■	■		■			

Other goals of research were to teach the users of hazard recognition and safety measures by having the user recognize, make note of, or fix hazardous conditions. These often require the user to enter the environment and avoid placing themselves in danger and taking note of the dangerous conditions. Within recognizing hazards, the users can also be placed through an inspection simulation. This requires the user to examine the equipment and environment used to make sure it is in proper working order. Anything that is wrong with the equipment and environment would then be marked and the user would have to determine the proper action to be taken.

Procedure training or training of proper use of equipment and operation of equipment within the working environment has also been done using VR within the mine industry.

More advanced systems have the goal for easily customizable programs. These programs allow for easy adaptation of the physical environment into the digital environment and simulate the actual working environment that the trainee will be working in instead of a generalized typical environment.

The mining technology unit (HATCH) in collaboration with MIRARCO of Laurentian University, both of Sudbury Ontario, Canada is investigating the application of 3D modeling and visualization with 3D CAD through the Virtual Reality Laboratory (VRL) at Laurentian University. The visualizations and VR are being used for improved safety including equipment design review for specific work environments, accident re-creation, and operator visibility improvement when driving mobile equipment in underground mines and are often easily distributed and viewed without the need of high end computer equipment. Through the use of visualization, the projects conducted end with a cost savings for design and improved safety for the final constructed product that otherwise would be hard to achieve through traditional design methods alone. (Delabbio, et. al. 2007).

The National Institute for Occupational Safety and Health (NIOSH) has developed a safety training software package for new mine employees called Miner Training Simulator (MTS). MTS is a computer based training tool that allows a trainee to enter a simulated mine environment and interact with the surroundings to learn the basic mining concepts, procedures, layouts, and escape routes. The program is customizable through script commands to change the actions in the simulations allowing for various degrees and scenarios of training (Ruff, 2001).

Research work at the School of Mining Engineering at the University of New South Wales, Australia is investigating the use of virtual simulation to replicate the mining work environment and present the users with problem-based learning exercises. The work involved a feasibility study, funded by the New South Wales Joint Coal Board Heath and safety Trust, on the usability of VR as a training tool for personnel in mining. The feasibility study led to more funding the produced the simulation of three issues that have high health and safety implications and are dependent on individual's actions: sprain and strain injuries, coal rib hazards, and self escape from underground mining. The main purposes of these simulations are to reduce accidents, create a safer working environment, and reduce operation cost by providing trainers with a powerful tool to create safety training programs and ultimately save lives (Stothard, et. al., 2004).

Work at the National Institute for Occupation Safety and Health (NIOSH), Spokane Research Laboratory, involved developing a VR training tool to educate mine workers on the hazards of mining as well as to train miners on evacuation routes and evacuation procedures. The goals of the project are to create a cost effective and safe training environment for mine personnel by putting them through training tasks and tests in a VR environment (Orr, et.al., In press).

Schafrik, et. al. (2003) investigated VR for accident recreation of haulage truck incidents in surface mining to help learn and subsequently teach what the causes of the accidents were through the use of a Computer-Based Training program. The work described in the paper focused on modeling the consequences of abandoning a moving fuel truck with failed brakes and the resulting effects of such actions.

Work by Kizil and Joy (In Press) at the Minerals Industry Safety and Health Center (MISHC), Australia, explored the benefits of VR for training and developed a number of VR applications for data visualization, accident reconstructions, simulation applications including haul truck simulation and inspection , risk analysis, and hazard awareness and training. Accident reconstruction conducted by the AIMS research unit at the University of Nottingham has been used for training and accident prevention. The same research group also conducted equipment simulation to help drivers become familiarized within common working environments, conditions, and principles of equipment operation.

Hollands, et. al. (2002) recognized that cost of equipment and the difficulties associated with customized development of the software as two leading reasons for restricting the widespread use of VR technologies towards training and other applications. The research work as developed by the AIMS Research Unit invested in developing an application toolkit for the purpose of creating VR-based training tools. The resulting system, SAFE-VR, uses a graphical user interface to combine 3D models into various training systems, from hazard spotting to equipment operation. The use of this toolkit could dramatically reduce the development time (and therefore cost) of VR training system.

The University of Missouri – Rolla is developing a VR training program for miners that focus on the proper installation of rock bolts using a jackleg drill. Through the use of a VR training program the trainee will be walked through the process of proper handling and operation of the bolting equipment. The main goals of the training are to reduce the chance of injuries that often occur during on the job training and learning (Dezelic, et. al., 2005).

3. PROPOSED SAFETY TRAINING STRUCTURE

The aim of this research is to offer a supplement to current training program. It is the intention of the research to offer a cost effective and convenient training program that teach the user and then quantify the knowledge gained through the training by assigning tasks for the user to complete. Virtual reality is being explored because it offers a realistic first person experience where the user can go through the training at their own pace, experience consequences and actions, and have their performance tracked.

In order to have a successful and beneficial safety training program, it is important for it to be well thought out with accurate and quality information that fits the needs of the industry. Through this research and as depicted in Figure 4, we are proposing a 4-step training program structure that was used during this research to aid in the development of the application:

Step-1: Data Collection.

The first step of developing a safety-training program is collecting and compiling data and information. In the case of the research conducted, this was done through site visits and literature review. The information was tabulated into a series of fact sheets where it was easily organized under categories. The categories were further developed in step 2 where they were placed within different training areas.

Step-2: Define Safety Training Areas

Within this step, the information that was gathered through the literature and site visit was reviewed and categorized into the categories of conveyor belt components and maintenance procedures, safety issues, hazard recognition, and trainee assessment. The categories were used to aid in the development and compilation of information to make sure it is complete and all areas are fully covered. Each category is further sub-divided into information based upon their criticality and frequency of occurrence as analyzed during the literature review. The information as it is structured within this step aides in the development of step 3, the VR prototype implementation.

Step-3: VR Prototype Implementation

The VR Prototype Implementation is developed in two stages. The first stage is to inform the user of the information that was compiled in step 2. The second stage is designed to test the user’s ability and capacity of knowledge to determine if the user has gained the proper knowledge through the training. The proposed VR prototype contains two modules, the instructional-based module and the task-based module. The instructional-based module is used to guide the user through the environment where they are familiarized with the conveyor belt and assemblies and the related hazard recognition and safety issues. The task-based module gives the user a task to accomplish and is assessed based on his performance. The second module is built off of the knowledge that was distributed within the first module as both a test and reinforcement of the knowledge given in the first session.

Step-4: Evaluation and feedback

The final step is to evaluate the developed program before implementation to make sure that the program is successful in reaching its goals of training the employee. Evaluations will be planned for the entire system on three levels. The first level is through industry feedback. This level is used to determine the accuracy and quality of the information that is being presented and will be used to make sure the tasks that the user is assigned in the second phase of the research is realistic to what would be asked in real life. The industry feedback will also be used to determine if the system would fit within their training needs as a supplement to current safety training programs. The second level of evaluation will be conducted using various users of different backgrounds and experience levels. The main purpose of this evaluation will be to test the usability of the system and determine any areas that need to be clarified to improve the understand ability of the application. Lastly, after both sessions are complete and revised through the feedback process, a general knowledge comparative test will be given to two separate test groups. One will be placed through typical training and the other will be given the instructional-based portion of the VR application. Both groups will be given the same general knowledge test. This study will allow for a determination if the VR application is more beneficial to the learning of the material.

It is expected that after the program is initially tested and evaluated, it will be adopted by the industry to allow new employees a good basis of knowledge so they can successfully complete their job safely. It should also allow for experienced employees to go through a 'refresher' course to make sure that their training is up to date. It is also important that the program is periodically evaluated and reviewed for completeness. It is also important to update the system as the technology changes in order to make sure all employees are aware of any new procedures for conducting their jobs.

The flexibility and relative ease of creating the virtual environments can allow for customization to a specific companies needs or to a specific plant layout. The information presented will be the similar in nature as the information compiled through the first two steps of the framework but can be presented with a different belt set-up if it proves of value to a specific company. The program can also allow for the addition of more equipment and machinery for plant specific situations if the need arises.

