January 2019

Training Effectiveness Analysis Of Osha Silica And Excavation Safety Standards For Construction

Bedel Desruisseaux
Wayne State University, fn3043@wayne.edu

TRAINING EFFECTIVENESS ANALYSIS OF OSHA SILICA AND EXCAVATION SAFETY STANDARDS FOR CONSTRUCTION

by

BEDEL DESRUISSEAUX

THESIS

Submitted to the Graduate School

of Wayne State University

Detroit, Michigan

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

2019

MAJOR: Civil Engineering

Approved By:

____

Advisor Date

DEDICATION

Dedicated to God, family and friends.

ACKNOWLEDGMENTS

Completion of this master thesis was possible with the inspiration and support of several individuals. I would like to express my sincere gratitude to all of them.

Firstly, I would like to thank my advisor, Dr. Mumtaz A. Usmen, Ph.D., PE for his valuable guidance, support and encouragement throughout my Civil Engineering study.

I would like to thank my co-advisor: Dr. Emrah Kazan, Ph.D. and my thesis committee member: Dr. Hwai-Chung Wu, Ph.D. for all of their guidance through this process; your discussion, ideas, and feedback have been invaluable.

I would like to express my special thanks to everyone at Wayne State University, Detroit, MI, USA and at the American University of the Caribbean, Les Cayes, Haiti who has helped me achieve this educational goal. I would like to acknowledge the financial support I received through graduate/teaching assistant scholarships from WSU Department of Civil and Environmental Engineering. I want to thank OSHA Susan Harwood Program. The data used for this research study was acquired through two Susan Harwood grants, SH-29666-SH6 and SH-31218-SH7.

Lastly, I would like to express my deepest appreciation to my wife, Rose Stephanie Loubeau, my daughter, Christ-Anne Berlourdes Desruisseaux, my mother, Ghislène Lucien, my father, Brunel Desruisseaux and my sisters, Naomie, Adeline and Flaure-Dany Desruisseaux, my uncle Jean Ledic Lucien, my friend Norbert Kidd and the priests, brothers and sisters in GOD at Our Lady of the Rosary parish for their endless love, support, and encouragement. I would like to thank other people who have also supported me such as, Mr. Nazaire Yvan, Mrs. Ann M. Clark, Mr. Jean Denis Lucien, Mrs. Ann Capela, Mr. & Mrs. Hervé Jocelyn, Mrs. Elizabeth Luzsinski, Mr. Jean Phillippes Lucien and Mr. Pierre Claude Desruisseaux. I am forever grateful to God, my family, colleagues and friends for supporting and encouraging me through all of my opportunities and experiences that made me who I am. Please, receive my appreciation of your support!

Bedel Desruisseaux

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Overview

This chapter emphasizes the reasons for continuing to provide safety training in the United States and determines the importance of safety training based on the latest analysis of the U.S. Bureau of Labor Statistics, U.S. Department of Labor, November 2018. “Training means maintenance and improvement of the level of performance of a person in a section or a department.”, Uma S. N, 2013. This study focuses on the analysis of different training topics and different delivery methods with one model of training effectiveness evaluation. The ultimate goal is to find out the most effective training system in order to improve safety of all workers.

1.2 Safety issues in the U.S. Construction industry based on OSHA

The two training topics are developed on Respirable Crystalline Silica (29 CFR 1926.1153) and on Excavation and Trenching (29 CFR 1926 Subpart P) safety standards, both applicable to the construction industry. In addition, the trainees who receive the silica and excavation trainings are primarily involved in the construction industry. The trainings are developed to recall workers their rights under the Michigan OSH Act, to tell them how to limit their exposures and to prevent health risks relevant to silica and excavation or trenching in their daily jobs, in addition to how to comply with the Occupational Safety and Health Administration (OSHA) standards. The model is not developed only to serve the construction industry and we aim to share and learn with other industries to improve safety of all workers.

Every workplace presents its own unique hazard. Nevertheless, everyone must be safe at work. According to the 2017 SURVEY OF OCCUPATIONAL INJURIES & ILLNESSES CHARTS PACKAGE released on November 8, 2018, the number of nonfatal occupational injuries and illnesses by private industry sector was 194.3 thousand and 3.8 thousand respectively for the U.S. construction industry in 2017. **Figure 1** shows a distribution of nonfatal occupational injuries and illnesses by private industry sector, 2017. Other industry sectors such as health care and social assistance, manufacturing, retail trade, accommodation and food services, transportation and warehousing recorded more injuries and illnesses than the construction industry in 2017. The other industry sectors have recorded fewer injuries and illnesses than the construction industry. The safest sector has been the mining, quarrying, and oil and gas extraction (U.S. Bureau of Labor Statistics, 2018).

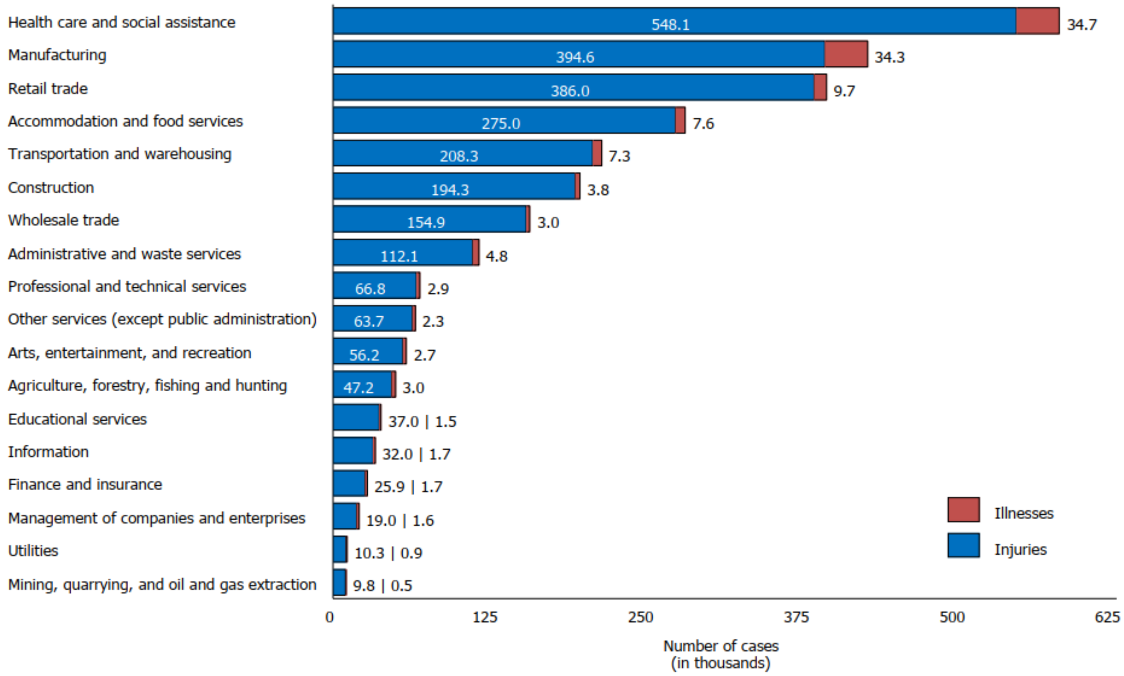

Figure 1: Distribution of nonfatal occupational injuries and illnesses by private industry sector, 2017

A total of 5,147 workers died from an occupational injury in 2017 (3.5 per 100,000 full-time equivalent workers) — approximately 99 a week or 14 deaths every day. This number has decreased by 1 percent from 2016. In other words, all-event total for 2017 is lower by 43 cases than the 2016 total. However, this diminution still keeps this number higher than the number archived for the last previous seven years between 2009 and 2015. During those seven years, the total of workers died did not reach five thousand. **Figure 2** shows the change in fatal work injury counts by event, 2016–17. (https://www.bls.gov/news.release)

The hazards associated with silica and excavation tasks vary among the events. The change in fatal work injury counts by event shows in **Figure 2** that the number of fatalities has increased for some events while the number has decreased for some other events. The event of exposure to harmful substances or environment comprises the Respirable Crystalline Silica standard which is one of the training topics. The event of falls, slips, trips has increased the most in term of fatalities from 2016 to 2017. During excavation and trenching activities, falls, slips and trips can happen if the recommended safety practices are not applied in a construction worksite.

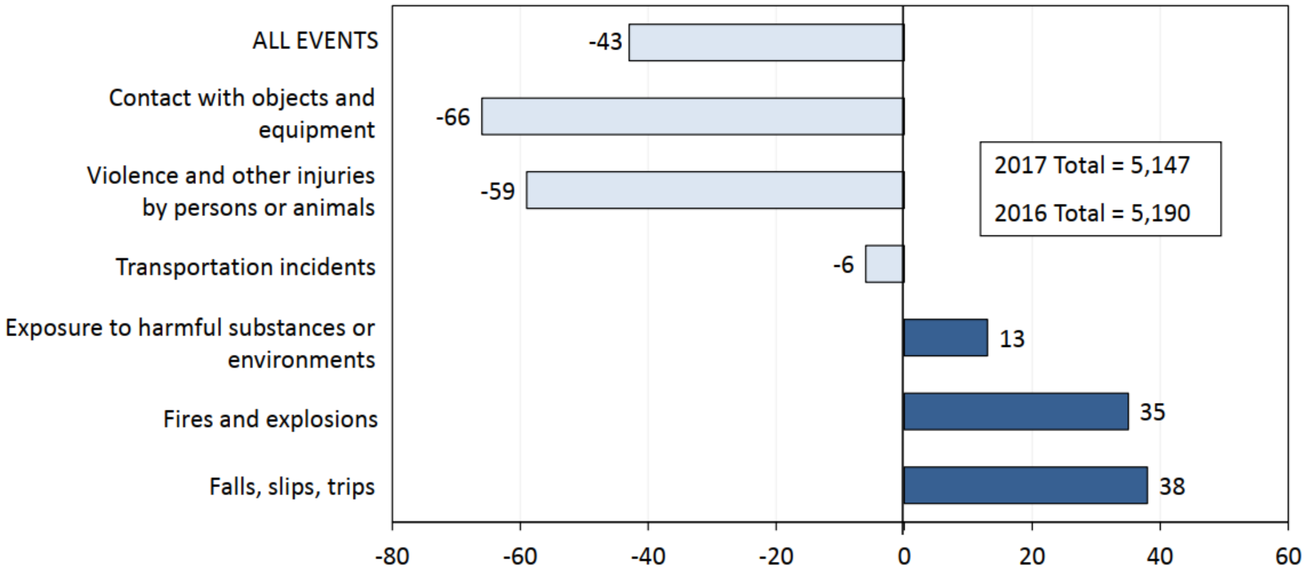

Figure 2: Change in fatal work injury counts by event, 2016–17

Out of 5,147 worker fatalities in private industry in calendar year 2017, 971 or 18.87% were in construction — approximatively, one in five worker deaths last year was in construction. (https://www.osha.gov/oshstats/commonstats.html). **Figure 3** shows that fatal occupational injuries are caused by the following main event or exposure: 1) falls, slips, trips (40 %); 2) transportation incidents (24 %); 3) exposure to harmful substances or environments (15 %); 4) contact with objects and equipment (14 %); 5) Violence and other injuries by persons or animals (6 %); 6) fires and explosions (1 %). Further decantation of those fatalities leads to the construction fatal four for 2017 which is developed in the next paragraph.

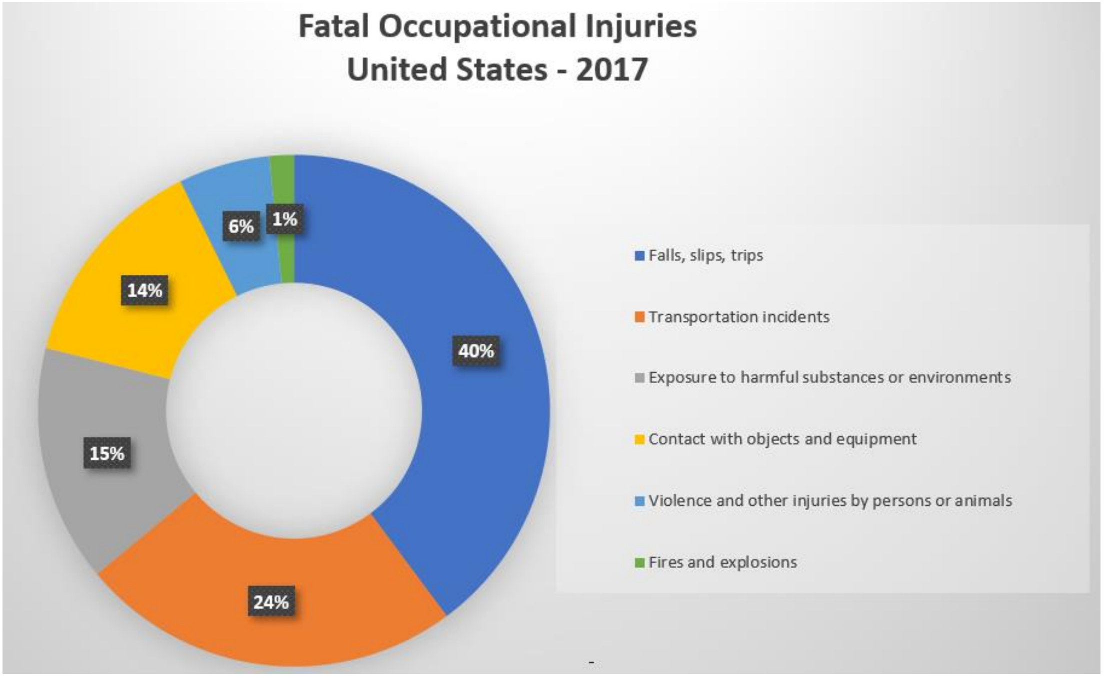

Figure 3: Fatal occupational injuries, United States - 2017

Among the fatal occupational injuries, the construction's fatal four remain falls, struck by object, electrocutions and caught-in/between. **Figure 4** shows the repartition of the fatal injuries. Fall has been counted for 381 of the 971 total deaths in construction in 2017. Unfortunately, falls caused approximately 39 % of total deaths in construction in 2017; followed by struck by object (80 deaths for 8 %); electrocutions (71 deaths for 7 %); and caught-in/between (50 deaths for 5 %). Caught-in/between includes construction workers killed when caught-in or compressed by equipment or objects, and struck, caught, or crushed in collapsing structure, equipment, or material. (https://www.bls.gov/iif/oshwc/cfoi/cftb0321.htm). The rest of 389 deaths represent other fatalities.