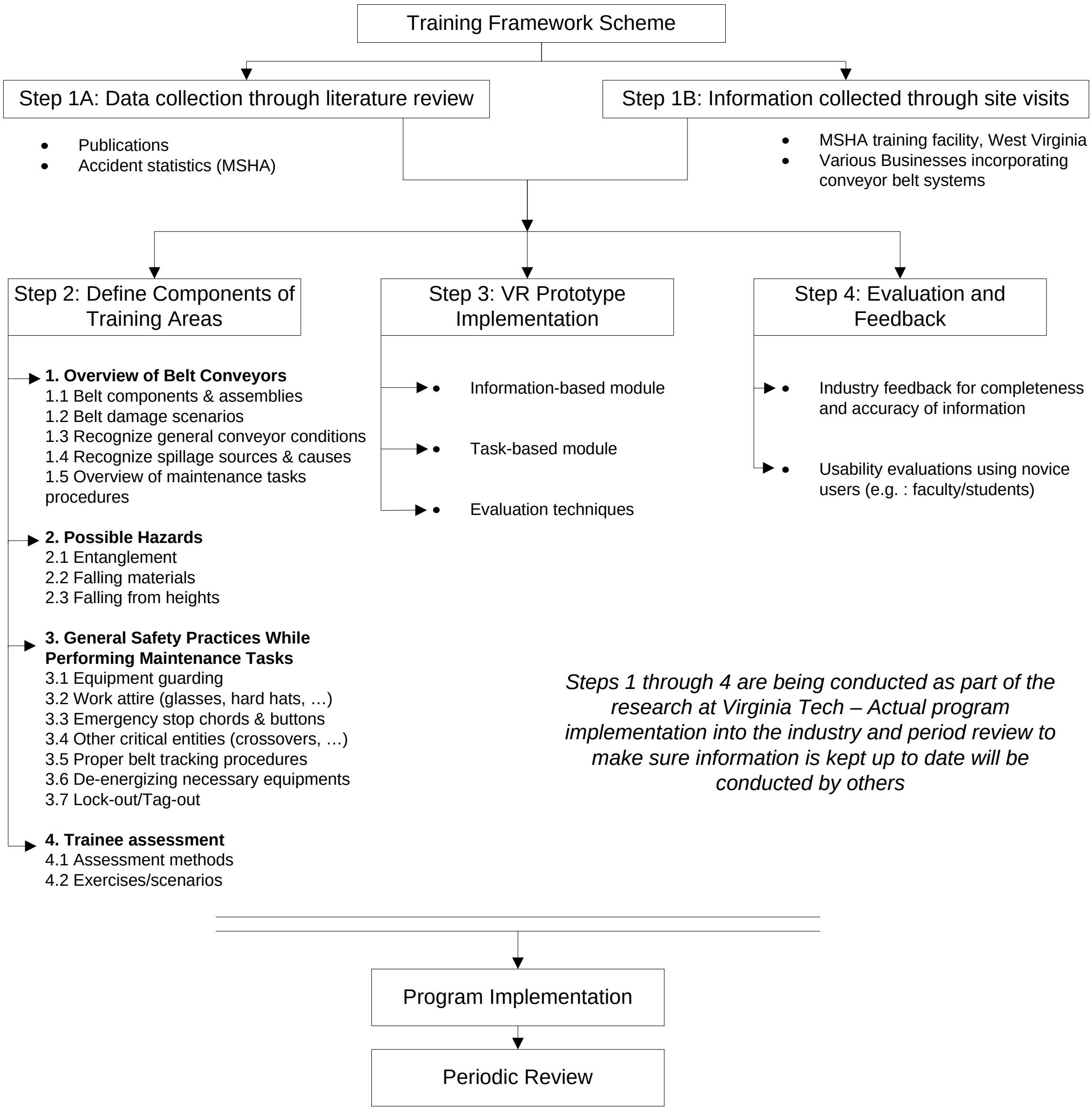


Fig. 4: Proposed Safety Training Structure

4. INSTRUCTIONAL BASED PHASE OF PROTOTYPE DEVELOPEMENT

The safety training prototype developed as per the structure described above contains two parts; the first phase is the instructional based research phase, and the second, being conducted in future research, is a task-based phase. This section of the paper focuses on the development of the first phase of research. In order to produce the training program that was developed within the first phase, preliminary research was conducted to see what has been done with VR as well as to determine what current conveyor belt safety practices exist within the industry. After the preliminary research was completed, information was compiled and the development of the VR environment was conducted. The information that was collected through the research was categorized into conveyor belt components, safety issues, hazard recognition and general maintenance practices. This information was then displayed within the virtual environment to train the user. After the development was completed, industrial feedback was used to check for accuracy and completeness and then make appropriate revisions to the program. Table 2 shows the structure of the instructional-based phase implementation that matches the categories as described in Fig. 4 under “Define Components of Training Areas.” The information that is given to the user at each station is also listed.

Table 2: Instructional-based phase implementation structure.

Training Areas per fig. 4		**Sub-Category**	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**	**Color**
1	Information about conveyors and belt conditions	Bend pulley				●			Green
		Take-up pulley				●			Green
		Return idler	●						Green
		Impact idler			●				Green
		Tail pulley			●				Green
		Feed chute			●				Green
		Troughed idler			●				Green
		Head pulley		●					Green
		Drive Motor		●					Green
		Recognizing belt damage	●						Yellow
		Recognizing general conditions (structure)				●			Blue
		Recognizing spillage sources				●			Blue
		Grease lines			❍				Green
		Removal of spilled material				●			Blue
		Maintenance of belt	●						Blue
2	Possible Hazards	Entanglement	●						Orange
		Falling Material				●			Orange
		Falling From Heights		●					Orange
3	General Safety Practices	Equipment Guarding	●						Red
		Work attire	●						Red
		Emergency Stop Cords & buttons			●				Red
		Protective Railings	●	●					Red
		Proper belt tracking procedures	●						Red
		De-energizing necessary equipment						❍	Red
		Proper start-up procedures (alarm)						❍	Red
		Lock-out & Tag-out					●		Red
		Harness when working at heights		❍					Red
		Use of Crossovers				❍			Red
4	Trainee assessment	Conducted in other research related to Task-Based Session development.							

● = Original Implementation ❍ = Revisions based on Feedback

Each station has been chosen on two accounts, if there is information that relates to one another, they are most likely contained in the same station, and then if there are components that are located close to each other, they are most likely listed at the same station.   The majority of the information is presented with a combination of captions and animations within the environment. Information pertaining to safety attire, belt damages, and belt maintenance that is heavy on text and difficult to animate is distributed in menu form with text and images but connected to the environment in an area related to the information.

The preliminary research and literature review was used to help determine examples of current research dealing with VR and determine what type of training needed to be produced. The key issues that were taken into consideration based on success of past projects was that the environment should show enough detail for the user to become familiarized with the conveyor belt configuration and be able to recognize the components and assemblies on any conveyor belt system. The virtual reality session offers an active mode of training to supplement current on-the-job training methodologies where as other training through slides, images, and videos is a more passive method of training. With this in mind, it was important that the experiences of the digital environment be easily transferred to real life situations where the user would be able to recognize hazards and safety complete tasks. After participating within the training, the operator should be able to competently participate in normal work activities around a conveyor belt system.

Once the goals of what the research is to accomplish were compiled a digital model of a conveyor belt system was created by using Autodesk's AutoCAD and 3D Studio Max. The model was developed through photos taken during the site visits and through different operations and design manuals such as *Foundations 3* (Swinderman, et. al., 2002). Mine Safety and Health Administration (MSHA) accident report data was also reviewed to help determine that three different configurations of conveyor belts (Fig. 5) were needed in order to simulate all inherent dangers. This led to the development of an inclined belt run that is fed by a crusher and dumps material onto a second belt run that is elevated and level. The elevated and level belt run then dumps material to a lower belt run that is at grade. With this chosen configuration all of the hazards can be simulated that are the cause of the major accidents reported by MSHA. The three part configuration also allows for the experience of safety precautions that are required with each piece of the overall plant configuration, some of which are proper guarding, falling materials, and falling hazards.

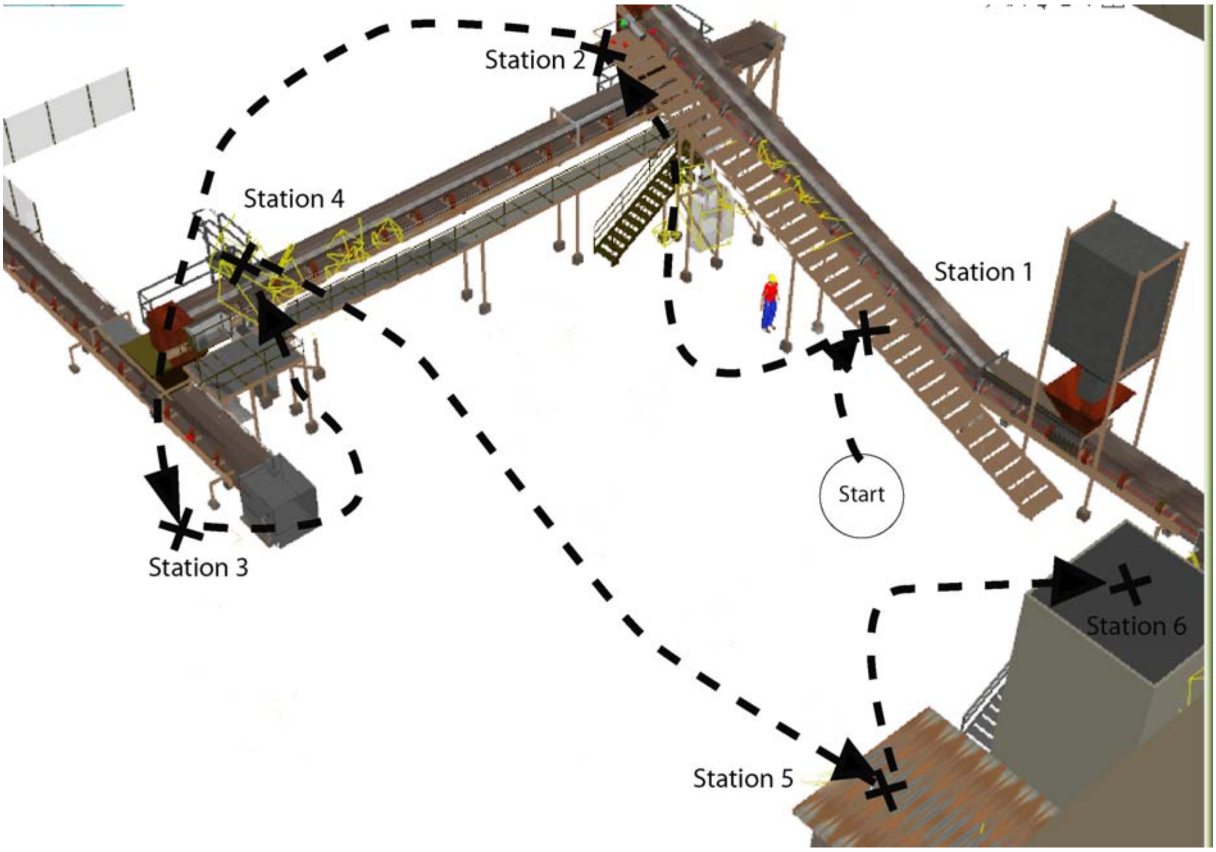


Fig. 5: DeepCreator belt overview with overlaid station markers and path of travel.

When the digital model of the conveyor belt and basic configuration was completed, the digital model was exported out of 3D Studio MAX and imported into Right Hemisphere's *Deep Creator*. Deep Creator was used because it is a Rapid Application Development (RAD) program with built in features for basic animations and modeling. A RAD program allows for the creation of a virtual environment with little programming needed for the basic functions. Within Deep Creator animations were added to simulate the belt moving. In order to allow for smooth navigation through the environment the poly count (number of surfaces) had to be reduced. This involved using multi-sided shapes instead of spheres and cylinders as well as removing sides of objects that are not visible during navigation and making sure that excess detail was not added to the model. One issue that was inherent through much of the literature review was to make sure that there was enough information to convey what is trying to be shown in order for the user to be able to recognize situations in real life, but to not add excessive detail that make the system slow and tedious to use. One of the goals during the environment development and animation was to make sure that the environment remained user friendly; part of this was to make sure the environment remained easy to navigate.

After the basic animations were added within Deep Creator other information had to be added that is presented to the user during the training. The information list in Table 2 provides the information available at each station, detailed information related to each item in Table 2 was developed by using a fact sheet. Fact sheets were the method used to document relevant information and keep track of resources. A station is a location at which there are a number of hot-points (objects with connected information) used to organize the information during development of the instructional-based phase. The user is taken on an automatic navigation through each station as shown in figure 5. The user can only advance once they have reviewed the information connected to all the hot-points at one station. There is also an option for the user to jump back to a station and re-examine pieces of information through a navigation map and "jump-to" buttons in the menu. An instruction screen is given at the beginning of the session to inform the user of the navigation process.

When the session is started the user is first taken on a flythrough over the conveyor set-up to allow them to become familiarized with the major parts of the environment and then stops at the first station. Within the first station the user is presented with information as listed in Table 2. The grouping of the information is based on the close proximity of the components of the belt and groups of information that presented.

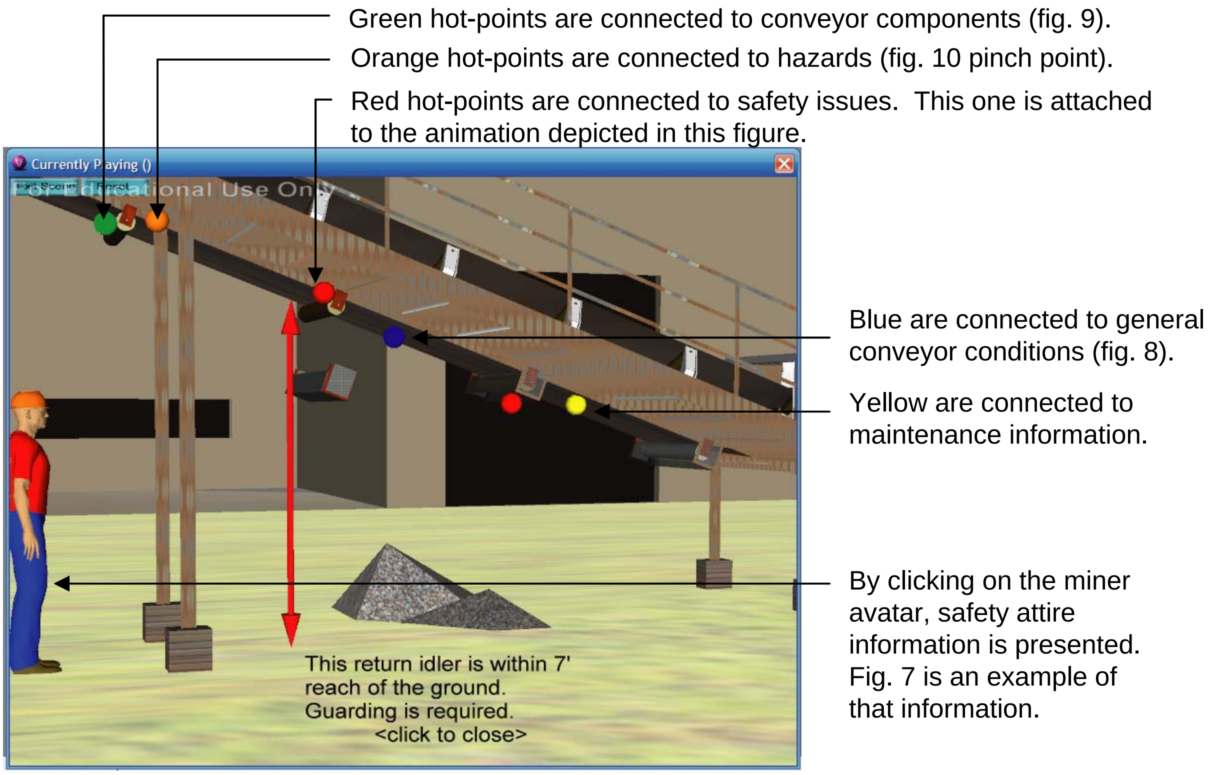


Fig. 6: Screenshot of station 1

At the first station (Fig. 6), the user is presented with a few options of information to view. The first one would be Safety Practices of proper work attire. This information is presented to the user as they select the glowing hat on the miner avatar in the scene. When the hard-hat is selected the user is shown an image of a prepared worker, as the user slides the mouse cursor over the different parts of the image, textual and image information is presented with requirements and recommendations for proper safety attire (Fig. 7). The information is either the MSHA requirements if there is a specific clause within the regulations, or the industry's common best safety practice when a specific federal regulation does not exist. The user is given information when the mouse is rolled over the hard-hat, safety-glasses, ears, hands, belt, clothing, and boots. This information, being considered important for the safety of the conveyor belt operator, is available for review whenever the miner appears on the screen.