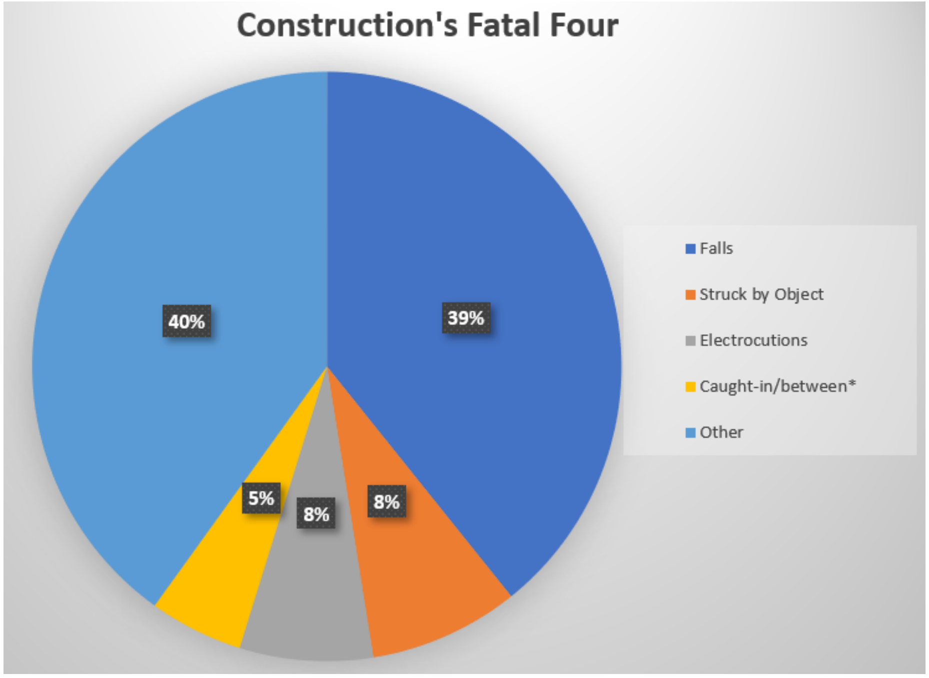

Figure 4: Construction's Fatal Four, United States - 2017

Tendonitis; fractures; carpal tunnel syndrome; multiple injuries and fractures; and amputations were identified as the five main injuries and illnesses in decremental order (U.S. Bureau of Labor Statistics, 2018). Those injuries and illnesses continue to happen in different construction tasks and other tasks in other industry sectors. Each training gives an employee the ability to prevent hazard, recognize hazard and how to correct hazardous situation in the workplace. A more experienced and trained employee can play the role of a competent person if he or she is designated by the employer. The culture of safety is also important inside the company. Training is part of the solution to mitigate safety issues. After completion of the training, management support is necessary to obtain the best behavior and results.

Respirable Crystalline Silica and Excavation hazards occur in multiple major events such as fall, slips, trips; contact with objects and equipment; exposure to harmful substances or environment; fire and explosions. According to **figure 5**, workers count for 2236, (43.44%) of 5,147 fatal work injuries, who have passed away in these events. The hazardous situations are present in multiple tasks. In addition, construction safety and health standards evolve due to changing industry practices and stakeholder expectations, and as the mandates get stronger for compliance with these standards, the need for training programs becomes more pronounced.

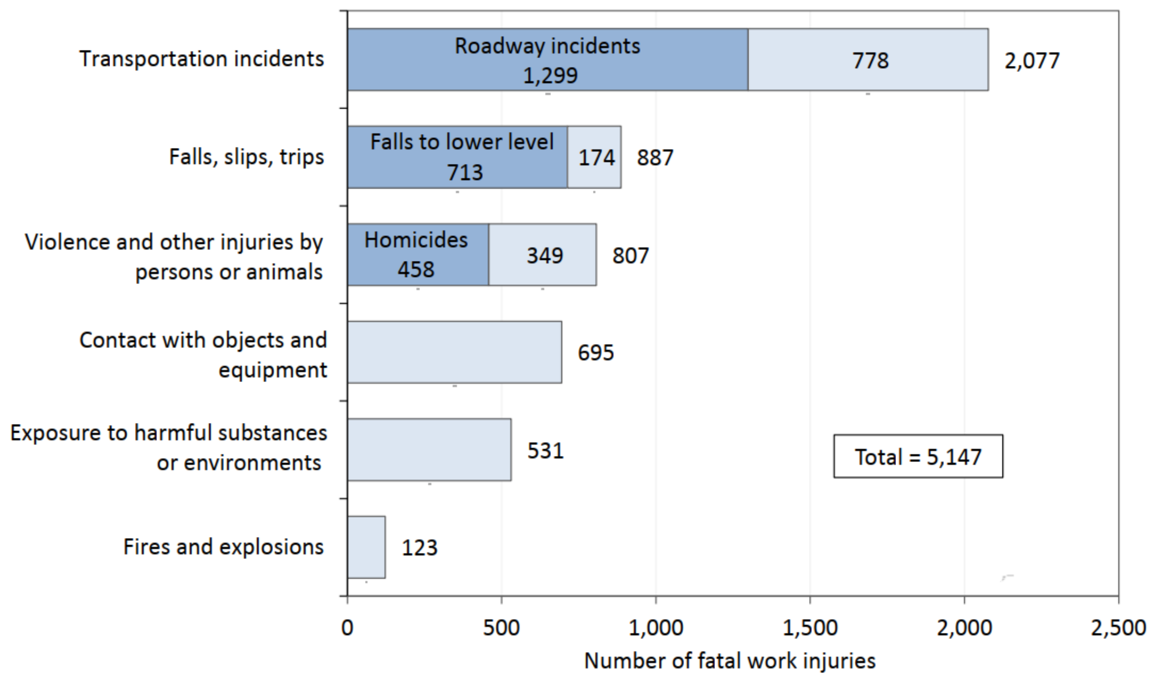

Figure 5: Fatal occupational injuries by major event, 2017

1.3 Occupational Safety and Health Administration (OSHA)

OSHA sets enforcement policy and targeted inspection programs, and responds to fatalities, catastrophes and complaints. Under federal law, all workers are entitled to a safe workplace. An employer must provide a workplace free of known health and safety hazards. However, OSHA is a small agency which contains approximately 2,100 inspectors responsible for the health and safety of 130 million workers, employed at more than 8 million worksites around the nation — which translates to about one compliance officer for every 62,000 workers or one officer for every 3800 worksites (https://osha.gov).

The inspectors penalize those who don't comply with OSHA standards. The top ten most frequently cited standard for all industries from October 1st , 2016 to September 30, 2017 were: 1) Fall protection, construction; 2) Hazard communication standard, general industry; 3) Scaffolding, general requirements, construction; 4) Respiratory protection, general industry; 5)

Control of hazardous energy (lockout/tagout), general industry; 6) Ladders, construction; 7) Powered industrial trucks, general industry; 8) Machinery and Machine Guarding, general requirements; 9) Fall Protection–Training Requirements; 10) Electrical, wiring methods, components and equipment, general industry. (https://www.osha.gov/Top_Ten_Standards.html)

OSHA also improves safety in the industry with outreach training programs. **Figure 6** shows the number of trainees who have been beneficiaries of trainings in last ten years. The number of trainees has continued to increase every year since the year of 2012. The number of trainees has reached the level of one million for the first time in the last ten years for the fiscal year of 2018. (https://www.osha.gov/dte/outreach/outreach_growth.html)

Figure 6: Outreach Training Program Annual Number of Trainees

Chun-Ling Ho and Ren-Jye Dzeng, 2010 have found that suitable education training mode and suitable training course content can reinforce the safe behavior of labor operation, no matter the age, education degree and information accomplishment of labor. For this reason, OSHA requires employers to provide training to workers who face hazards on the job. Before engaging in any potentially hazardous activities, workers must receive appropriate safety training from their employer, as defined in OSHA standards. (https://www.osha.gov/dte/). OSHA also creates training materials, distributes training grants to nonprofit organizations, and provides training through authorized education centers to prevent fatalities, injuries and illnesses.

1.4 Training Topics

The trainings are developed on Respirable Crystalline Silica (29 CFR 1926.1153) and on Excavation and Trenching (29 CFR 1926 Subpart P); all as applicable to the construction industry. The training material development and program delivery and evaluation efforts are associated with the recently revised standards promulgated by the US Department of Labor Occupational Safety and Health Administration (OSHA).

1.4.1 Respirable Crystalline Silica Standard

Crystalline silica is a common mineral found in the earth's crust. It is a common mineral found in many naturally occurring and man-made materials used at construction sites. Silica, also called silicon dioxide, is a compound of the two most abundant elements in Earth’s crust, silicon and oxygen, SiO_2. The mass of Earth’s crust is 59 percent silica, the main constituent of more than 95 percent of the known rocks. Silica has three main crystalline varieties: quartz (by far the most abundant), tridymite, and cristobalite. (https://www.britannica.com/science/silica)

Silica sand is used in construction product in the form of Portland cement, concrete, and mortar, as well as sandstone. Respirable Crystalline Silica is released in the air by grinding and polishing glass and stone; in foundry molds; in the manufacture of glass, ceramics, silicon carbide, ferrosilicon, and silicones; as a refractory material; and as gemstones. Most often, silica gel is used as a desiccant to remove moisture. For instance, sand, stone, concrete, and mortar contain crystalline silica. It is also found in common products such as glass, pottery, ceramics, bricks, and artificial stone.

Silica is almost everywhere but it is only dangerous if it is small enough to become respirable. Respirable crystalline silica is a very small particle at least 100 times smaller than ordinary sand size of 0.0625 mm (or 1⁄16 mm) to 2 mm. Silica is respirable because of its size. Silica can be considered as a nanomaterial; a material having particles or constituents of nanoscale dimensions, or one that is produced by nanotechnology. Unfortunately, silica can enter inside the human body; especially in a person's lung. It is small enough to be inhaled during normal inspiration.

Workers who inhale these very small crystalline silica particles are at increased risk of developing serious silica-related diseases, including: Silicosis, an incurable lung disease that can lead to disability and death; Lung cancer; Chronic obstructive pulmonary disease (COPD); and Kidney disease. According to OSHA, people in the U.S. who are exposed to silica at work are estimated to 2.3 million. To protect workers exposed to respirable crystalline silica, OSHA has issued two respirable crystalline silica standards: one for construction, and the other for general industry and maritime. (https://www.osha.gov/dsg/topics/silicacrystalline/)

Silica exposure has been increased with the increased use of nanotechnology materials. Respirable Crystalline Silica is created when drilling, grinding, cutting, sawing, and crushing stone, concrete, brick, block, rock and mortar. In order words, the activities such as sanding or drilling into concrete walls; sawing brick or concrete; abrasive blasting with sand; grinding mortar; manufacturing brick, concrete blocks, stone countertops, or ceramic products; and cutting or crushing stone result in worker exposures to respirable crystalline silica dust. Industrial sand used in certain operations, such as foundry work and hydraulic fracturing (fracking), is also a source of respirable crystalline silica exposure.

The first thing to know about the silica standard while performing one of the above tasks is the Action Level (AL): Exposures at or above this concentration (25 $\mu g/m^3$ 8-hour TWA), trigger requirements for exposure assessment. The standard should be applied if the task performed is above the action level. The engineering control method should be used to protect workers from exposure to respirable silica dust. The second is the Permissible Exposure Limit (PEL): The maximum amount or concentration of a chemical that a worker may be exposed to under OSHA regulations (50 $\mu g/m^3$ 8-hour TWA). If the task performed is above the PEL level, the employer must provide and the employee should use an adequate respirator in addition to the engineering control method. The AL and PEL levels vary with the Time Weighted Average (TWA): the time-weighted average exposure for the work shift. The standard does not apply if the exposure is below the allowed AL as an 8-hour time-weighted average (TWA) under any foreseeable conditions.

The silica standard provides specified exposure control if the task is covered by the standard. Employers can either choose to 1) Use a control method laid out in Table 1. This (https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1153) is a link to access to this table. Or 2) Alternative exposure control methods such as to measure workers' exposure to silica and independently decide which dust control methods work best to limit exposures to the PEL in the workplaces.

Regardless of which exposure control method is used, all construction employers covered by the standard are required to: 1) Establish and implement a written exposure control plan that identifies tasks that involve exposure and methods used to protect workers, including procedures to restrict access to work areas where high exposures may occur. 2) Designate a competent person to implement the written exposure control plan. 3) Restrict housekeeping practices that expose workers to silica where feasible alternatives are available. 4) Offer medical exams- including chest X-rays and lung function tests-every three years for workers who are required by the standard to wear a respirator for 30 or more days per year. 5) Train workers on work operations that result in silica exposure and ways to limit exposure. 6) Keep records of exposure measurements, objective data, and medical exams.

1.4.2 Excavation and Trenching Standard

Excavation and trenching are among the most hazardous construction operations. The Occupational Safety and Health Administration's (OSHA) Excavation standards, 29 Code of Federal Regulations (CFR) Part 1926, Subpart P, contain requirements for excavation and trenching operations. (U.S. Department of Labor - Occupational Safety and Health Administration - OSHA 2226-10R 2015)

OSHA defines an excavation as any man-made cut, cavity, trench, or depression in the Earth's surface formed by earth removal. A trench is defined as a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth of a trench is greater than its width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 m).

OSHA classifies the soil into four categories. 1) Stable rock – the most stable type; 2) Type A – very stable. (e.g. clay, cemented soils); Type B – less stable than type A (crushed rock, sand – silt mixtures); Type C – less stable than type B. (unstable gravel and sand). OSHA requires protective systems for excavations deeper than 5 ft in all type of soils except in stable rock. Furthermore, the protective systems such as sloping, benching and shoring should be designed by a registered Professional Engineer (PE) for excavation deeper than 20 ft for any soil type and for excavation exceeding 5 ft in depth in type C soils.

OSHA Excavation and Trenching standard recalls the workers their rights; how hazardous soil is; a cubic yard of soil may weigh as much as a small car (2700 pounds), enough to kill a worker; and how to control cave-in hazard in the workplace with 1) Engineering Controls such as protective systems (sloping, benching, shoring); access and egress (ramps and ladders); protective system selection; protective system installation, maintenance and removal and 2) workplace control such as training and site inspection, by a competent person and Professional Engineer (PE). (https://www.osha.gov/Publications/osha2226.pdf)

Lastly, in order to comply with OSHA standards during an excavation and trenching operation a competent person or professional engineer needs to consider the following excavation hazards: traffic; proximity and physical condition of nearby structures; soil classification; surface and ground water; location of the water table; overhead and underground utilities; weather; quantity of shoring or protective systems that may be required; fall protection needs; and other equipment. Employers also need to maintain materials and equipment used for protective systems; to provide means of access and egress for workers; to provide protective equipment, and to have a rescue or recovery operation plan.

Trenching and excavation work presents serious hazards to all workers involved. Cave-ins pose the greatest risk and are more likely than some other excavation-related incidents to result in worker fatalities. Employers must ensure that workers enter trenches only after adequate protections are in place to address cave-in hazards. Other potential hazards associated with trenching work include falling loads, hazardous atmospheres, and hazards from mobile equipment. The compliance with the Excavation and Trenching safety standards is required during the performance of excavation and trenching activities that are covered by the standard.

1.5 Safety Training Delivery Methods

Training can be provided in different ways such as synchronous virtual classroom technology blended with traditional face-to-face classroom, self-directed, self-paced, web-based training, classroom or instructor led, interactive methods, hands-on training, computer-based training, online or e-learning. The respirable crystalline silica and a part of the excavation and trenching trainings have been delivered with a traditional delivery method. The other part of the excavation and trenching training has been delivered with an online delivery method.

1.5.1 Traditional Training

Traditional training is considered as face-to-face classroom, interactive methods and hands-on training because of the key role of the instructor. Even though e-learning training methods are evolving, traditional training methods remain the most popular training methods for trainers. However, the success of this type of training depends on the performance of the lecturer, and it is more applicable to small group of trainees.

The outreach program of OSHA has reached a total number of 1,066,005 trainees for the fiscal year of 2018. Trainees counted for 340,022, this means that 31.9 percent of the trainees have received their training online. The rest, 68.1 percent of the training delivery system, has been conducted by using traditional methods. A traditional delivery method has also been used to deliver the respirable crystalline silica and a part of the excavation and trenching trainings.

1.5.2 Online Training

As workplaces become increasingly more complex, technologically advanced and decentralized, employee safety training must continue to evolve as well. Thus, more employers and OSH professionals are turning to online tools. More economical and less time-consuming than traditional classroom-based programs, online training can reach more employees at a lower cost. (Glenn Trout, 2016). Online training could be self-paced, self-directed and computer-based.