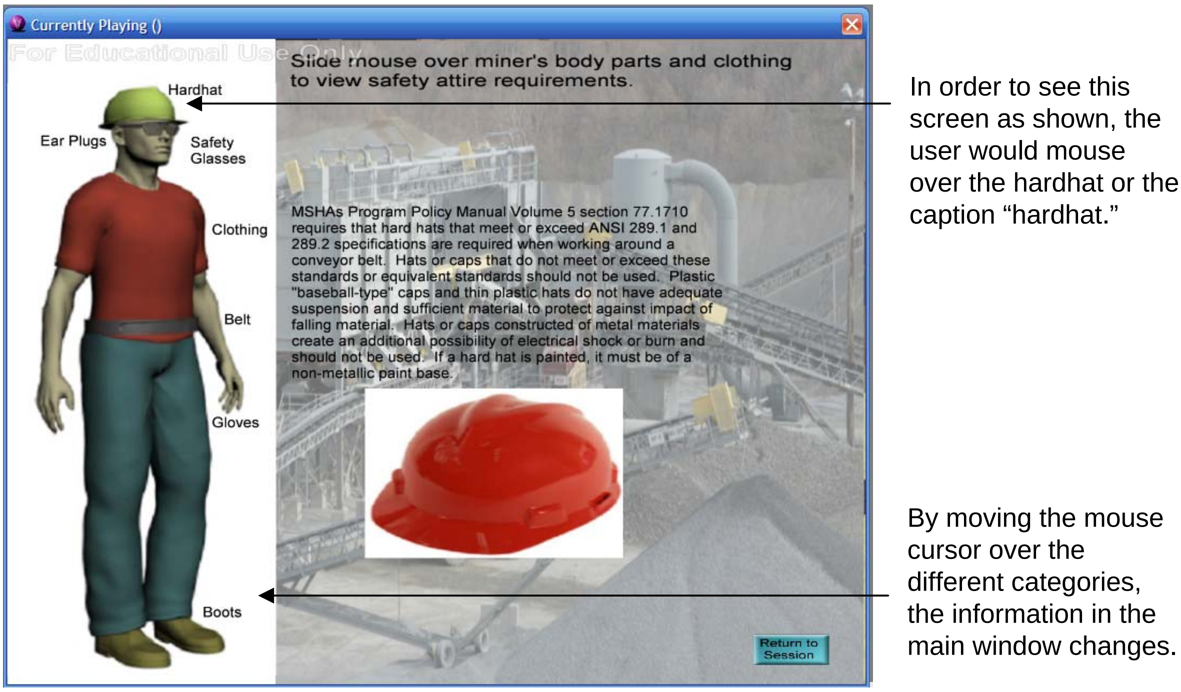


Fig. 7: Safety attire information sample with mouse-over at hard-hat.

Also at the first station the user is presented with information about the conveyor an how to recognize belt damage such as belt camber and cupping, edge damage, recognizing worn surfaces, top cover cracking, and heat damage (Fig. 8). This information is presented in a similar method as the safety attire information is presented to the user. Connected to the recognition of damages is also the proper maintenance of the belt which includes proper splicing and patching techniques with diagrams and text shown as a step by step basic instructional. The instructions are generalized tasks as specific training is needed in order to successfully complete these tasks safely and successfully.

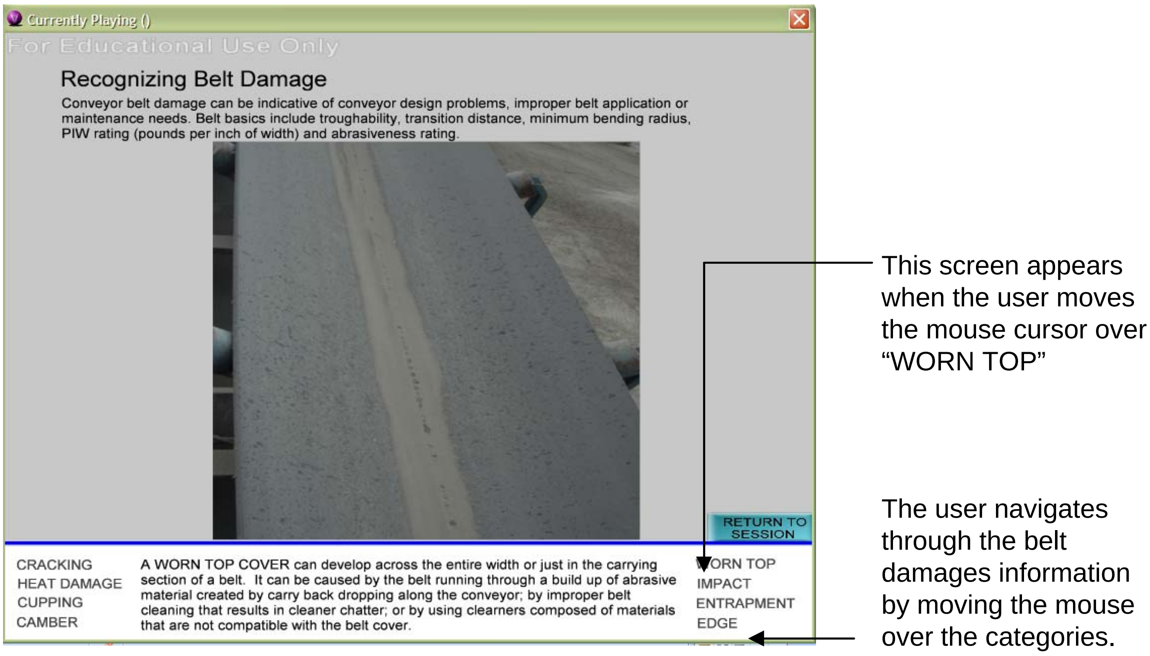


Fig. 8: Belt conditions information sample with mouse-over at “Worn Top”.

Another hot-point at station 1 is connected to the return idler (Fig. 9). The method of which the return idler is presented is the same as all the components that are listed in Table 2. When the hot-point associated with the return idler is selected, the camera view adjusts to the component. The component then flashes a different color while a caption describing what the component does is shown. The purpose of including the components within the instructional-based session is to allow for the users to become familiar with the environment and when assigned a task dealing with a particular component, he or she should be aware of the area they are going to be working on.

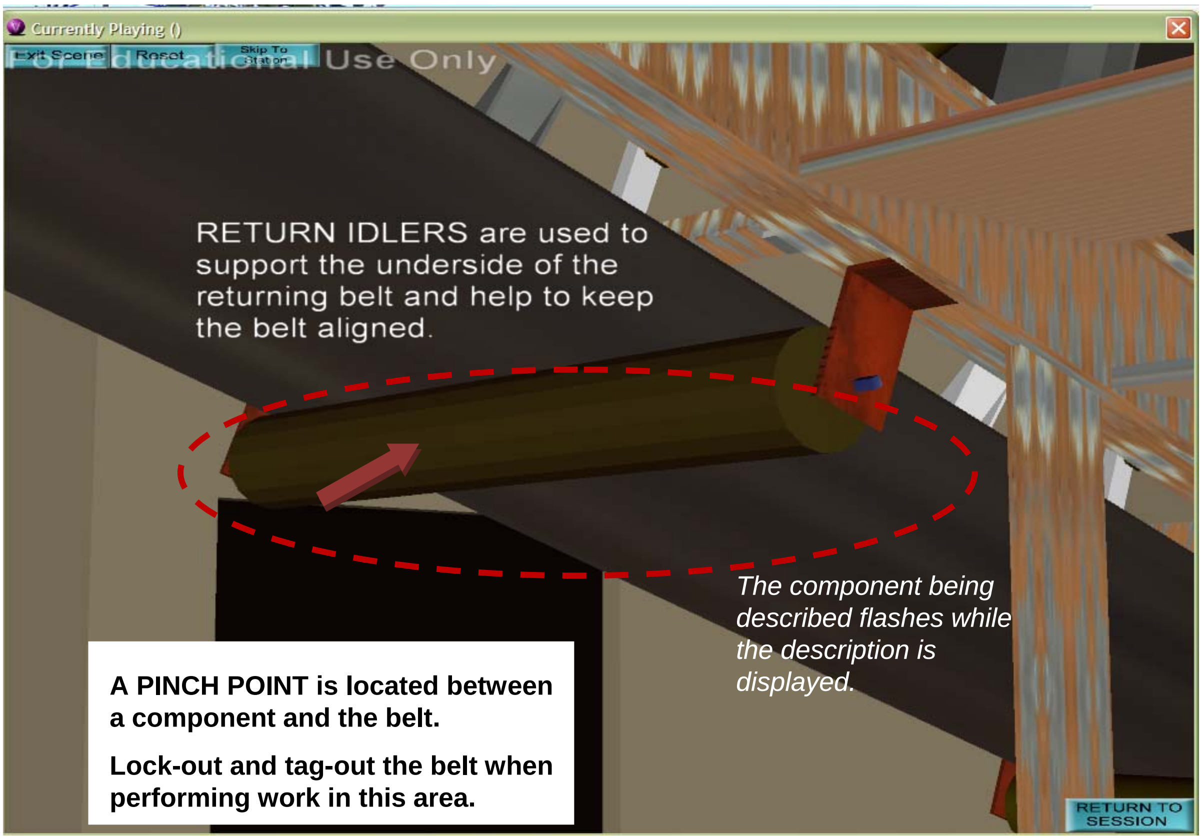


Fig. 9:Example of Component Information.

Another hot-point at the first station that is associated with the return-idler is entanglement and an example of a pinch-point, or a location that entanglement is likely to occur. The method used to introduce the information pertaining to entanglement and the pinch-point is shown in two screens, one to show the definition of entanglement, and the other to give an example of a pinch-point. The example of the pinch-point (fig. 9) gives a description of what you are looking at and then animates an arrow pointing out the specific area between the return idler and belt where a pinch-point would exist.