The successful growth of online training is rooted in a deeper understanding of employee learning behaviors. Today's workforce is younger and culturally diverse, so companies can no longer adopt a one-size-fts-all approach to deploying critical safety information (Glenn Trout, 2016). Therefore, the other part of the excavation and trenching training has been delivered with an online delivery method.

Online training can be considered as one of the reasons why older workers have higher fatal injury rate than young workers, according to **figure 7** (U.S. Bureau of Labor Statistics, Current Population Survey, Census of Fatal Occupational Injuries, 2018). Despite their experiences, the advance of technology and the complexity of training tools can make it more difficult for older workers to stay updated in ways to protect themselves. Thus, the necessity of continuing to consider a blend with the traditional training method.

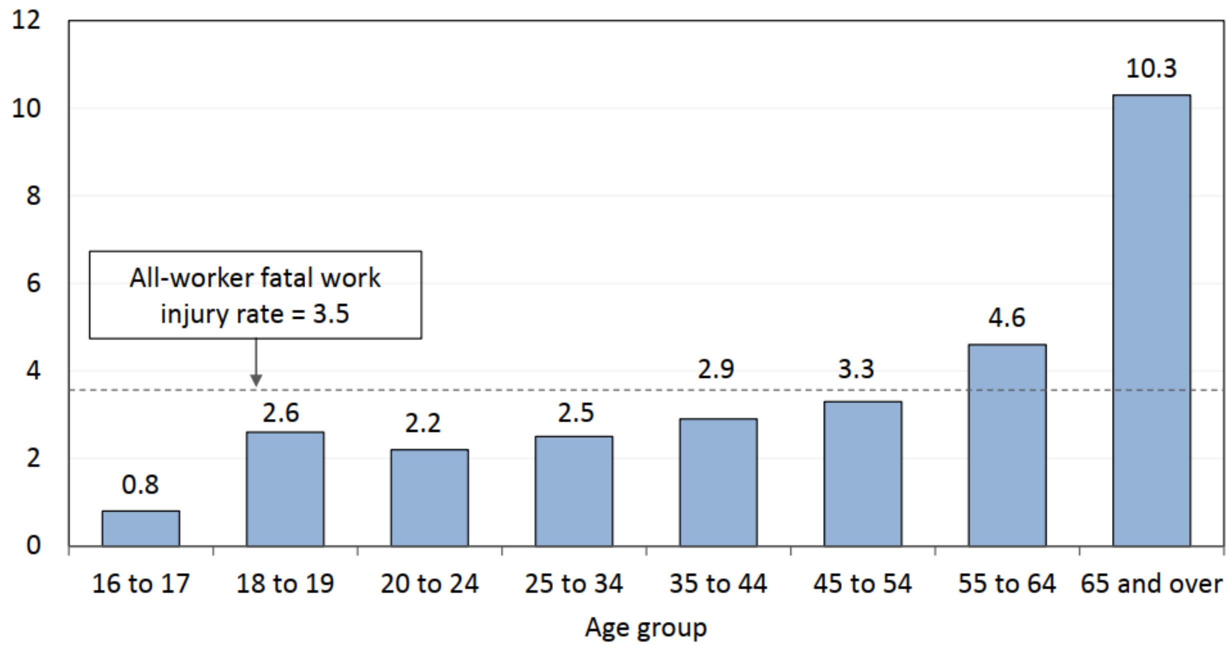

Figure 7: Rate of fatal work injuries per 100,000 full-time equivalent workers by age group, 2017

1.6 Donald Kirkpatrick Training Effectiveness Evaluation Model

A trainer's goal for a training is to make it a valuable experience. The trainer wants the trainees to feel good about the instructor, topic, materials, presentation and venue. (https://www.mindtools.com/pages/article/kirkpatrick.htm). Refer to chapter 2 for further details about Kirkpatrick training evaluation model. Workplaces are larger, more spread out and more diverse than ever. As a result, training solutions must accommodate multiple facilities, learning styles, cultural differences and different languages. (Glenn Trout, 2016). The following paragraphs provide information about ways to evaluate safety training.

The primary model for answering evaluation questions in regard to training has been a four-level evaluation approach proposed by Donald Kirkpatrick. Others, such as Warr, Bird, and Rackham, 1970, have proposed similar four-level evaluation approaches, although Kirkpatrick's is known best (Roger Kaufman, John M. Keller). The four levels of training evaluation criteria proposed by Kirkpatrick are: 1) Reaction: how learners feel about the training. 2) Learning: learner performance on test. 3) Behavior: the extent to which learners implement or transfer what they learned. 4) Result: organizational benefits, stated in terms of organizational performance or return on investment derived from a training. The multiple influences on results pertaining to transfer and organizational effects are associated with other performance improvement operations such as initiatives of strategic planning, organization development.

Susan Harwood training grants also used level 1, 2, 3 of Kirkpatrick to evaluate training effectiveness. Level 1, 2, 3 and 4 of evaluation are linked or interconnected. (Alliger et All.,). In a similar approach, the model of Kirkpatrick is also adopted to evaluate the training systems at levels 1 and 2 only.

1.7 Problem Statement

Construction industry is continuously trying to improve its record of safety. Even though a lot of time and money are invested in training, some safety issues still remain. This study picks two relevant topics that demand the most needed attention. The first grant topic is on respirable crystalline silica and the second is on excavation and trenching.

Compliance to OSHA standards provide the safest and best practices to reduce fatalities, injuries and illnesses. With the data collected from two of the grants received from Susan Harwood, the construction management lab at Wayne State University conducts analysis to determine the effectiveness of the training systems utilized.

Training is an essential solution to safety issues. In this study, we aim to know how effective is our training systems by using the level 1 and level 2 of Kirkpatrick model of training effectiveness evaluation.

1.8 Objective of the study

The objective of the study is to find the effectiveness of the training systems used for Respirable Crystalline Silica and Excavation. The two mentioned grants are used as case studies to apply the Kirkpatrick model of training effectiveness evaluation. The findings can be used for effective training in the construction industry and ultimately to improve safety of all workers.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

This chapter focuses on the overall processes of safety training effectiveness evaluation. It covers topics related to training delivery, evaluation and effectiveness, and Kirkpatrick level 1, 2, 3 and 4 of training effectiveness evaluation. The Kirkpatrick model of learning evaluation is mostly used for training effectiveness evaluation. In addition, the research need and justification of the study are developed.

2.2 Safety Training based on OSHA standards and resources

Knowledge of the standard is the primary key for successful implementation of best safety practices for elimination of hazardous situation in the workplace. Workers must receive appropriate safety trainings from their employer before being engaged in any hazardous activities. For this reason, OSHA offers three different ways a worker can be trained.

First of all, the outreach program such as OSHA 10-Hour and 30-Hour certificates programs which provide workers with some safety responsibility a greater depth and variety of training on hazard identification, avoidance, control and prevention. Secondly, OSHA Training Institute Education Centers also deliver occupational safety and health training to the public and private sectors in all industries. Lastly, SUSAN HARWOOD TRAINING GRANT which are grants awarded by OSHA on a competitive basis to nonprofit organizations to help them develop and deliver training programs to workers and employers. This study is based on data from SUSAN HARWOOD training grants.

2.3 Background on SUSAN HARWOOD Training Grants

The U.S. Department of Labor’s Occupational Safety and Health Administration (OSHA) has awarded $9.3 million in Susan Harwood federal safety and health training grants to 74 nonprofit organizations nationwide, in 2018. The grants are to provide educational and training programs to help employees and employers recognize serious workplace hazards, implement injury prevention measures, and understand their rights and responsibilities. OSHA also awards

$1million in direct grants to five organizations to train and protect workers involved in hurricane recovery activities. “OSHA National News Release – U.S. Department of Labor, October 1, 2018.”

The Susan Harwood Training Grants Program funds grants to nonprofit organizations, including community and faith-based groups, employer associations, labor unions, joint labor-management associations, colleges, and universities. Target trainees include small-business employers and underserved vulnerable workers in high-hazard industries. “OSHA National News Release – U.S. Department of Labor, October 1, 2018 (https://www.osha.gov/news/newsreleases/national/10012018).

For the fiscal year of 2018, SUSAN HARWOOD Training Grants Program trained 50,133 workers for 10.5 million dollars. In the last five years, 443, 579 workers have received training for this grant for a cost of 52.7 million dollars. (https://www.osha.gov/dte/sharwood/statistics.html). The link for the Targeted Topics and Grant Recipients for the Susan Harwood Training Grant Program: (https://www.osha.gov/dte/sharwood/FY_2018_Susan_Harwood_Grant_Awardees_Abstracts.pdf). In the last five years, our research team from the Department of Civil and Environmental Engineering at Wayne State University provided training to approximately 3,000 construction industry workers and employers in the State of Michigan on various occupational safety subjects through the federal grants received from the Department of Labor (DOL) Occupational Safety and Health Administration (OSHA) Susan Harwood Training Grants program.

2.3.1 Purpose of the SUSAN HARWOOD Training Grant

The Susan Harwood Training Grant program provides funds for developing training materials and providing training to workers and/or employers to recognize, avoid, abate, and prevent safety and health hazards in their workplaces. (https://www.osha.gov/dte/sharwood/best-practices.html). The program emphasizes six specifics objectives: 1) Educating workers on their rights and educating employers on their responsibilities under the Occupational Safety and Health Act. 2) Educating workers and employers in small businesses. 3) Training workers and employers about new OSHA standards. 4) Training at-risk worker populations. 5) Training workers and employers about high-risk activities or hazards identified by OSHA through the Department of Labor's Strategic Plan, as part of an OSHA special emphasis program or other OSHA priorities. 6) Providing technical assistance to employers and workers.

2.4 Safety Training Delivery Methods based on OSHA

The total number of trainees was 1,066,005 for the fiscal year of 2018. 340,022 trainees, 31.9 percent of the trainees, have received their training online. The rest, 68.1 percent of the trainees, have received their training using traditional methods. Another important remark from **Figure 8** is that online percentages continue to increase annually. (https://www.osha.gov/dte/outreach/outreach_growth.html)

Figure 8: Outreach Training Program – Online Trainees as a Percentage of Total Trainees

2.5 Safety Training Evaluation Methods for Susan Harwood Training Grants

The best practices for evaluation of Susan Harwood Training Grants are three required training evaluations which are based on the Kirkpatrick Training Evaluation model—Level 1: Reaction, Level 2: Learning, and Level 3: Behavior/impact – for capacity building grants only. The Kirkpatrick Training Evaluation Model is one of the most widely used models of training evaluation. (For more information see *Evaluating Training Programs*, by Donald Kirkpatrick, 1975.)

The tool used to assess level 1 is a Training Reaction Survey. Sometimes called "smile sheets", training reaction surveys measure the trainee's immediate perceptions of the quality and usefulness of the training. Level 2 is recommended to be assessed by Learning assessments. Learning assessments measure the skills, knowledge, or attitude that the trainees retain as a result of the training. Pretests and post-tests are used, the variation between pretest and post-test scores shows the knowledge gained during training. Alternately, small group activities can serve as a "post-test" to see if participants have gained the knowledge.

Level 3 is recognized as training impact assessments. Training impact evaluations are typically conducted three to six months after the training and can be conducted by written/electronic surveys or by focus groups. Measures include the level of worker involvement on safety committees, increases in the number of formal complaints filed, or increases in sharing safety and health information with co-workers who have not participated in training. (https://www.osha.gov/dte/sharwood/best-practices.html).

2.6 Safety Training Effectiveness

Gulgun Mistikoglu et al., 2014, in a study on decision tree analysis of construction fall accidents involving roofers found that roofers who received safety training were less susceptible to fatality, and accidents involving new construction or addition caused more fatalities than the ones occurring in renovation and rehabilitation type projects. Training is generally recognized to result in, but is not limited to, improved productivity, reduced turnover, improved quality and safety in the construction industry. The Canadian Apprenticeship Forum (2006) found that for each $1 invested in the training of an apprentice a benefit of $1.38, on average, accrued to the employer, i.e. the benefit cost ratio was 1.38:1.

Yinggang Wang et al., 2010, found that investment in craft training was indeed profitable to a project's bottom line in terms of a project being both profitable to the contractor and being completed on schedule. The authors also found that surprisingly very few companies and training organizations were measuring the benefits and cost of craft training. The survey found that only

13% of the respondents indicated that they measured the costs and benefits of their craft training efforts. The two most frequent reasons given for not measuring the costs and benefits were that respondents did not know what should be measured, and many considered training to be essential regardless of any measured return.

Kazan and Usmen, 2018 found that workers who were not trained according to OSHA regulations were 2.54 times more likely to be the victim of a fatal accident than those who were trained. Safety management practices are recognized to not only improve working conditions but also positively influence workers' attitudes and behaviors with regard to safety, thereby reducing accidents on construction sites.

Appropriate training not only includes workers in Occupational Health and Safety programs and activities; it also helps them to acquire the knowledge and skills required for their tasks, and informs them about potential workplace hazards. Such training is very effective in reducing the number of unsafe acts (Iraj Mohammadfam et al., 2016).

Given the current technological environment and the time and cost of construction safety education and training, the effectiveness for introduction of e-learning in construction safety education training was investigated. It was found that increasing occupational safety via the e-learning mode proved to be highly feasible (Chun-Ling Ho et al., 2010). The authors had found in their study that e-learning mode improved learning effectiveness.

Glenn Trout, 2016, supported that online tools were more economical and less time-consuming than traditional classroom-based programs. According to the author online training can reach more employees at a lower cost. Today's online training solutions take workplace and workforce changes into account to improve the way training is conducted.

2.7 Training Effectiveness Evaluation

In 2009, the American Society For Training and Development (ASTD) reported that 78% of training events measured level 1 and 2 while levels 3 and 4 were only measured 25% and 15% of the time, respectively. The highest difficulties found in tracking the result of training are the change of position and various employment of the trainees in the market and the lack of information shared by companies. Another problem is that this measurement is often difficult, due to organizational limitations and because results are the most distal from training “Handbook of training evaluation, 3rd edition, Jack J. Phillips”. Nevertheless, there remains an important need to assess in all businesses, especially in the construction industry.

2.7.1 Kirkpatrick Training Effectiveness Evaluation

Kirkpatrick's evaluation model is a widely used tool to evaluate training effectiveness. A fairly recent study by the American Society For Training and Development (ASTD) reveals that over 60 percent of organizations that evaluate their training programs use the Kirkpatrick model (https://www.td.org/insights/astd-new-study-shows-training-evaluation-efforts-need-help). This study also follows this model, which guides and enables the evaluation of training at four progressive levels.

2.7.1.1 Level 1

The level 1 of Kirkpatrick is reaction evaluation which demonstrates how the trainees felt, and their personal reactions to the training or learning experience, customer satisfaction, engagement and relevance. It is the degree to which participants find the training favorable, engaging, and relevant to their jobs. Trainees verify if the quality of the program and instructor are acceptable. Learner and/or instructor reactions after training; satisfaction with training; ratings of course materials; effectiveness of content delivery could be evaluated at this level.

This task is completed from the answers of the questions asked in the post-training opinion survey, feedback form, verbal feedback, and observation of trainee’s behavior during training. Reactions are assessed by asking trainees how well they like the program. (Eduardo Salas et al., 2006). In this level, trainers measure how the people being trained react to the training; understand how well the training has been received; improve the training for future trainees; and make changes based on information gathered.

Alliger et al. (1997) showed a modest relationship between reactions, learning and transfer of learning when they differentiated between affective reactions (enjoying training) and utility reactions (training's perceived usefulness). Warr et al. (1999) also used a multidimensional reaction measure that differentiated between enjoyment of training, perceptions of usefulness and perceived difficulty. When they made these kinds of differentiators, they found evidence that reactions could be correlated to learning and good learning outcomes.

2.7.1.2 Level 2

The level 2 of Kirkpatrick determines learning evaluation which is the measurement of the increase in knowledge or intellectual capability from before to after the learning experience. Learning refers the degree to which participants acquire the intended knowledge, skills, attitude, confidence, and commitment based on their participation in the training.

This evaluation is feasible firstly by formative methods such as knowledge test/check, discussion, individual/group activity, role play, simulation; secondly by summative methods such as knowledge test/quiz/pre-test and post-test, presentation, teach back, action planning, demonstration, performance test, interview, focus group/group interview. "Handbook of training evaluation, 3rd edition, Jack J. Phillips". The variation between the pre and post results determines learning improvement. The pretest and the posttest scores are compared to see the percentage of improvement. There is improvement if the posttest result is greater than the pretest result.

Baldwin and Ford (1988) were one of the first researchers to introduce a model which proposed three sets of factors related to transfer of learning: (a) trainee characteristics, including ability, personality and motivation; (b) training design, including a strong transfer design and appropriate content; and (c) the work environment, including support and opportunity to use.

Even when learning occurs in training, it is increasingly clear that the transfer climate may either support or inhibit application of learning on the job (Holton et al., 2001; Mathieu et al., 1992). Several studies have established that the transfer climate can significantly affect an individual's ability and motivation to transfer learning to job performance (Huczynski and Lewis, 1980; Roullier and Goldstein, 1993; Tracey et al., 1995; Xiao, 1996).

2.7.1.3 Level 3

The level 3 of Kirkpatrick measures behavior evaluation that is the extent to which the trainees apply the learning and change their behaviors. This level is less easy to quantify and interpret than reaction and learning evaluation. After a training has been completed, a specific time is not identified for when to begin the evaluation at this level. A trainer can do the evaluation after 30 days, 60 days or 90 days or more. It depends on the objectives, expectations and time allocated for the training and the observation. For each period of time, the observation of change in behavior may vary. Other industry such as logging industry has found that training participants have applied knowledge gained from the training throughout their weekly work activities three months after training (Level-3). (Evaluation of safety management and leadership training using mobile technologies among logging supervisors, journal of Agromedicine).

2.7.1.4 Level 4

The level 4 of Kirkpatrick is the result evaluation which has an effect on the business or environment resulting from the improved performance of the trainee. Return on expectation (ROE) and return on investment (ROI) (Level 4 of Kirkpatrick Model) of a company are recognized to be relevant to training effectiveness. However, the evaluation of training at level 4 remains the least to be done because external factors greatly affect organizational and business performance. “Companies that rely primarily on training events alone to create a good job performance achieve around a 15% success rate” – Brinkerhoff, 2006.

2.8 Research Need and Justification

This study is based on two sets of data collected from two grants. The first grant project has been to develop training materials for respirable crystalline silica exposure in the construction industry, covering the identification, evaluation and control of the related hazards while reviewing OSHA’s standard on respirable crystalline silica (29 CFR 1926.1153). The last grant is based on the Excavation and Trenching (29 CFR 1926 Subpart P) standard. The requirement for this grant has been also to develop its training materials. The training materials have been used after OSHA approval in a training system which consists of components covered in more detail in chapter 3.

Quarterly and close out reports have been sent to OSHA as agreed upon in the proposals. They contain the evaluation of the training systems which show the demographic information, reaction (level 1) of the trainees and the success rate of the training.

However, the objective of this study is to find statistically significant correlation of level 1 and level 2, factors affecting Reaction: level 1 - Perception of Knowledge Improvement (PKI), and how Reaction: Level 1 - Perception of knowledge Improvement (PKI) affects Learning: level 2 - Knowledge Improvement Ratio (KIR). The findings are used to improve the overall training systems based on the reaction and recommendation of the trainees.

CHAPTER 3: METHODOLOGY

3.1 Overview

This chapter presents the components of the training systems. First of all, the training materials development covers the appropriate standard based on Susan Harwood requirements. Secondly, a delivery system design has been developed by our research team from the Department of Civil and Environmental Engineering at Wayne State University (WSU) and approved by OSHA. The third component is the recruiting and marketing approach and process to select the construction workers and other employees who need the trainings. Fourthly, the training delivery is implemented. And finally, the data are collected and analyzed through Kirkpatrick model of training effectiveness evaluation at levels 1 and 2.

3.2 Training Materials Development

The work reported here was undertaken under the sponsorship of federally funded grants provided by the OSHA Susan Harwood program in 2017 and 2018. The training materials developed consisted of PowerPoint instructional modules; pretests and posttests to measure incremental knowledge gain; and survey instruments to evaluate the efficacy of the training materials and training delivery systems used in implementing the programs.

The training has been developed in English. In order to reach the Spanish workers, the training materials have been translated into Spanish. The English and Spanish translations of the training materials have been completed and submitted to OSHA for approval. However, this study only uses the data of the English speaking trainees.

This study only focuses on two training materials. The first training material is based on respirable crystalline silica exposure in the construction industry, covering the identification, evaluation and control of the related hazards while reviewing OSHA’s standard on respirable crystalline silica (29 CFR 1926.1153). The second training material is developed on the Excavation and Trenching (29 CFR 1926 Subpart P) standard. All the training materials development has covered the appropriate standard and followed the Susan Harwood program requirements.

3.3 Delivery System Design

Each grant has started with a kick-off meeting where the WSU project team met with the IUOE Local 324 training leadership. During this meeting, project details, objectives and goals are discussed, and planning of the grant activities is initiated. Discussions are held, and suggestions are made on trainee recruitment activities, as well as inviting additional people to the Grant Advisory Committee (GAC).

At the beginning, each project is successfully initiated and the GAC is established successfully. Key personnel are identified during the GAC meetings. A success factor to achieve the task is early interaction with the people who compose the Grant Advisor Committee (GAC) and to get their commitment prior to grant application. Also, the review of existing training resources and needs assessment activity are done.

The committee is composed of Wayne State University (WSU), Operating Engineers Union, and industry representatives. Dr. Mumtaz Usmen of WSU and Mr. Donald O'Connell of the IUOE Local 324 Labor Management Education Committee co-chair the Grant Advisory Committee (GAC). They have had five GAC meetings as scheduled in the proposal. In these regularly scheduled meetings, the committee review project goals and progress towards these goals. An overview of the project is presented, followed by the need assessments for the project. Afterwards, details of how additional trainee recruitment can be done is discussed, with various suggestions coming from the committee members such as such as Emrah E. Kazan, PhD; T. Kulaksik, MS; J. Vaglica, PhD, PE. Guidance and direction are provided to the project team by this group, so the efforts and end products are relevant to the needs of the industry.

The role of the committee is involved in guiding and supporting the efforts. The materials are developed and continuously modified/improved through feedback received from the Grant

Advisory Committee and the trainees. Improvement of operability and reliability are the focus of their efforts.

Afterwards, details of how additional trainee recruitment can be done are discussed, with various suggestions coming from the committee members. Some new contacts from the local construction industry and from new unions/agencies are identified; a list of new groups to be contacted is created; and responsibilities are assigned to various GAC members to pursue recruitment activities with these groups to advertise the grant training opportunity and to enroll new trainees.

3.4 Recruiting and Marketing Approach and Process

Two of the members of the WSU team, Dr. Mumtaz Usmen and Dr. Emrah Kazan, attended the two-day Susan Harwood Trainer Exchange that was held in Washington, D.C. in February, 2015. As part of their attendance, they participated in workshops focusing on Best Practices & Evaluation for Universities/Colleges, Mobile and Online Learning, Training for Construction Workers and Needs Assessment sessions. This event presented fruitful ideas to compare their efforts with those of other grantees and to gain knowledge of best practices.

WSU team members shared their observations and lesson learned from the OSHA Susan Harwood Training Exchange event with the Grant Advisory Committee (GAC) members. A suggestion on issuing certificates to trainees was introduced and supported by the GAC members. It was decided to issue two type of certificates (Certificate of Completion - Trainees who score at least 72 % in the posttest; and Certificate of Participation - Trainees who attend the training sessions but do not achieve the minimum 72 % success rate).

Separately, the group has made a presentation on the grant, training materials, and the delivery system to the Michigan Apprenticeship Steering Committee, Inc. (MASCI). MASCI is an advocacy group made up of professionals from the education industry, manufacturing sector, construction trades and governmental departments of Michigan. Although there is no request for training by any member of this group, they have been made aware of this integrated training system as a possible future resource.

During a meeting, GAC members raised the issue of whether the delivery system requires somebody from the WSU Team to be present at site during training. This suggestion has been welcomed and discussed by the WSU Team. It has been explained to the GAC members that the experience to date has shown that the system is not 100% glitch free; however, with adequate computer expertise and experience, the glitches can be overcome on site to enable continuation and completion of the training sessions by all trainees. Thus, WSU Team has decided to prepare an explanatory document which lists problems that trainees may experience and their possible solutions, which may be related to the web portal, smartphone/tablet settings, hot spots, etc.

The GAC members advertise each year the training grant by having a booth at a one day exhibit event, the Annual Michigan Construction Safety Training Day, in Novi, Michigan. This event is organized by the Associated General Contractors of Michigan. They prepare a poster and hand out flyers as part of this effort, reaching out to a good number of safety professionals from different construction companies. In fact, the members received considerable interest and requests for training sessions from the Michigan Aggregates Association (MAA) shortly after this event. MAA has scheduled some training sessions for operating engineers in aggregate plants and other workers.

The GAC members attended the Wayne State University Constitution Day activity, on September 17, 2015, held on the Macomb Community College campus. This was a debate entitled "The meaning and interpretation of the U.S. Constitution", which was moderated by Jocelyn Benson, Dean of Wayne State University Law School. The team also attended the Wayne State University Constitution Day activity titled Wayne State Civic Festival 2016, on September 15, 2016, held on the Wayne State University campus. They also attended the Wayne State University Constitution Day activity titled Wayne State Civic Festival 2017 in the fourth quarter, on September 14, 2017, held on the Wayne State University campus. They exhibited the project poster on those events, on site, and answered questions from the visitors.

3.5 Training Delivery

Self-paced independent online and instructor led traditional are the two training delivery methods used and evaluated in the scope of this study.

3.5.1 Self-Paced Independent Online

Training is delivered through self-paced PowerPoint instruction using an internet based mobile training delivery system. The delivery system involving QR codes, integrating a proprietary internet portal link with portable cell phones or tablets or computers is adopted for the use of the training materials. This integrated training delivery system is tested and debugged.

All trainees utilize their cell phones or tablets or computers to access the training system by scanning the QR code developed by the project team. The QR code used in the project is shown in **Figure 9**; it is provided to the trainees at the beginning of the training sessions.

Figure 9: QR Code

During the training session, trainees are required to complete the following 5 steps embodied in the training delivery system sequentially as shown in **Figure 10**.

Figure 10: Training Delivery System flow chart

Within this system, once the trainees scan the QR code, they are taken to a registration page to complete online registration; it is the sign-up page (See **Figure 11**). In this sign-up step, the trainees answer some questions on their background, which enable the trainer to capture demographic information. The first training step is taking a pretest to allow the trainer to establish a baseline on how much the trainee already knows on the targeted content. The next step by the trainees is taking self-paced instruction by following a PowerPoint training module that presents health and safety information on the topic.

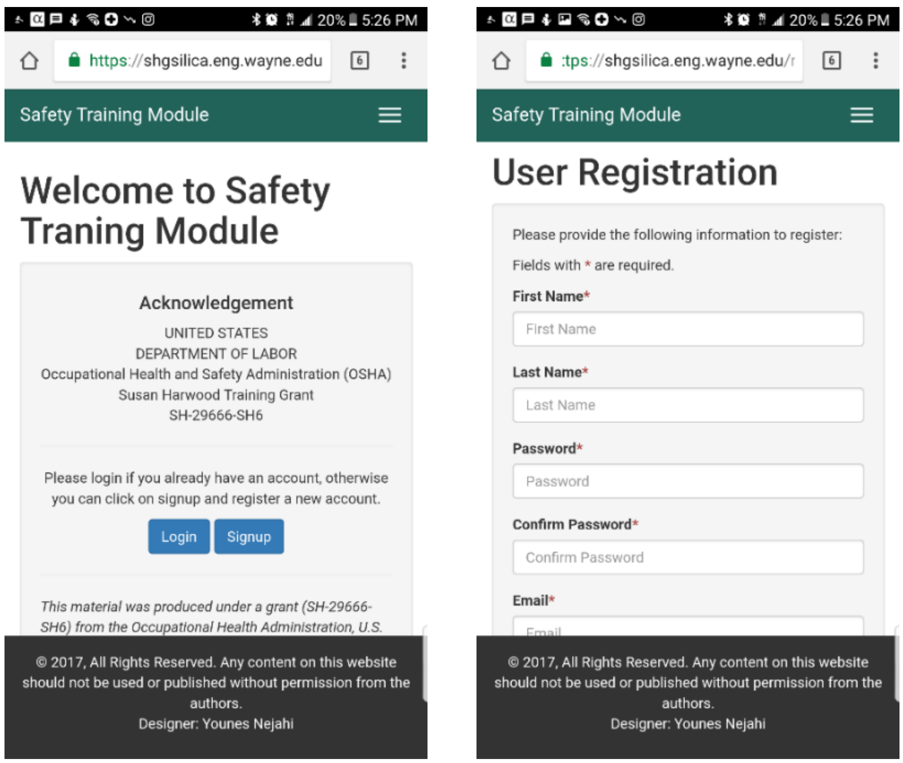

Figure 11: Training Delivery Homepage and Sign-up.

Typically, the training offered covers essential information that comes from the most recent version of the pertinent OSHA standard. Depending on the breadth and depth of the content, there will be one or more posttests on the material presented, which concludes the actual training delivered.

As the pretest and posttest questions are the same, a comparison of the pretest and posttest scores directly indicate knowledge gain (or loss), corresponding to Level 2 evaluation in

Kirkpatrick's learning evaluation model (Kirkpatrick, 1998). The Posttest/Pretest Ratio is adopted as the measure of Knowledge Improvement Ratio (KIR). This ratio shows to what extent the posttest score is higher, same, or lower than the pretest score. An example of pretest and posttest question is shown in **Figure 12.**

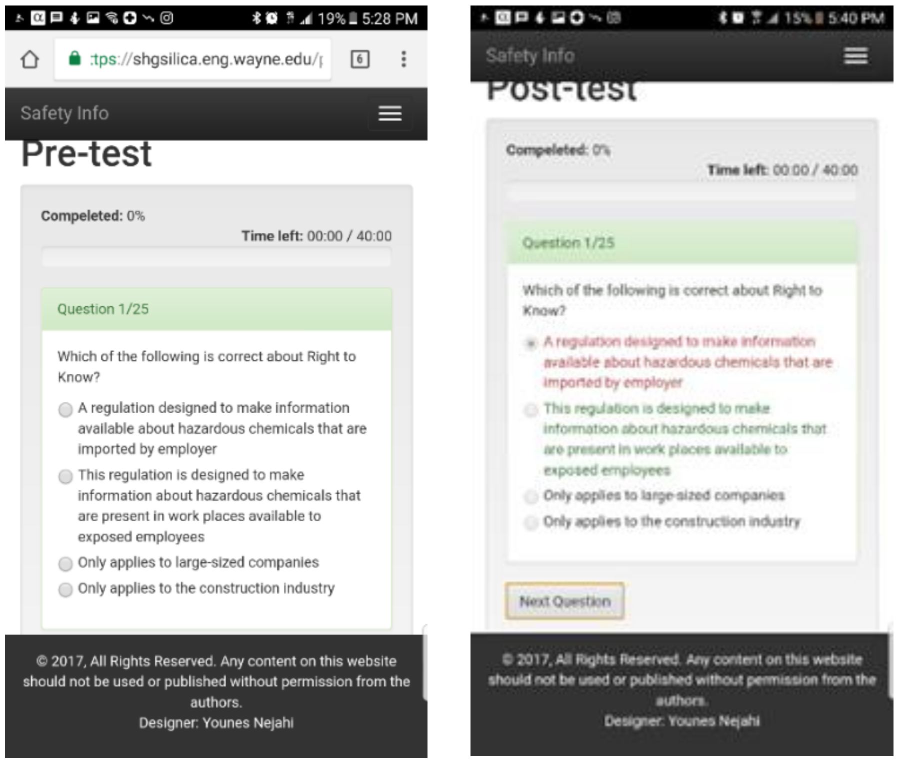

Figure 12: Pretest and Posttest Sections

The final step is an opinion survey (See **Figure 13)** given to the trainees with questions intended to measure their perceptions of the efficacy and effectiveness of the training, the training materials utilized, and the delivery system. Once the post-test is completed trainees proceed onto the survey which captures more demographic information on the trainees and obtains feedback from them on training/system effectiveness. The survey answers are used for level 1 evaluation in Kirkpatrick's reaction evaluation model and for continuous improvement based on the recommendations of the trainees.