After the user has viewed all of the information associated with the first station the program will take them to each station until the program is completed. Each type of hot-point is displayed in a similar matter as the information that is described for Station 1. Along the path of travel that the user is taken, there are also markers that bring back some of the safety and hazard information that was mentioned earlier in the session. One example of this is at the first station where there is guarding missing. The system, through animation, replaces the guarding and states why there should be guarding at that location. At the completion of the program the user will have the option of entering the informational-based phase through manual mode or to continue to the task-based phase of the research that is being developed to test their knowledge of the information that has been presented.

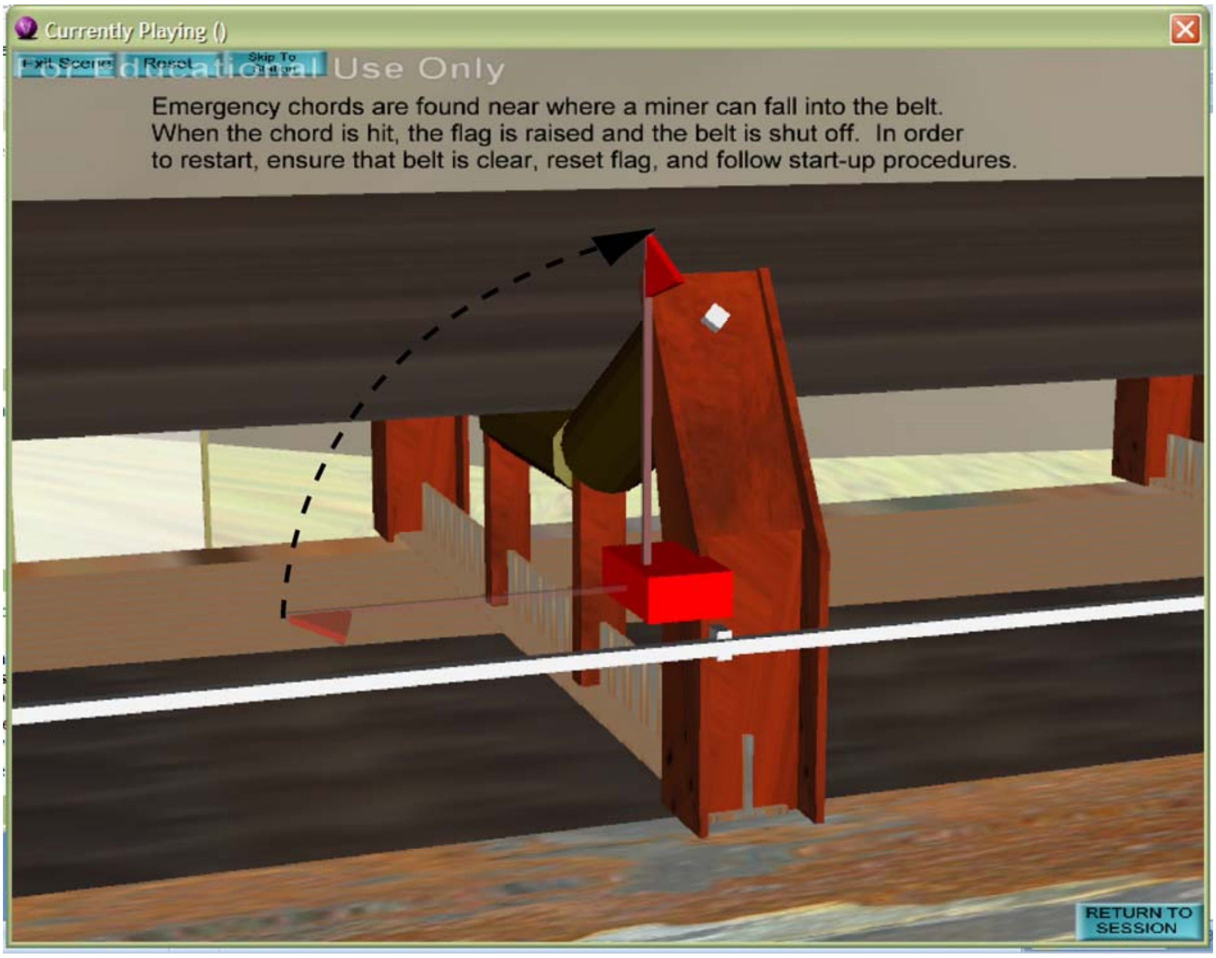
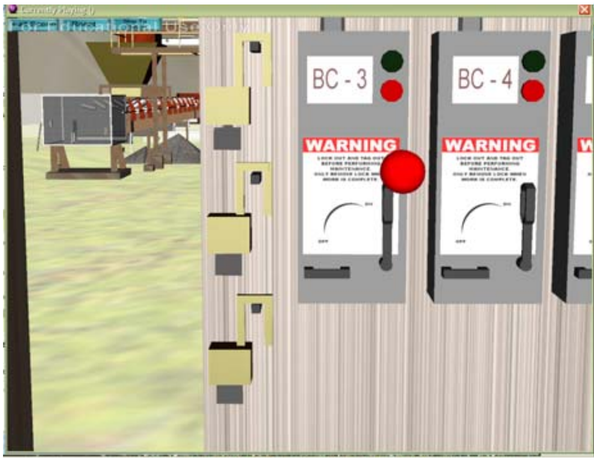
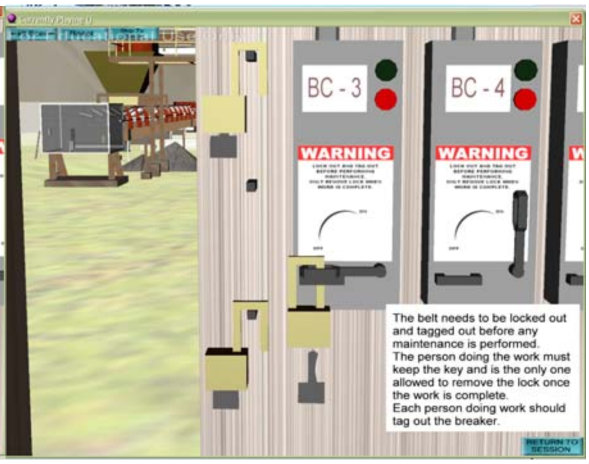


Fig. 10: Example of Pinch Point location as animated when orange hot-point is selected.

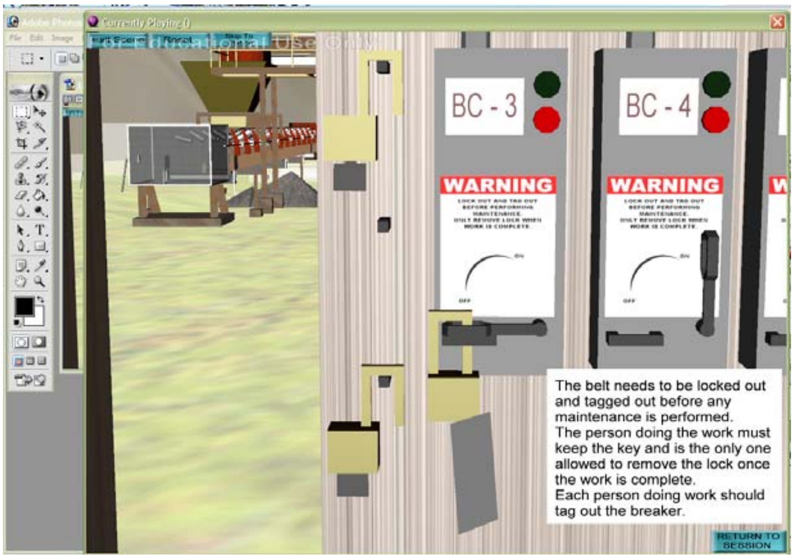
Upon reviewing each hot-point at the first station the user is taken to the next station and the process continues through the completion of the session. The information through the remaining stations is presented in a similar manner to that of station 1. There are some situations were actions are described. One such example is located within station 3 and deals with the emergency stop chord (fig. 10). In this example, it shows the reaction to the emergency stop chord being pulled. When there is an emergency around the conveyor, the stop chord can be pulled to stop that portion of the belt and the flag rises in order to signal the area where the chord was tripped. The last form of information that is presented are processes, in stations 5 and 6 processes are shown to the user on how to properly and safely turn on and off the conveyor system and lock-out and tag-out the system when performing maintenance tasks. These procedures use captions to describe the process and animations show the process that needs to be taken. The example of lock-out and tag-out (fig. 11) starts while the user is in the breaker room. The hot-point is selected and the sound of the belt stops. The lever on the breaker is then turned from the on position to the off position with a lock being taken from the wall and locked on the breaker. The next step is to remove the key and place a tag, all of which are animated to show the process.