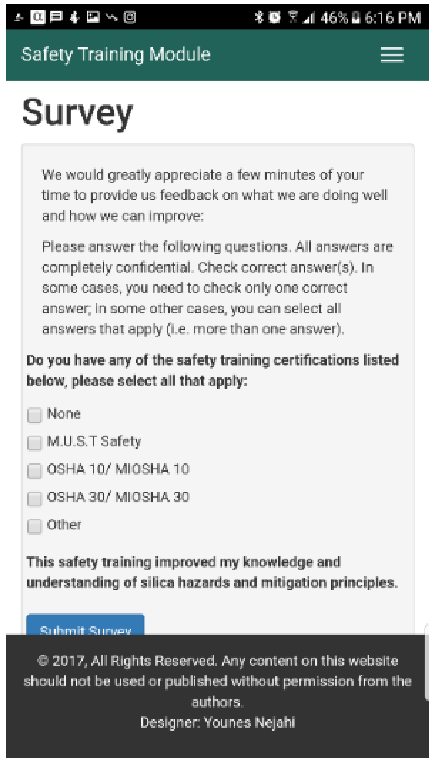

Figure 13: Opinion Survey section

Based on a minimum score of 72 percent on the posttest, the trainees subsequently receive a certificate of participation or completion. The trainees obtain their pretest and posttest scores at the end of the session and download their certificates from the portal. Finally, trainees are guided to logout from the system, concluding the training session.

3.5.2 Instructor Led Traditional

For the traditional training delivery method, the same steps are followed except the QR code scan. For this method, the training modules and exercises are presented in power-point and projected like in a regular classroom by an instructor. The trainees use pens and pencils to fill hard copy of sign up, pretest, posttest and survey. The data are collected and used later for analysis. However, the trainees cannot obtain their pretest and posttest scores nor receive their certificates at the end of the session. Nevertheless, the instructor goes over the questions one by one and clarifies all ambiguities before leaving the training room. The pretest and posttest will be graded later carefully. Based on a minimum score of 72 percent on the posttest, the instructor subsequently sends a certificate of participation or completion to each trainee by mail.

3.6 Training Effectiveness Evaluation (Levels 1 & 2)

Each time training is delivered, it is important to know how it has been delivered to ensure if the training is effective at some levels. For this study, training effectiveness is measured and evaluated through Kirkpatrick Training Evaluation Model (Level-1: Reaction, and Level 2: Learning). A questionnaire/survey is used to capture demographic information on the trainees, and to obtain feedback from them on training/system effectiveness which is used for Level-1 assessment. The survey form is shown in **Appendix A**. Pre-test and post-test are incorporated in each training module, and are used for assessing Level 2: Learning.

This study is based on two sets of data collected from two grants. The first set of data is 721 trainee's responses, collected in 2017 from Respirable Crystalline Silica training, covering the identification, evaluation and control of the related hazards while reviewing OSHA's standard on Respirable Crystalline Silica. The previous set of data has been collected from an Instructor Led Traditional delivery method. The data from the second grant is 405 trainee's responses, collected in 2018 from Excavation and Trenching training. The last set of data is divided into 176 trainee's responses for the Instructor Led Traditional and 229 trainee's responses for the Self-Paced Independent Online training delivery methods.

3.6.1 Type of Data Collected

For this study, the reaction of the trainees in regards to knowledge improvement, understanding, topic, time, materials, presentation, usefulness of training and the instructor are gathered in an opinion survey anonymously. The answers to the questions are rated on a Lickert scale (1-worst; 5-Best). The answers are served as data for level 1: reaction.

The first question of the survey in **Appendix A** stipulates that "The training improved my knowledge". The trainee's answers for this question are recorded as "Perception of Knowledge Improvement (PKI)". The other seven questions of the survey are also used in the abbreviation form of <u>S</u>urvey <u>Q</u>uestion with its Number; for example, <u>SQ#</u>. The abbreviation used for each question of the survey is:

1. This safety training improved my knowledge. (PKI preferred over SQ1)
2. Overall, the safety training materials presented were easy to understand. (SQ2)
3. The PowerPoint presentation was easy to read and follow. (SQ3)
4. The objectives of this training were clearly defined. (SQ4)
5. The topic covered was relevant to me. (SQ5)
6. The time allotted for this training was sufficient. (SQ6)
7. This training experience will be useful in my work. (SQ7)
8. The instructor was knowledgeable on the training subjects. (SQ8)

In the pre-test and posttest forms, the trainees answer the questions about the subjects developed in the PowerPoint slides. The questions are multiple choice and true/false. Each question is relevant to subjects that the trainees should know and can find relevant to safety in their job applications. The answers served as data to evaluate level 2: learning. The posttest score is divided by the pretest score to obtain a ratio which is called knowledge Improvement Ratio (KIR). For instance, Pretest score and Posttest score of a trainee proved if there is Knowledge Improvement (KI).

Trainees receive two types of certificates which are: Certificate of Completion - Trainees who score at least 72 % in the posttest; and Certificate of Participation - Trainees who attend the training sessions but do not achieve the minimum 72 % success rate. The pretest and posttest scores can be less, or equal, or greater than 72 %. Consequently, the Knowledge Improvement Ratio (KIR) which is the Posttest/Pretest ratio can be less than 1, or equal 1 or greater than 1. Therefore, the following four cases are considered:

1. Pretest greater than or equal to 72 % and Posttest greater than or equal to 72 %;
2. Pretest greater than or equal to 72 % and Posttest less than 72 %;
3. Pretest less than 72 % and Posttest greater than or equal to 72 %;

4. Pretest less than 72 % and Posttest less than 72 %.

Other information is collected from the trainees for further comparison. The sign-up form shown in **Appendix B** presents some of the demographic information collected from the trainees. The information collected includes level of education, job classification, years in industry and past safety training. The results also show the frequency distribution of the trainee's demographic information for each training delivery method and topic. The reasons and the relations between their demographic information, reaction and learning will be studied further in another paper.

This study evaluates only the relations and significances between the trainees' reactions: level 1 which consists of the first question, Perception of Knowledge Improvement (PKI) and the seven (7) other questions of the survey and learning: level 2 which consists solely of Knowledge Improvement Ratio (KIR).

3.6.2 Construction of Variables

In this study, the independent variables are recognized as perception of knowledge improvement, understanding, presentation of the materials, objectives, topics, time, usefulness of the training and instructor. Level 1: Reaction is calculated for each question of the survey. The posttest score is divided by the pretest score to obtain a ratio which is used to measure learning as knowledge improvement between the two tests. Level 1 survey questions are considered as the independent variables and level 2 as the dependent variable.

Analyses are conducted to find whether the independent and dependent variables possess some statistical significances among them. The findings also aim to clarify whether one training delivery method is more effective than another. Results of the analysis are presented in the results chapter.

3.7 Data Analysis

Each training delivery method is evaluated separately. Training has been conducted in English for all cases. Training material and program delivery details and the acquisition and analysis of all the data pertaining to training effectiveness evaluation are based on Kirkpatrick levels 1 and 2.

Two different analyses are conducted on the aggregate data for each training topic and its delivery method. Firstly, a univariate analysis is performed on the data. Then cross tabulation is conducted on the data of each training topic and delivery method. The next chapter provides the bar charts and tables for demographic information, level 1 and level 2 derived from the statistical analyses results.

3.7.1 Univariate Analysis

Univariate analysis has been conducted by using SPSS to describe the data. Descriptive statistics provide important information about variables to be analyzed (Hun Myoung Park, 2008). The data is analyzed to find the frequency distribution of trainee's demographic information. The results are shown in the result section of the study. For this study, a bar chart is used to show how each variable is distributed.

3.7.2 Multivariate Analysis

The survey questions are used to evaluate the reaction of the trainees as level 1. The posttest/pretest ratio is calculated to measure level 2. Cross tabulation is a statistical tool that is used to analyze categorical data. It has been conducted to compare the relationship between level 1 and level 2 for each training topic and delivery method. Chi-square statistic is also calculated to test of statistical significance or interdependence between level 1 and level 2 variables. The results are shown in the fourth chapter of the study.

3.8 Research Questions

The percentage of trainee's agreement, neutrality or disagreement to each question is calculated from the survey results. Level 1: Reaction is measured through survey questions 1 through 8. A new metric is identified to measure learning effectiveness. The posttest scores are divided by the pretest scores and give the knowledge Improvement Ratio (KIR) – Level 2. The effectiveness of each training delivery is examined with cross tabulation of level 1 and level 2 in order to find statistical significance or interdependence between the variables and to find which training system has been the most effective. The research questions of the study are solely:

1. How does training effectiveness vary in different training delivery methods such as online and traditional?
2. What are the metrics or variables to determine training effectiveness?
3. How consistent are the trainees in their answers for level 1 and level 2?

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of the data collected and analyzed in this study. Firstly, the frequency distribution of demographic information of the trainees is obtained with univariate analysis for each training delivery method. Secondly, cross tabulation analyses are conducted to determine the relationships and significances between the Perception of Knowledge Improvement (PKI) of the trainees and their knowledge Improvement Ratio (KIR); and the relationships and significances between the Perception of Knowledge Improvement (PKI) of the trainees and the other seven (7) questions of the survey (understanding, topic, time, materials, presentation, usefulness of training and instructor).

4.2 Univariate Analysis Findings

Univariate analysis results for level of education, experience, job classification and past safety training of the trainees are presented in the following paragraphs. They cover the frequency distribution of the demographic data about the personnel participating in each training.

4.2.1 Frequency Distribution of Demographic Data for Respirable Crystalline Silica Training

4.2.1.1 Trainee’s Level of Education for Respirable Crystalline Silica Training

The distribution of the trainee’s level of education was analyzed for the 721 cases as shown in **Table 1**. It was found that 48.44 % of the trainees had High School Diploma/GED. They were followed by 31.5 % of trainees with some college degree. Among the trainees, 7.67 % and 7.53 % respectively had bachelor and associate degrees. Trainees with no high school degree constituted a small percentage (2.41 %). Similarly, trainees with graduate degree were represented by the same percentage. **Figure 14** shows that our training program has mostly reached an audience of construction workers with High School Diploma/GED and some college degree.

Table 1: Frequency Distribution of Trainee's Level of Education

Trainee's Level of Education		Frequency	Percent	Valid Percent
	No High School Degree	17	2.4	2.4
	High School/GED	341	47.3	48.4
	Some College Degree	222	30.8	31.5
	Associate Degree	53	7.4	7.5
	Bachelor's Degree	54	7.5	7.7
	Graduate Degree	17	2.4	2.4
	Total	704	97.6	100.0
Missing		17	2.4	
Total		721	100	

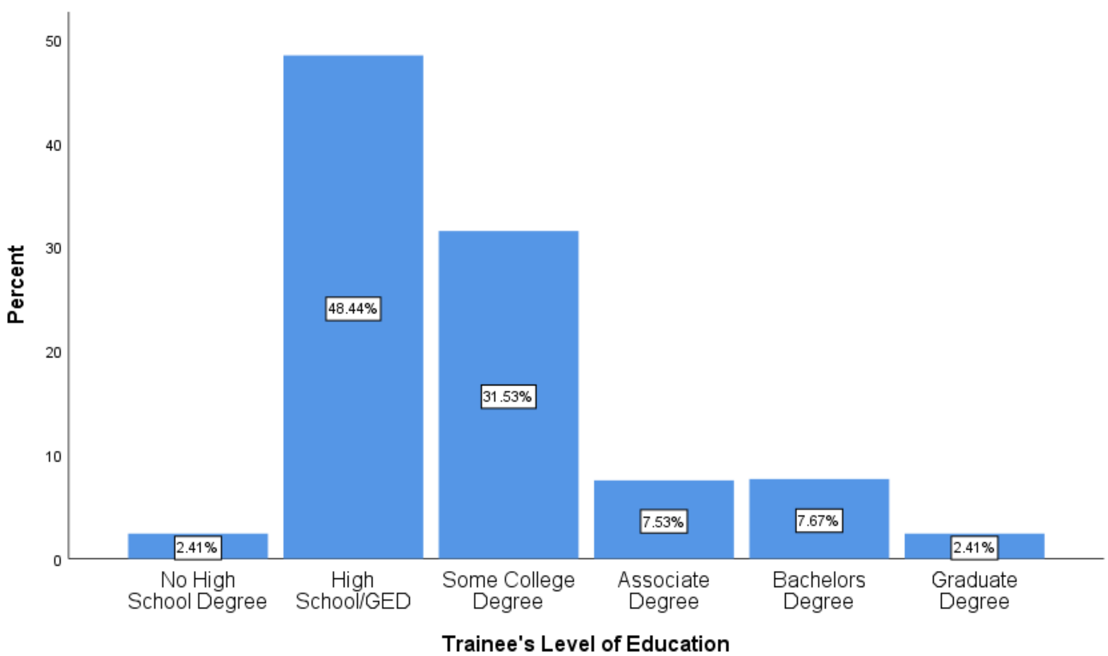

Figure 14: Percentage Distribution of Trainee's Level of Education

4.2.1.2 Trainee's Job Classification for Respirable Crystalline Silica Training

It is shown in **Table 2** that there were more operating engineers in our training sessions than any other category. **Figure 15** shows that operating engineers represented 50.35 % of the trainees. Trainees who chose the "other" as their job classification indicated their job classification as administrative directors, safety directors, owners, project directors, project managers with engineers representing 18.60 %. Masons, laborers and bricklayers represented 11.33 %, 10.21 % and 9.51 % respectively.

Table 2: Percentage Distribution of Trainee's Job Classification

Trainee's Job Classification		Frequency	Percent	Valid Percent
	Bricklayer	68	9.4	9.5
	Laborer	73	10.1	10.2
	Mason	81	11.2	11.3
	Operating Engineer	360	49.9	50.3
	Other	133	18.4	18.6
	Total	715	99.2	100.0
Missing		6	.8	
Total		721	100	

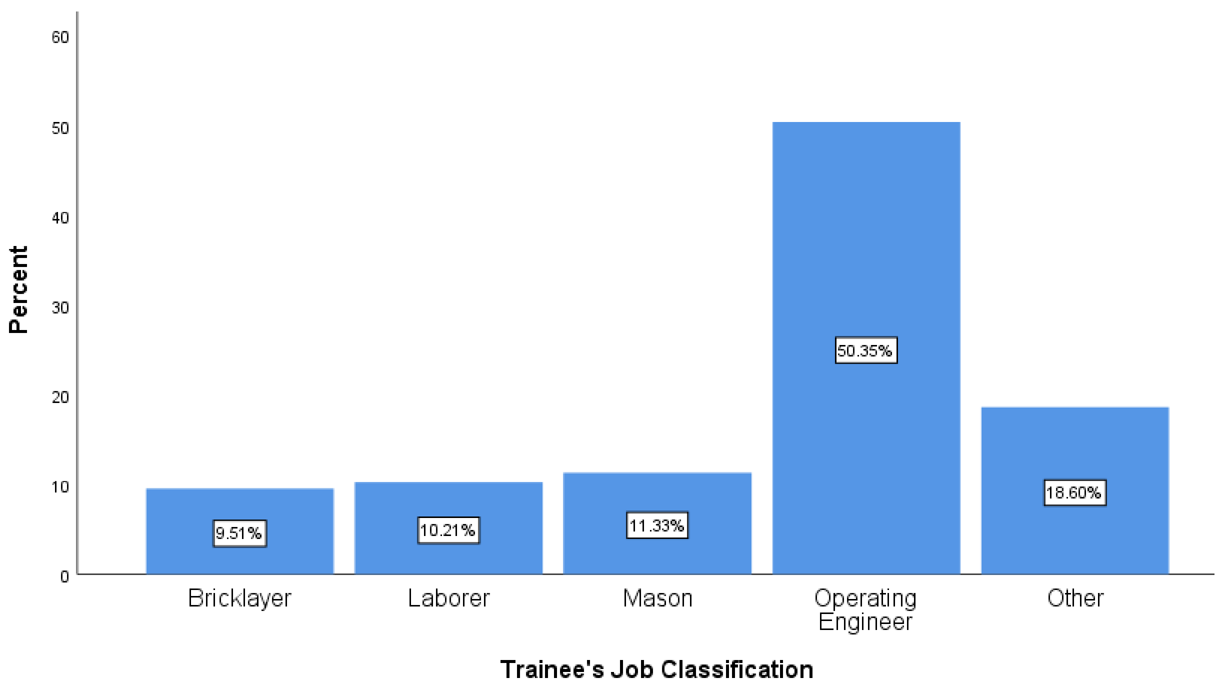

Figure 15: Percentage Distribution of Trainee's Job Classification

4.2.1.3 Trainee's Experience in Years for Respirable Crystalline Silica Training

Years that the trainees spent in the construction industry were also analyzed and the results shown in **Table 3** indicate that the highest frequency of the total were trainees who had spent more than 20 years in the industry. The number of trainees with more than 20 years of experience was 366 (52.4 %). Trainees with experience between 16 and 20 years comprised 16.02 % and the percentage of trainees with experience between 1 and 5 years was 15.59 % as shown in **Figure 16**. Trainees with years of experience between 11 and 15 years was 8.58 % and the percentage of trainees with experience between 6 and 10 years was 7.44 %. It can be observed that a reasonable number of trainees who were new in the industry received the training.

Table 3: Percentage Distribution of Trainee's Experience in Years

Trainee's Experience in Years		Frequency	Percent	Valid Percent
	1 to 5 years	109	15.1	15.6
	6 to 10 years	52	7.2	7.4
	11 to 15 years	60	8.3	8.6
	16 to 20 years	112	15.5	16.0
	20+ years	366	50.8	52.4
	Total	699	96.9	100.0
Missing		22	3.1	
Total		751	721	100.0

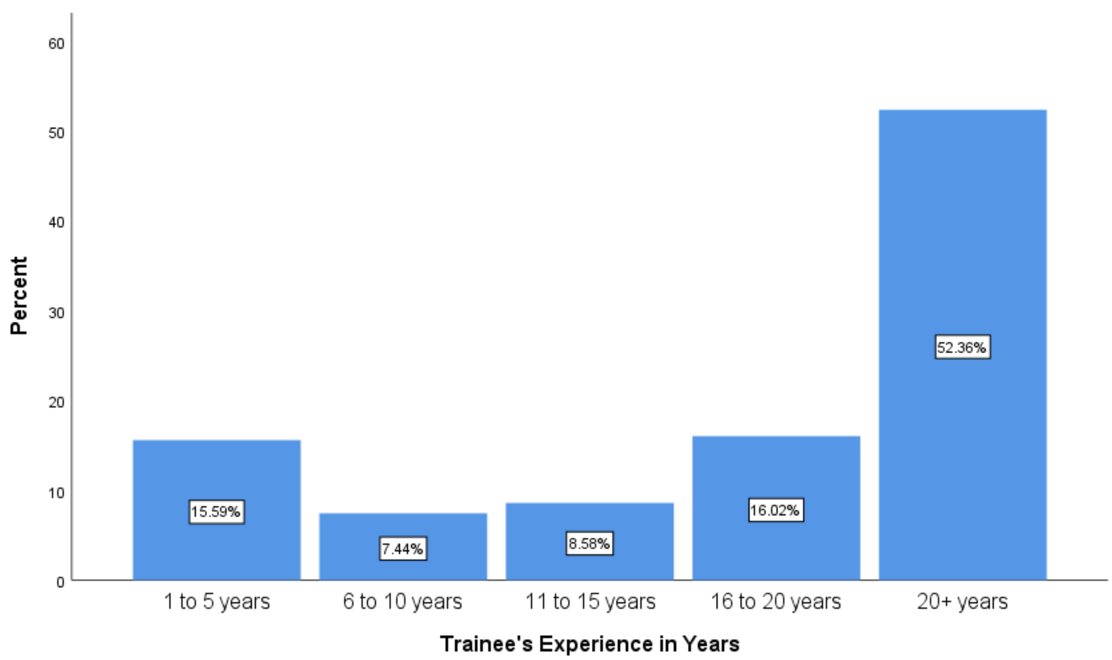

Figure 16: Percentage Distribution of Trainee's Experience in Years

4.2.1.4 Trainee's Past Safety Training for Respirable Crystalline Silica Training

The distribution of the trainee's past safety training was also included in the univariate analysis. It can be observed in **Table 4** that most of the trainees had already received a safety training. Trainee's counted for 514 or 72.29 % as shown in **Figure 17** who answered positively that they have previously been trained. The trainees who had not previously been trained represented 27.71 %. A modest number of construction workers (197) had received the respirable crystalline silica training as their first safety training.

Table 4: Percentage Distribution of Trainee's Past Safety Training

Past Safety Training		Frequency	Percent	Valid Percent
	NO	197	27.3	27.7
	YES	514	71.3	72.3
	Total	711	98.6	100.0
Missing		10	1.4	
Total		721	100	

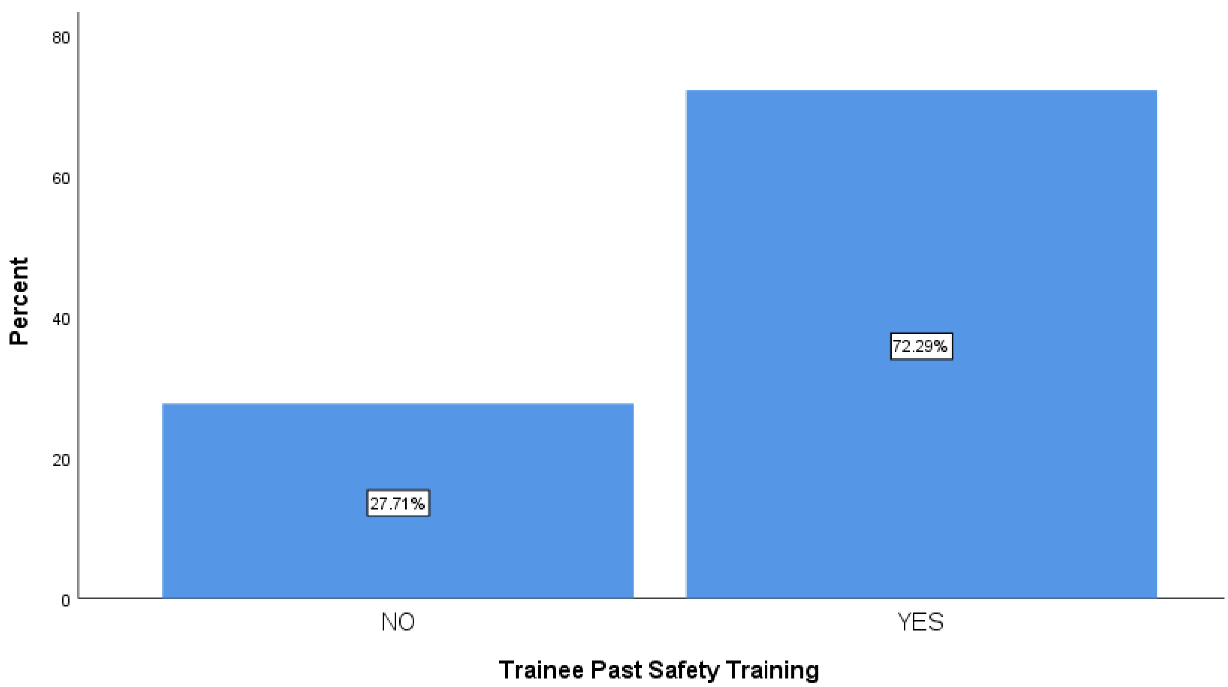

Figure 17: Percentage Distribution of Trainee's Past Safety Training

4.2.2 Frequency Distribution of Demographic Data for Excavation and Trenching Training

4.2.2.1 Trainee's Level of Education for Excavation and Trenching Training

The distribution of the trainee's level of education shown in **Table 5** indicate that 48.86 % of the trainees had High School Diploma/GED. They were followed by 31.25 % of trainees with some college degree. Among the trainees, 10.23 % had graduate degree. Trainees with bachelor degree constituted a small percentage (3.98%). Similarly, trainees with associated degree were represented by the same percentage. **Figure 18** shows that our training program has mostly reached construction workers with High School Diploma/GED and some college degree.

Table 5: Percentage Distribution of Trainee's Level of Education

Trainee's Level of Education	Frequency	Percent	Valid Percent
High School/GED	86	21.2	48.9
Some College	55	13.6	31.3
Associate Degree	7	1.7	4.0
Bachelor Degree	7	1.7	4.0
Graduate Degree	18	4.4	10.2
Other	3	.7	1.7
Total	176	43.5	100.0
Missing	229	56.5	
Total	405	100.0	

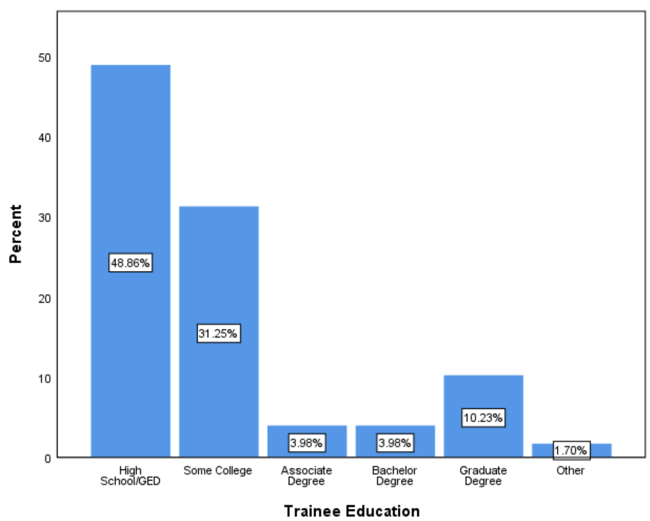

Figure 18: Percentage Distribution of Trainee's Level of Education

4.2.2.2 Trainee's Job Classification for Excavation and Trenching Training

According to the statistical results displayed in **Table 6**, the operating engineers were predominant in our excavation and trenching training sessions. **Figure 19** shows that operating engineers represented 39.26 % of the trainees. Trainees who chose the "other" as their job classification indicated their job classification as administrative directors, safety directors, owners, project directors, project managers with engineers representing 24.69 %. Construction laborers and pipelayers represented 19.26 % and 16.79 % of the trainees respectively.

Table 6: Percentage Distribution of Trainee's Job Classification

Trainee's Job Classification	Frequency	Percent	Valid Percent
Operating Engineer	159	39.3	39.3
Construction Laborer	78	19.3	19.3
Pipelayer	68	16.8	16.8
Other	100	24.7	24.7
Total	405	100.0	100.0

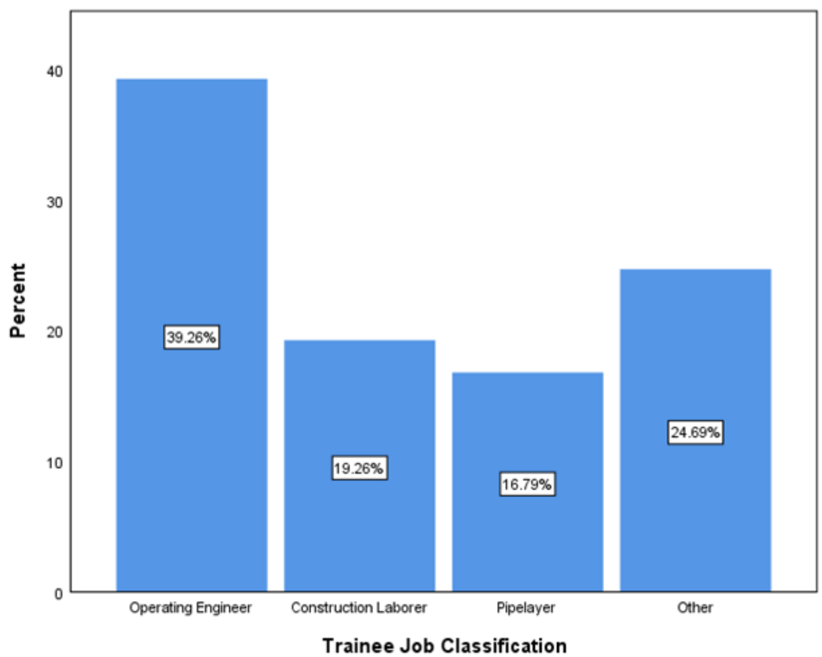

Figure 19: Percentage Distribution of Trainee's Job Classification

4.2.2.3 Trainee's Experience in Years for Excavation and Trenching Training

The statistical results shown in **Table 7** indicate that the highest frequency among the total were trainees who had the least experience in the industry. As given in **Table 7**, the number of trainees with 1 to 5 years of experience was 222 (54.81 %). Trainees with more than 20 years of experience comprised 18.52 % and the percentage of trainees with experience between 6 and 10 years was also 9.14 % as shown in **Figure 20**. Trainees with years of experience between 11 and 15 years was also 9.14 % and the percentage of workers with experience between 16 and 20 years was 8.40 %.