A. Station 5 hotpoint.



B. Lock-out animation – lock placed and key removed.



C. Lock-out animation – tag with name hung to finish animation.

Fig. 11: Lock-out & Tag-out process animation.

5. INDUSTRY FEEDBACK

An industry feedback process was adopted following the first implementation phase of the Instructional-based Module. Several visits were conducted with major surface mining companies that utilize conveyor belts in their process plants with the objective of acquiring industry expert’s feedback on content and structure of the application. Repeated visits over a process of nine months allowed to record comments, revise content, and structure and receive additional feedback (Figure 12). Overall three companies were visited with a total of eleven industry experts attending the various meetings. Of those eleven individuals that have reviewed the application three are safety professionals, three are involved with safety education processes within the plants and the rest were engineers, foreman, and maintenance personnel.

Overall, the industry’s response to the application was very positive. The initial challenge was contacting industry professionals to get the initial meeting scheduled. This was aided with the help of contacts received through the Virginia Center for Coal and Energy Research located at Virginia Tech. Once the initial meetings were conducted to inform the industry members what our intentions were and what the research is about, they were more than willing to continue with follow-up meetings and to give us feedback. Their reasons for this included the potential value they see for using the type of application that has been developed within their training programs. Some comments that were expressed were that they would like to see applications developed to encompass the use of other equipment and pieces of machinery in their quarries, ideas that were documented and will be considered for future research.

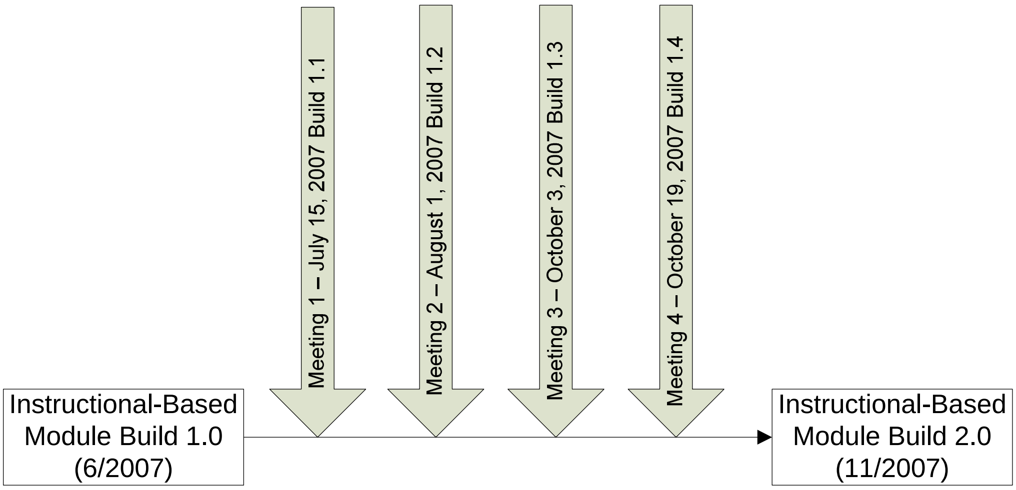


Fig. 12: Industry Feedback Structure

During the demo of the application, the research team posed specific questions to help center the focus of the discussion. Industry members were also encouraged to ask questions, make comments, and interrupt whenever they saw something that needed to be discussed. The questions that were the basis of the discussion are:

- Is the information presented at this station reasonable?
- Is there any information that can be added?
- Is anything graphically misrepresented?
- Was any of the presented information difficult to understand?

Other general questions included:

- Would this fit your training needs and how can it be improved to better supplement your training needs?
- Can you see a program like this being a valuable addition to your current training program?

The questions were given at the beginning of the meeting; this made the attendees aware of the types of comments that were needed to better improve the application to fit the industries needs. The results of these feedback sessions are documented in Appendix B. Thirty-seven unique comments were received varying from components that were missing to safety procedures. Twelve comments were based on existing information and remaining comments dealt with information that the industry professionals thought would be a good addition to the program. The majority of the comments, twenty, consisted of clarifying and adding safety issues to the application. The remaining comments were split between general conveyor information, components, and hazard recognition. All the comments were reviewed and determined to be relevant to the improvement of the application and were implemented to produce Build 2 of the application.

In addition to feedback on quality and accuracy of information we asked a questions pertaining to how they thought their industry would accept this type of training application. When asked if they thought this type of application would benefit their training program the overwhelming response was "yes". Some of the reasons that were given included that the application would allow for self-exploration of the individual under their own pace, and that interaction would enhance the learning by "trying". From their experience, the training professionals have realized that many employees, especially when going through the required annual training tend to lose focus on slide-show presentations and videos that they see year after year. They believe that if the employee had the interaction and was in control of the environment it would allow them to stay more focused and hopefully learn more. Another benefit of this application that industry recognized was that many of the new employees have used computers their whole life and are technologically inclined. The industry professionals feel that a VR application that represents a video game that many of the employees are familiar with would allow for a unique learning experience that they would be interested in.

6. SUMMARY

Virtual reality has been used in different areas of the mining industry and has been proven as a successful and valuable method of training. The technology has not yet been used for conveyor belt safety training. This research is the use of virtual reality for conveyor belt safety training as part of a larger effort for developing a safety training program for belt conveyors. It is believed that virtual reality can offer an interactive and active learning experience for mine employees that work with and around conveyor belt systems that in turn can be more effective than typical video and "Power-Point" presentations that are passive by nature.

Although the first phase, the instructional-based session, uses virtual reality and the virtual environment as a training tool, the second phase, a task-based session that is being developed is taking full advantage of some of the benefits of virtual reality by replicating real life situations and making the user think them through. Cognitive learning and active learning are theories of teaching and training that require the trainee to think out a process through self-explanation and not to just repeat what was taught (Aleven and Koedinger, 2002). The task-based phase of virtual reality being developed which require the user to complete a task and along the way the application will track the movement of the user and the actions taken. The system will then give direct consequences and immediate feedback by tracking and tallying what is needed, taking advantage of some cognitive learning theories and practices. The task-based phase will be put through similar feedback sessions as the instructional-based session where it will be reviewed by industry professionals for content accuracy and realism of experience to make sure the tasks are realistic to what an employee would have to complete in real life.

Upon completion of the feedback sessions, the entire application will be placed through an evaluation to judge the usability of the system. Test groups of various skill levels will be given the application to explore. Upon completion the users will be given a list of evaluation statements that they will have to rate their agreement with. These statements will deal with navigation, presentation of information, and the digital environment. This information will then be used to make Build 3 of both sessions. Once Build 3 is completed the VR application will go through a comparative analysis to help judge if the traditional method of learning or the VR application offers a better method of training. This will be done by using a test group to go through the VR application and second group to go through traditional training methods of videos and slide-shows followed by a general knowledge test. The test results will then be compared to see if there is any benefit of one training application over another.

Further application of the research will introduce various task-based scenarios of different levels of difficulty and test the virtual reality system against typical training sessions in order to determine if there is a difference of gain of knowledge between the training methods.

When both phases of the prototype are completed, it will offer a comprehensive training program that informs the user and then tests the knowledge of the user. The main goal of the program is to inform the users of safe working procedures around a conveyor belt system and ultimately reduce the number of accidents that occur due to lack of knowledge and skill. It is hoped that this training program will be a valuable asset to the safety training professionals within the industry and prove itself as a useful too to improve jobsite safety.

7. ACKNOWLEGMENTS

This research is being developed with support of a NIOSH Grant # 1 R01 OH008716-01 *Virtual Environment (VE) Applications to Improve Mining Health and Safety Training.* The views expressed in this paper are those of the authors and do not necessarily reflect those of NIOSH.

8. REFERENCES

Aleven, V. and Koedinger, K. (2002) An effective metacognitive strategy: learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive Science*, 26: 147-179.

Cope, M., Gray, M., Denby, B., Hollands, R. & Burton, A. (2001), Virtual Reality in Mine Safety, *29th International Conference of Safety in Mines*, Szczyrk, Poland, 8-11 October.

Delabbio, Fred C., et. al. The application of 3D CAD visualization and virtual reality in the mining & mineral processing industry. *HATCH*. Mining Technology Unit. http://www.hatch.ca/Mining_Mineral_Processing/Articles/3D_CAD_Visualization_Virtual_reality_in_MMP.pdf, retrieved February 6, 2007.

Dezelic. V. et. al. (2005). Training for new underground rock bolters using virtual reality. *Computer Applications in Mining Industries (CAMI) Conference,* November 2, 2005.

Goldbeck, L. (2003). Conveyor Safety and Education. *Aggregates Manager*, October, 2003. Mercor Media.