Table 7: Percentage Distribution of Trainee's Experience in Years

Trainee's Experience in Years	Frequency	Percent	Valid Percent
1 to 5 years	222	54.8	54.8
6 to 10 years	37	9.1	9.1
11 to 15 years	37	9.1	9.1
16 to 20 years	34	8.4	8.4
20+ years	75	18.5	18.5
Total	405	100.0	100.0

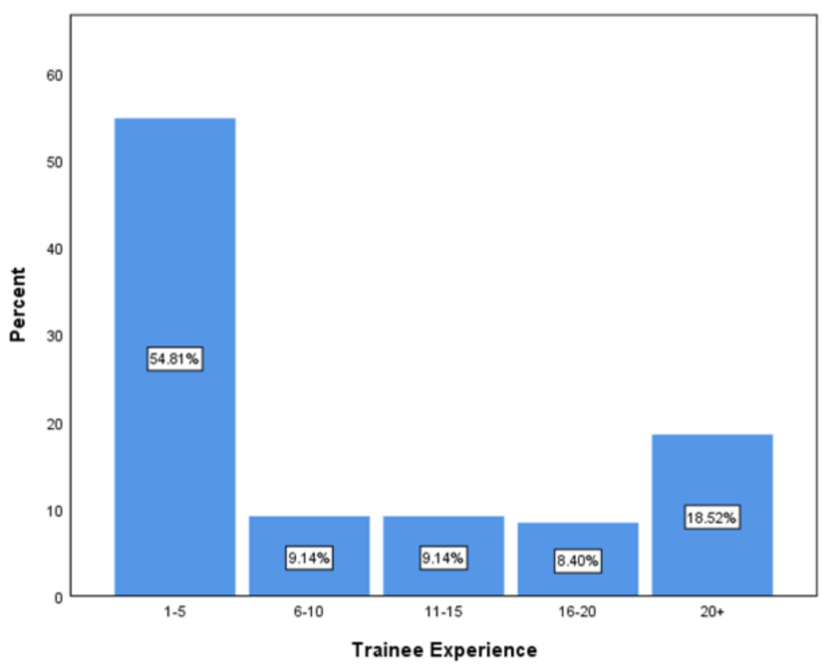

Figure 20: Percentage Distribution of Trainee's Experience in Years

4.2.2.4 Trainee's Past Safety Training for Excavation and Trenching Training

The distribution of the trainee's past safety training was also analyzed in the univariate analysis. It can be observed in **Table 8** that 233 of the trainees had already received a safety training. Trainees who had previously been trained accounted for 57.53 % of total as shown in **Figure 21**. The trainees who had not previously been trained represented 42.47 %. A modest number of construction workers (172) had received the excavation training as their first safety training.

Table 8: Percentage Distribution of Trainee's past Safety Training

Past Safety Training	Frequency	Percent	Valid Percent
NO	172	42.5	42.5
YES	233	57.5	57.5
Total	405	100.0	100.0

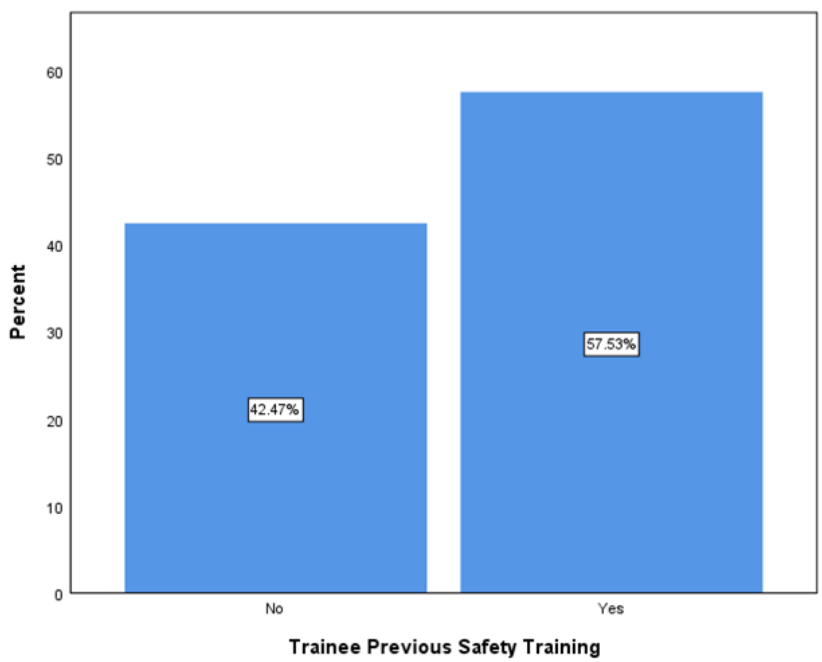

Figure 21: Percentage Distribution of Trainee's Past Safety Training

4.3 Cross Tabulation for Respirable Crystalline Silica Training

Before performing cross tabulation on the data set, different cases were identified as shown in **Table 9**. Knowledge Improvement Ratio (KIR) was calculated by dividing the Posttest score with the Pretest score for each trainee. The results placed the trainees in the corresponding KIR for each case. A case could have one, two or three Knowledge Improvement Ratio (KIR). Knowledge Improvement Ratio (KIR) less than 1 or equal to 1 meant that the trainee's knowledge had degraded or remained at the same level after the training. The trainees improved their knowledge when the ratio was greater than 1.

Table 9: Silica Training Data Distribution

Silica Training Cases	Knowledge Improvement Ratio (KIR)	Quantity of Trainee	Total
1) Pretest greater than or equal to 72 and Posttest greater than or equal to 72	< 1	21	247
	= 1	38	
	> 1	188	
2) Pretest greater than or equal to 72 and Posttest less than 72	< 1	8	8
3) Pretest less than 72 and Posttest greater than or equal to 72	> 1	363	363
4) Pretest less than 72 and Posttest less than 72	< 1	8	103
	= 1	19	
	> 1	76	
		Total	721

Cross Tabulation was used to find the relationships between level 1 responses to questions one through eight of the survey in **Appendix A** and the level 2 results from KIR computations. Question number one in the survey was considered as a metric for Perception of Knowledge Improvement (PKI) and the other seven questions were used as variables for level 1: Reaction. Knowledge Improvement Ratio (KIR) was used for learning - level 2. Only the significant findings are presented in a tabulated form for the cross tabulation between knowledge

Improvement Ratio (KIR), Perception of Knowledge Improvement (PKI) and the other seven (7) questions of the survey. Refer to sections 4.3.1, 4.3.2 and 4.3.3.

4.3.1 Cross Tabulation Results for Pretest greater than or equal to 72 and Posttest greater than or equal to 72 for Respirable Crystalline Silica Training

4.3.1.1 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 10** indicate that among the 247 trainees, 42 (17%) and 112 (45%) respectively increased their knowledge, and they agreed and strongly agreed that the training have improved their knowledge. As shown in **Figure 22**, 9 (3.64%), 14 (5.66%), 10 (4%) and 19 (7.69%) of the trainees respectively who did not improve their knowledge agreed and strongly agreed otherwise that the training has improved their knowledge. It is found that there is no significant association ($\chi2(8) = 8.623$, $p = 0.375$) between KIR and PKI.

Table 10: KIR vs PKI for case 1

		The training improved my knowledge (PKI)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	<1	0	1	1	9	10
	=1	1	1	3	14	19
	>1	5	4	25	42	112

a. KIR vs PKI $\chi^2(8) = 8.623$, p: 0.375

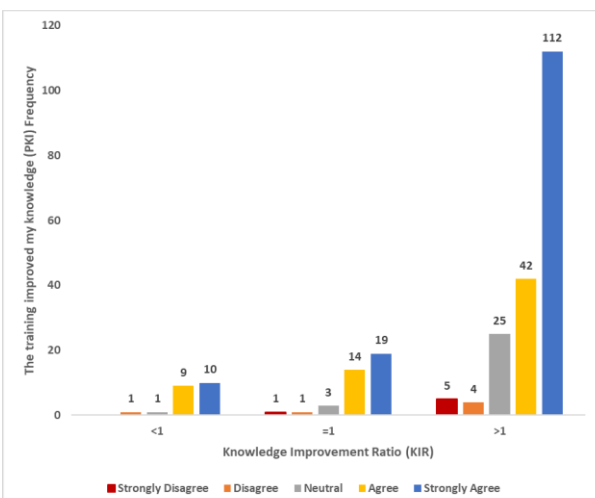

Figure 22: KIR vs PKI for case 1

4.3.1.2 PKI vs SQ2 for Respirable Crystalline Silica Training

The cross tabulation results for Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2) which was asking if the training was easy to understand shown in T**able 11** indicate that 38 (15.38%), 45(18.22%), and 82 (33.2%) of the 247 trainees respectively agreed and strongly agreed about PKI and SQ2. It can be observed in **Figure 23** that none of the trainees had changed their answers from agreement to strong disagreement. It is found that there is a significant association ($\chi2(16) = 228.907$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2).

Table 11: PKI vs SQ2 for case 1

		The training was easy to understand (SQ2)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	2	1	0	0
	Disagree	1	3	2	0	0
	Neutral	1	3	20	5	0
	Agree	0	2	18	38	7
	Strongly Agree	0	1	13	45	82

a. PKI vs SQ2 $\chi^2(16) = 228.907$, p: 0.000

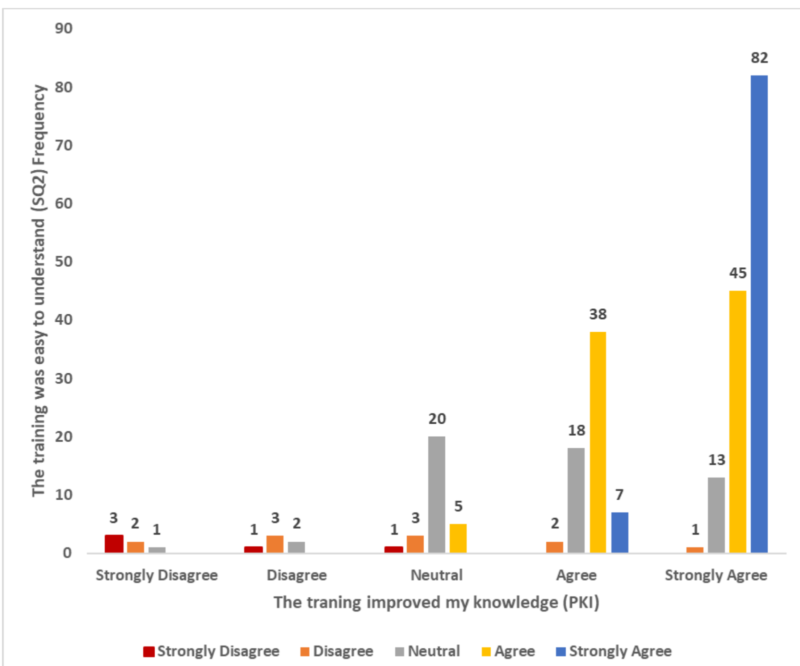

Figure 23: PKI vs SQ2 for case 1

4.3.1.3 PKI vs SQ3 for Respirable Crystalline Silica Training

For the cross tabulation results between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3) which was asking if the training media was easy to read and follow, 38 (15.38%), 35(14.17%), and 94 (38.06%) of the 247 trainees respectively agreed and strongly agreed about PKI and SQ3 (see **Table 12**). It can be observed in **Figure 24** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association ($\chi2(16) = 293.543$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3).

Table 12: PKI vs SQ3 for case 1

		The training media was easy to read and follow (SQ3)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	1	0	1	0
	Disagree	0	3	2	1	0
	Neutral	1	1	21	5	1
	Agree	0	4	16	38	7
	Strongly Agree	0	0	12	35	94

a. PKI vs SQ3 χ^2 (16) = 293.543, p: 0.000

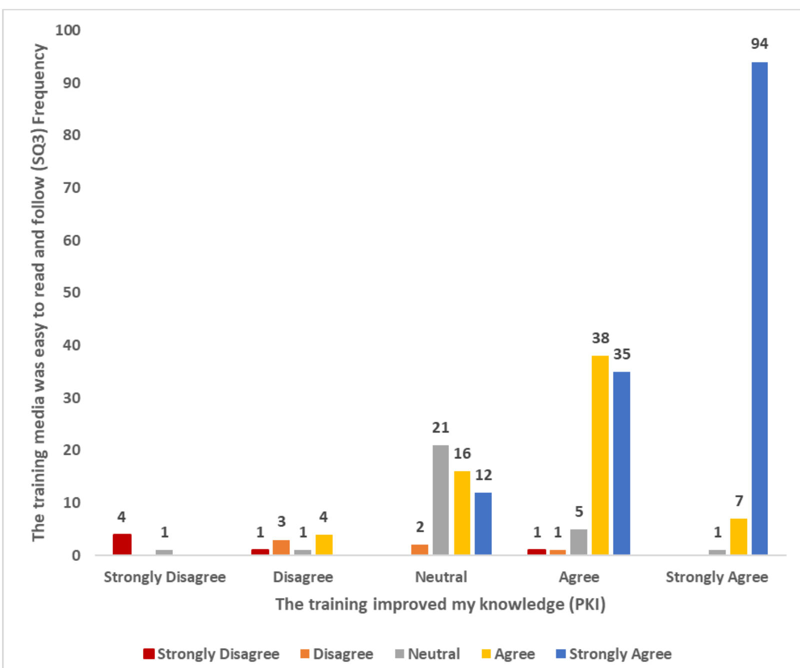

Figure 24: PKI vs SQ3 for case 1

4.3.1.4 PKI vs SQ4 for Respirable Crystalline Silica Training

Between the Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4) which was asking if the training objectives were clearly defined, 37 (15%), 28 (11.34%), 19 (7.69%) and 109 (44.13%) of the 247 trainees respectively agreed and strongly agreed about PKI and SQ4 **(**See **Table 13)**. It can be observed in **Figure 25** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association (χ2(16) = 282.642, p = 0.000) between Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4).

Table 13: PKI vs SQ4 for case 1

		The training objectives were clearly defined (SQ4)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	1	0	1	0
	Disagree	2	2	1	1	0
	Neutral	1	1	18	8	1
	Agree	0	1	8	37	19
	Strongly Agree	0	0	4	28	109

a. PKI vs SQ4 χ^2 (16) = 282.642, p: 0.000

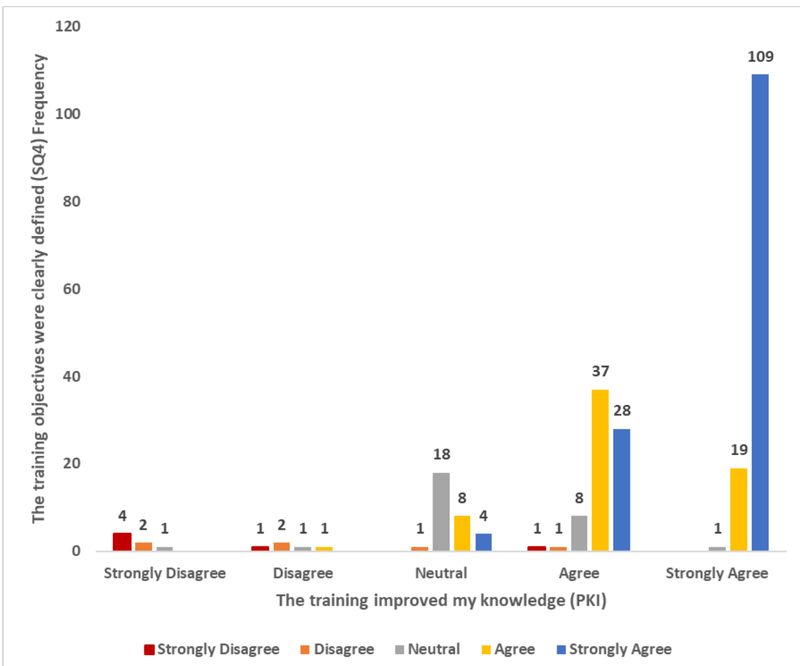

Figure 25: PKI vs SQ4 for case 1

4.3.1.5 PKI vs SQ5 for Respirable Crystalline Silica Training

In **Table 14,** none of the trainees had changed their answers from agreement to strong disagreement. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5) which was asking if the training topic was relevant to the trainee, 29 (11.74%), 18 (7.29%), 28 (11.34%) and 111 (44.94%) of the 247 trainees respectively agreed and strongly agreed about PKI and SQ5 **(**See **Figure 26)**. It is found that there is a significant association ($\chi 2(16)$ = 164.918, p = 0.000) between Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5).