Haller, M., et. al. (1999). omVR – A Safety Training System for a Virtual Refinery. *Topical Workshop on Virtual Reality and Advanced Human-Robot Systems,* Vol. X, Tokyo, Japan, pp. 291-298, June.

Hollands, R. et. al. (2000). Equipment Operation and Safety Training Using Virtual Reality and SAFE-VR. *Minesafe International 2000,* Perth, WA. 3-8 September.

Kizil, MS, and Joy, J. What can Virtual Reality do for Safety?. *The University of Queensland, Minerals Industry Safety and Health Centre,* In Press.

Mine Safety and Health Administration (MSHA). (2007) www.msha.gov. U.S. Department of Labor.

Orr, T.J., M.T. Fligenzi, and T.M. Ruff, Desktop Virtual Reality Miner Training Simulator, *International Journal of Surface Mining, Reclamation and Environment.* In Press.

Ruff, T.M. (2001). Miner Training Simulator: User's Guide and Scripting Languarge/Documentation. *NIOSH*. U.S. Department of Health and Human Services. Pittsburg, PA, DHHS Publication No. 2001-136.

Shafrik, S.J., Karmis, M., and Agioutantis, Z. (2003) Methodology of Incident Recreation Using Virtual Reality. *2003 SME Annual Meeting,* Feb. 24-26, Cincinnati, Ohio.

Schultz, George A. (2003). Training for Conveyor Safety, *Materials Handling Management,* 58(11), 28-29.

Schultz, George A. (2002). Conveyor Safety and Regulartions. *Materials Handling Management,* 57(10), 18-20.

Stothard, P.M., Galbin, J.M., and Fowler, J.C.W. (2004) Development, Demonstration, and Implementation of a Virtual Reality Simulation Capability for Coal Mining Operations. *Proceedings ICCR Conference,* Beijing, China.

Swinderman, R., Goldbeck, L., and Marti, A. (2002). Foundations 3: The Practical Resource for Total Dust & Material Control. Martin Engineering, Neponset, Illinois, U.S.A.

United States Bureau of Labor Statistics. (2007) CPI Inflation Calculator *U.S. Department of Labor.* www.bls.gov *retrieved on 13 November 2007.*

9. APPENDIX

9.1 Appendix A: Summary Review of Belt Related Fatal Accidents between 1995-2007

Table 3: Summary review of belt-related fatal accidents reported by MSHA between 1995-2006

Accident Category	MSHA Case References	Maintenance Task Performed	Belt Assembly contributing to accident	Accident Scenario
1.0 Entanglement	M-1996-21	Cleaning - spilled and built-up material	Head pulley	The miner climbed onto the conveyor to shovel off material. The conveyor started, and the miner was transported approximately 150' where he was caught in an 8" gap between the head pulley cross member and the pulley.
	C-1996-7	Installation/repair	Power rollers	During the repairing of conveyor belt, the miner was pushing on the belt with his hands to maintain tension between the belt and power rollers to help feed the belt thru the tandem drive rollers on the belt drive. He became entangled between the two power rollers of a belt conveyor drive.
	C-1997-27	Installation/repair	Drive motor	The miner was standing on the belt conveyor structure beside the drive roller sprocket, while performing repair work on broken chain between the drive motor and drive roller. The drive motor unexpectedly became energized and the miner became entangled in the drive unit. The electrical power to the drive had not been locked out and tagged, and the drive unit had not been blocked against motion.
	M-1996-16	Installation/repair	Crusher	While helping in setting up two portable crushers, the miner got crushed between two crushing units.
	M-1997-7	Cleaning - spilled and built-up material	Tail pulley	The actual reason for the accident is not known as there are no eyewitnesses but it is believed that the miner was working around energized conveyor belt. The victim became entangled in an unguarded tail pulley and died.
	M-1997-29	Loading of pit material in the feed hopper	Return idler	A truck with load of pit material was loading material in the feed hopper. While raising the truck bed truck driver noticed the screen feed conveyor surging. After getting down from the truck he saw the victim's right arm had become entangled between unguarded return idler and conveyor belt. How accident happened is not clear, as there was no eyewitness.
	M-1997-18	Belt alignment	Tail pulley	The miner went underneath the unguarded portion of the belt to the adjustment bolt on the East side of the tail pulley as the belt was starting to untrack because of built up material in the wings of the pulley. The victim became entangled in an unguarded tail pulley while

				conveyor was in motion and died.
	M-1997-2	Cleaning - spilled and built-up material	Tail pulley	The victim was caught in an unguarded tail pulley of the crusher belt and died. There are no eyewitnesses to the accident but it appears that the miner was attempting to remove frozen material from the moving belt while belt was in motion.
	M-1998-17	Cleaning – spilled and built up material	Drive pulley and bend pulley	Accident occurred due to failure to de-energize the conveyor before cleaning. The victim's arm got pulled into pinch points between unguarded drive pulley & the bend pulley.
	M-1998-20	Cleaning – belt assembly	Return idler	While cleaning return idler, the victim was caught and drawn into pinch point between unguarded return idler and moving belt.
	M-1998-14	Cleaning – spilled and built up material	Tail pulley	The victim was cleaning material from around an unguarded conveyor belt tail pulley under the crusher. The self-cleaning tail pulley caught his clothing, drawing him onto the conveyor and he was wedged between the conveyor and a tension (snubber) pulley.
	M-1999-12	Belt alignment	Return Idler	The victim's arms got caught and drawn between the unguarded return idler and the belt resulting into the death of the victim. Accident occurred due to failure to provide crossover to safely access both sides of conveyor.
	M-1999-31	Cleaning – belt assembly	Return idler	The victim was caught & drawn into the pinch point at an unguarded return roller wile conveyor was in motion.
	M-1999-52	Installation/repair	Self-cleaning pulley	The accident occurred due to entanglement of victim's clothes in an unguarded self-cleaning pulley. The victim had entered into a confined space area containing an unguarded self-cleaning pulley that was in operation to shovel the spilled material from along side of the conveyor belt.
	M-2000-13	Maintenance of service equipment	Tail pulley	While working on the maintenance of a front end loader (used for cleaning and clearing material around the belt), Accident occurred due to entanglement in an unguarded tail pulley while conveyor was in motion.
	M-2000-12	Belt alignment	Bend pulley	The victim and a co-worker were making adjustments to a new conveyor installation. The victim was aligning the extended grease lines for the bend pulley from inside the conveyor frame. The victim became entangled in the unguarded bend pulley and died.
	M-2001-2	Cleaning – spilled and built up material	belt	Accident was caused by the failure to de-energize the power to the conveyor. The victim became entangled in a conveyor belt and died.
	M-2001-26	Cleaning – spilled and built up material	Take-up pulley	Accident occurred because maintenance was being performed while conveyor components were in motion. The victim became entangled in

				the discharge belt take up pulley and died.
	C-2001-7	Inspection	Take-up pulley	Accident occurred during an examination of a 54" belt conveyor drive take-up unit while the belt conveyor was still in motion. The rotating rollers of the belt conveyor take-up unit detached the victim's left arm.
	M-2002-16		Conveyor snub pulley	While monitoring the stockpiling of crushed ore over feeders, the victim was fatally injured at an open pit copper operation. His shovel became entangled in an unguarded conveyor snub pulley.
	M-2002-29	Cleaning – spilled and built up material	Tail pulley	Accident occurred while the victim was removing fines that had packed around a winged type tail pulley of a belt. As the spillage was removed, the bound conveyor belt moved backward a short distance and caught the victim's arm between the belt and the tail pulley.
	M-2005-1	Cleaning – spilled and built up material	Return idler	Worker was cleaning spilled material underneath the conveyor belt. Accident occurred because a guard had not been installed on the return idler. The miner was cleaning spilled material underneath the moving belt and became entangled in an unguarded return idler.
	M-2005-20	Cleaning – spilled and built up material	Return idler	Accident occurred when miner was cleaning up the built-up material on a return idler. His shovel got caught between moving belt and return idler.
	M-2005-18	Belt alignment	Tail pulley	Worker was making adjustments to the belt. Accident occurred due to performing repair work around an unguarded tail pulley. The victim's arm became entangled in the moving belt and tail pulley.
	M-2006-5	Cleaning – spilled and built up material	Tail pulley	Accident occurred when the victim entered the area under the crusher and travelled near the backside of the discharge conveyor tail pulley to clean the spillage beneath the crusher discharge from the sides of the conveyor tail pulley and his clothing became entangled in the rotating tail pulley.
	M-2006-9	Installation/repair	Return idler	Worker was adjusting the return idlers while the belt was in motion. He became entangled between the belt and the return idler.
	C-2004-19	Installation/repair	Tail pulley	Accident occurred while the miner was trying to install belt scraper at a tailpiece while the belt was in motion. A chain attached to the scraper was caught by the belt, dragging it and the victim into the tail pulley.
	M-25-2007	Cleaning	Take-up Pulley	Accident occurred while the victim was trying to shovel spilled material behind an unguarded take-up pulley. His shovel got entangled in between an unguarded take-up pulley and moving belt.

2.0 Collapse of structure, belt components or falling material	M-1997-20	Sampling	conveyor belt	A worker was sampling material coming off the bin feeder. The discharge conveyor belt under the storage bin was running and caused the material within the bin to slide and engulf the miner. The victim died from suffocation.
	M-1997-15	Installation/repair		A large portion of roof and rib (22 feet long x 42 inches wide x 26 inches thick), fell onto the miner resulting in fatal injury.
	M-1997-13	Installation/repair	Drive unit	While installing belt conveyor drive unit the chain on the lever hoist holding the boom suddenly broke and the boom section swung toward the drive unit crushing the miner against the drive roller.
	M-2000-3	Cleaning – belt assembly	Shaft kiln draw floor	Accident occurred while cleaning of the shaft kiln draw floor. Accident was caused by the failure to lock out the tripper conveyor and block the counterweight against motion before cleaning the guarded framework. The victim was crushed between a descending counterweight and counterweight's guard.
	M-2001-29	Cleaning –	Feed hopper	The victim was pounding on the sides of the hopper with a bar and hammer and working from the elevated bucket of the front end loader attempting to free the flow of materials inside the primary feed hopper. The victim entered the feed hopper to dislodge a hang up, when he was engulfed by material and suffocated.
	M-2002-19	Installation/repair	belt	Victim was repairing portable conveyor system. Accident occurred due to removing of a support structure on a portable conveyor. The conveyor was positioned on a hydraulic jack supported by two wooden blocks when it shifted and fell crushing the victim.
	M-2002-40	Installation/repair	Belt walkway	Victim was engaged in the removal of lower sections of walkway near tail pulley for replacement. Accident occurred when the walkway section collapsed killing the worker.
	M-2004-11	Cleaning – spilled and built up material	Hopper	While clearing the blockage of material at discharge chute accident occurred when the victim entered the hopper from the top without wearing a secured safety harness and lanyard when the material suddenly gave way and engulfed him.
	M-2004-19	Cleaning – spilled and built up material	belt	The victim was using a water hose to clean spillage under a conveyor. A large rock fell from a conveyor located overhead and struck him, resulting in fatal injuries.
	M-2004-9	Installation/repair	Crusher/belt	The victim was dismantling a crusher. Accident occurred when the victim was attempting to remove the pin from a support arm, was struck by a portion of the conveyor resulting in fatal injury.

	M-2006-24	Installation/repair	Head pulley	Worker was standing underneath the head pulley section of a conveyor preparing to attach a chain that was to be used to move the conveyor. The accident occurred when the bolts connecting the conveyor truss sections in the conveyor's frame failed, causing the head pulley section to fall and strike the victim.
	M-2001-12	Installation/repair		The victim was fatally injured while helping to assemble the plant. Accident occurred due to failure to provide suitable rigging equipment and to properly attach it to the load being hoisted. Need more explanation to show falling parts.
3. 0 Falling from height	M-1995-36	Installation/repair	Take-up pulley	A cement take-up pulley weight for a conveyer was being lifted into position by a crane. The miner was riding on the 3,000-pound weight as it was being lifted. One of the pins pulled out of the weight causing the miner to lose his balance and fall 35 feet to the ground.
	C-1995-41	Cleaning - spilled and built-up material	belt	The belt structure was being used to route and sort coal at the discharge locations where the different grades of coal are discharged and stored on the ground. Six miners were shovelling the coal spillage when the belt structure shifted, broke free, and fell. One miner fell with the collapsed structure and died.
	C-1995-21		belt	A roof-bolting machine operator was attempting to cross a moving conveyor belt. The miner lost his balance and fell onto the belt, which carried him over a head roller, resulting in fatal injuries.
	M-1996-20	Installation/repair		The miner was working on an elevated crusher installing bolts in the I-beam supports for the crusher hopper. He slipped off the crusher and fell 15 feet to the ground resulting in fatal injury.
	M-2004-16	Installation/repair	belt	During the installation of conveyor belt, the victim was standing on the steel support structure for the conveyor and fell 12 feet when the rope he was pulling unexpectedly came loose from the end of the belt.
4.0 Miscellaneous	M-2002-12	Cleaning – spilled and built up material	belt	Worker was clearing a blockage inside a cement clinker drag conveyor located in a tunnel. The victim got fatally burned due to outburst of the steam.
	M-2006-11	Installation/repair		Victim was working from the bucket of a front-end loader to install a roller on a conveyor belt 15 feet above ground. Accident occurred when the loader moved forward crushing the victim against the conveyor framework.
	M-2005-31			The victim was moving a radial stacking conveyor to a new location. He was fatally injured when the wheels of the conveyor got stuck and rolled over him.

	C-2005-6	Cleaning – other		Worker was removing a piece of canvas that was wrapped around the section feeder rotary pick breaker. Accident occurred when the rotary breaker started pulling the victim under the picker.
	C-2004-8	Cleaning – belt assembly		Accident occurred due to performing belt-cleaning task on the moving conveyor belt. This is not clear. We need more explanation

---

9.2 Appendix B: Reviewers Comment Summary

Station	New or Existing	Comment	Meeting
1		**Miner – Safety Information (Safety)**	
	E	Jewellery, rings to be added as part of miner work attire (Law in Virginia)	3
	N	Might want to mention the need for respiratory protection, MSHA does not require it, but it is a common practice	3
1		**Entanglement (Hazard)**	
	E	Miner becomes entangled in environment	2
1		**Pinch Point (Hazard)**	
	E	Move arrow to a lower height of an idler that would be an issue	3
1		**Recognizing Belt Damage (Safety)**	
	E	Mention causes of belt damages in the text.	3
	E	Use picture of belt splicing and damages instead of sketch/diagram	3
1		**Inspect Handrails (Safety)**	
	E	Max. Railing ht 42” & middle rail ht 21” from walking surface	3
	E	Detailed pre-shift inspection- of Handrail, walkways, guarding, etc. does not happen. Only obvious issues are typically noticed.	3
	E	Failed weld joints is a major problem	3
1		**Falling Material (Hazard)**	
	E	A miner should have constant awareness of the possibility of material falling from a conveyor belt.	4
2		**Falling From Heights (Safety)**	
	N	Add scenario for fall protection in relation to using safety harness.	3
2		**Drive Motor (Component)**	
	E	Drive motor guarding very important. Guards need to be bolted	3
2	N	**Harness needed to perform work (Safety)**	
	N	Catwalk can only access one side of the conveyor belt. A harness is needed when working on any part of the conveyor not immediately accessible from the catwalk.	3

3		**Tail Pulley (Component)**	
	E	Need guards above gravity take up at walkway level	3
3		**Missing Guarding (Safety)**	
	N	Individual components needs to be guarded Guards need to be 4”-6” above ground to hose out the spillages underneath.	3
	E	Tail pulley guards are good looking in the animations but not practical- use site pictures to update it.	3
3		**Impact Idler (Component)**	
	N	Need to show guarding around the impact idler.	3,4
4	N	**Cross-over (Component)**	2
	N	Need guarding at any exposed moving parts near the crossover catwalk	3
4		**Bend Pulley (Component)**	
	N	Need guarding near catwalk & crossover	4
4		**Take-up Pulley (Component)**	
	N	Need guards above gravity take up at walkway level	3,4
	N	Grease lines should run from the take-up pulley and bend pulley to a location on the catwalk or on the ground	4
5		**Lock-out & Tag-out (Safety)**	
	N	In animations add names on the locks or tags to the locks.(tag out procedure)	3
	N	More than one lock can be placed on a breaker if more than one person is working on that piece of equipment.	3
	N	Only the person who placed the lock should remove the lock. Only the foreman (or project manager depending on plan) can remove someone’s lock after contacting the person, or after thorough inspection to make sure that work is complete and that person is not within the area of the conveyor belt.	3
	N	Each worker is responsible for their locks; they need to be tagged or labeled with who is responsible for the lock. Some locks are kept on the person; others are kept in a cabinet near the breakers, depending on the operation.	3
6	N	**Control Tower Alarm (Safety)**	2
6	N	**Start-up Procedures (Safety)**	2
G	N	Missing emergency shut-off on inclined belt	2
G	N	Go-back buttons	2
G	N	Grease lines can be used for lubricating bearings	2
G	N	Start-up Procedures	2
G	N	Explain what the alarm is used for	2
G	N	The belt needs to be stopped before the breaker is turned off, otherwise it might explode or start a fire.	2
G	N	Consider having material spilled on catwalk and how to deal with it.	4