Table 14: PKI vs SQ5 for case 1

		The training topic was relevant to me (SQ5)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	0	3	0	0
	Disagree	2	1	2	1	0
	Neutral	2	2	12	8	5
	Agree	0	1	7	29	28
	Strongly Agree	0	0	12	18	111

a. PKI vs SQ5 χ^2 (16) = 164.918, p: 0.000

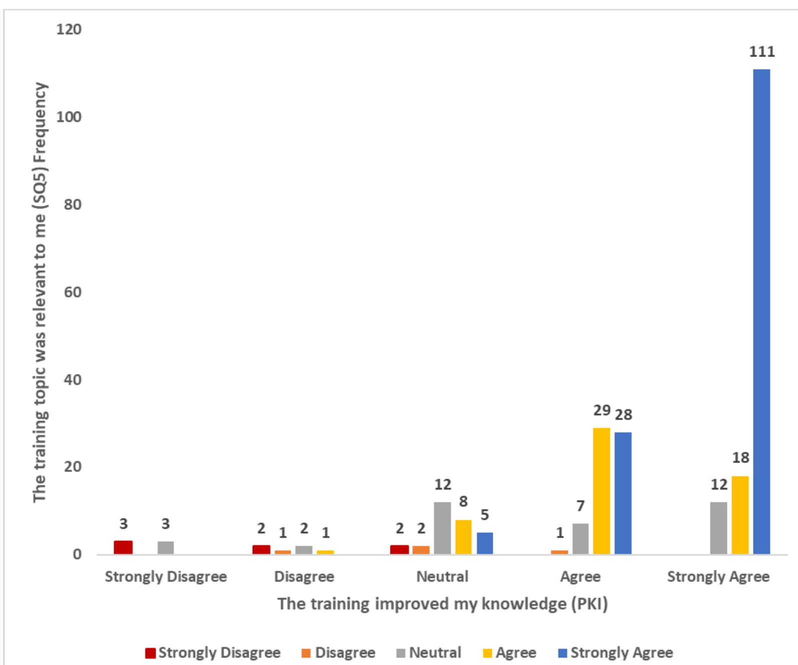

Figure 26: PKI vs SQ5 for case 1

4.3.1.6 PKI vs SQ6 for Respirable Crystalline Silica Training

The Survey Question six (SQ6) was asking if the training time allocation was sufficient. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question six (SQ6), 36 (14.57%), 25 (10.12%), 20 (8.1%) and 101 (40.89%) of the 247 trainees respectively agreed and strongly agreed about PKI and SQ6 **(**See **Figure 27)**. In **Table 15,** only 4 (1.62%) of the trainees strongly disagreed to both PKI and SQ6. It is found that there is a significant association (χ2(16) = 267.307, p = 0.000) between Perception of Knowledge Improvement (PKI) and the Survey Question six (SQ6).

Table 15: PKI vs SQ6 for case 1

		The training time allocation was sufficient (SQ6)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	0	1	1	0
	Disagree	0	2	1	3	0
	Neutral	0	0	15	11	3
	Agree	0	2	7	36	20
	Strongly Agree	0	4	11	25	101

a. PKI vs SQ6 χ^2 (16) = 267.307, p: 0.000

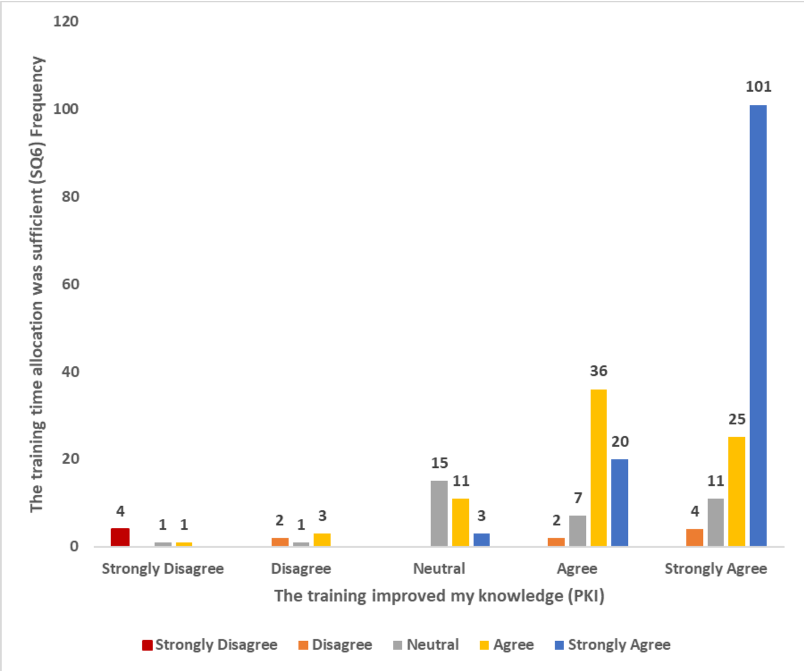

Figure 27: PKI vs SQ6 for case 1

4.3.1.7 PKI vs SQ7 for Respirable Crystalline Silica Training

Among the 247 trainees, 24 (9.72%), 12 (4.86%), 36 (14.57%) and 119 (48.18%) respectively agreed and strongly agreed about PKI and SQ7 (see **Table 16** and **Figure 28)**. The Survey Question seven (SQ7) was asking if the training would be useful in their work. A number of 15 (6.07%) of the trainees remained neutral and 10 (4.05%) of them disagreed or strongly disagreed about their perception of knowledge improvement and training's usefulness. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question seven (SQ7), It is found that there is a significant association ($\chi 2(16) = 292.483$, $p = 0.000$).

Table 16: PKI vs SQ7 for case 1

		The training will be useful in my work (SQ7)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	0	0	2	0
	Disagree	2	4	0	0	0
	Neutral	1	3	15	6	4
	Agree	0	1	4	24	36
	Strongly Agree	0	0	10	12	119

a. PKI vs SQ7 $\chi^2(16) = 292.483$, p: 0.000

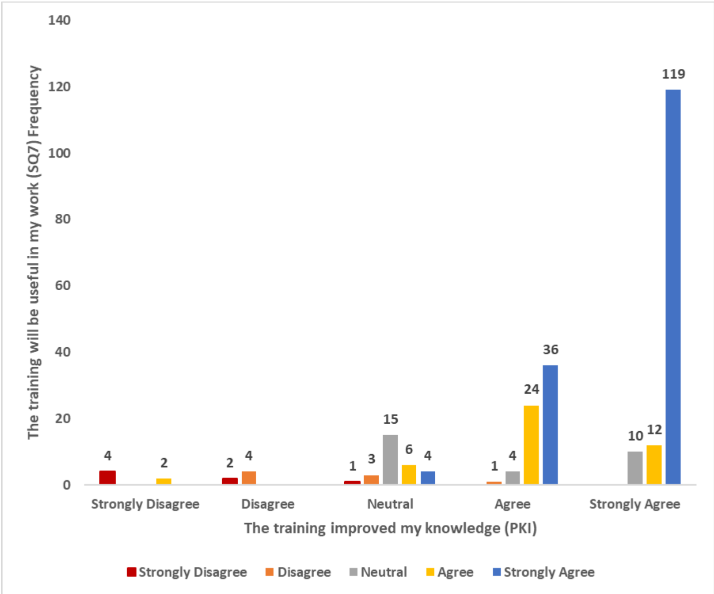

Figure 28: PKI vs SQ7 for case 1

4.3.1.8 PKI vs SQ8 for Respirable Crystalline Silica Training

The Survey Question eight (SQ8) was asking if the instructor was knowledgeable. Among the 247 trainees, 22 (8.91%), 12 (4.86%), 41 (16.6%) and 125 (50.61%) of them respectively agreed and strongly agreed about PKI and SQ8 (see **Table 17** and **Figure 29).** A number of 15 (6.07%) of the trainees remained neutral. None of the trainees had changed their strong agreement into strong disagreement in their answers. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question eight (SQ8), It is found that there is a significant association (χ2(16) = 426.295, p = 0.000).

Table 17: PKI vs SQ8 for case 1

		The instructor was knowledgeable (SQ8)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	6	0	0	0	0
	Disagree	0	3	1	1	1
	Neutral	0	2	15	4	8
	Agree	0	0	2	22	41
	Strongly Agree	0	0	4	12	125

a. PKI vs SQ8 χ^2 (16) = 426.295, p: 0.000

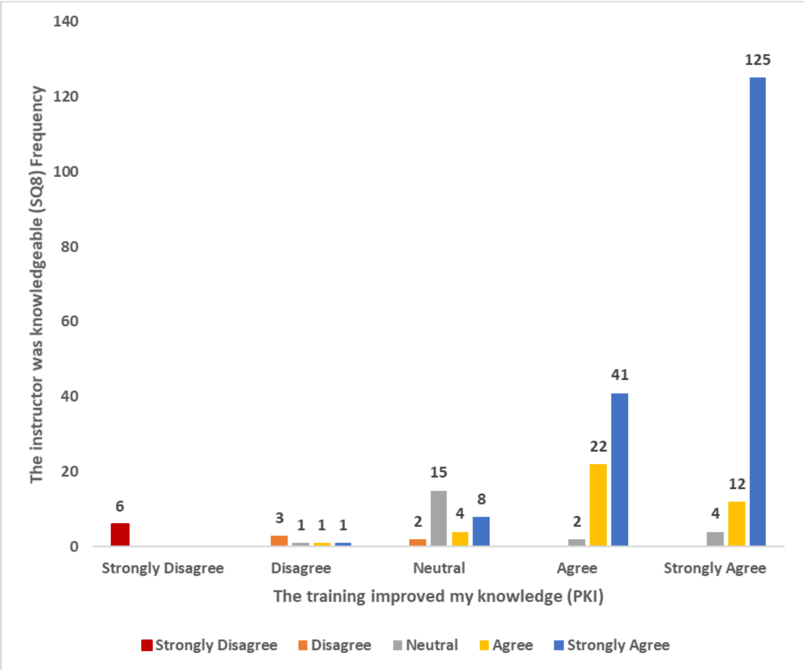

Figure 29: PKI vs SQ8 for case 1

4.3.2 Cross Tabulation Results for Pretest less than 72 and Posttest greater than or equal to 72 for Respirable Crystalline Silica Training

4.3.2.1 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 18** indicate that among the 363 trainees, 99 (27.27%) and 208 (57.3%) respectively increased their knowledge and they agreed and strongly agreed that the training had improved their knowledge. As shown in **Figure 30**, 48 (13.22%) of the trainees respectively remained neutral even though the training had improved their knowledge. Nevertheless, 4 (1.19%) of them disagreed and the same percentage strongly disagreed to PKI even though their KIR was greater than 1. No statistics are computed because the KI Ratio is a constant.

Table 18: KIR vs PKI for case 3

		The training improved my knowledge (PKI)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	>1	4	4	48	99	208

a. No statistics are computed because Knowledge Improvement Ratio is a constant.

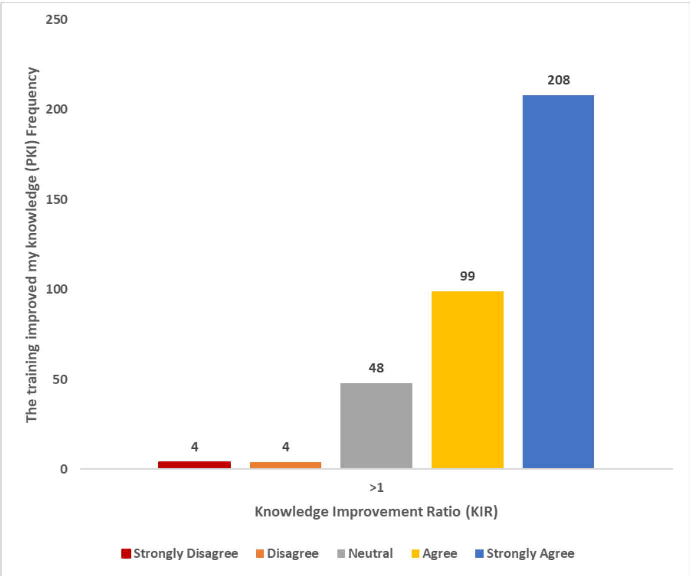

Figure 30: KIR vs PKI for case 3

4.3.2.2 PKI vs SQ2 for Respirable Crystalline Silica Training

The cross tabulation results for Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2) which was asking if the training was easy to understand shown in **Table 19** indicate that 62 (17.08%), 77(21.21%), and 113 (31.13%) of the 363 trainees respectively agreed and strongly agreed about PKI and SQ2. It can be observed in **Figure 31** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association ($\chi 2(16) = 271.783$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2).

Table 19: PKI vs SQ2 for case 3

		The training was easy to understand (SQ2)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	1	2	1	0	0
	Disagree	1	2	1	0	0
	Neutral	1	7	32	6	2
	Agree	0	2	27	62	8
	Strongly Agree	0	2	16	77	113

a. PKI vs SQ2 χ^2 (16) = 271.783, p: 0.000

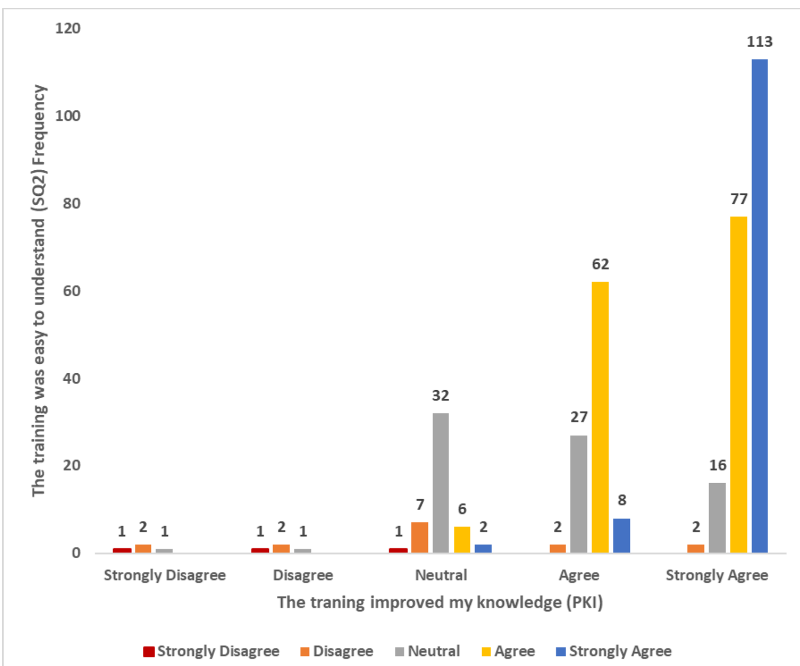

Figure 31: PKI vs SQ2 for case 3

4.3.2.3 PKI vs SQ3 for Respirable Crystalline Silica Training

For the cross tabulation results between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3) which was asking if the training media was easy to read and follow, the results shown in T**able 20** indicate that 57 (15.7%), 61(16.8%),17(4.68%) and 128 (35.26%) of the 363 trainees respectively agreed and strongly agreed about PKI and SQ3. It can be observed in **Figure 32** that none of the trainees had changed their answers from agreement to strongly disagreement. It is found that there is a significant association ($\chi 2(16) = 321.311$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3).

Table 20: PKI vs SQ3 for case 3

		The training media was easy to read and follow (SQ3)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	1	2	1	0	0
	Disagree	0	4	0	0	0
	Neutral	1	7	33	5	2
	Agree	0	2	23	57	17
	Strongly Agree	0	1	18	61	128

a. PKI vs SQ3 $\chi^2(16) = 321.311$, p: 0.000

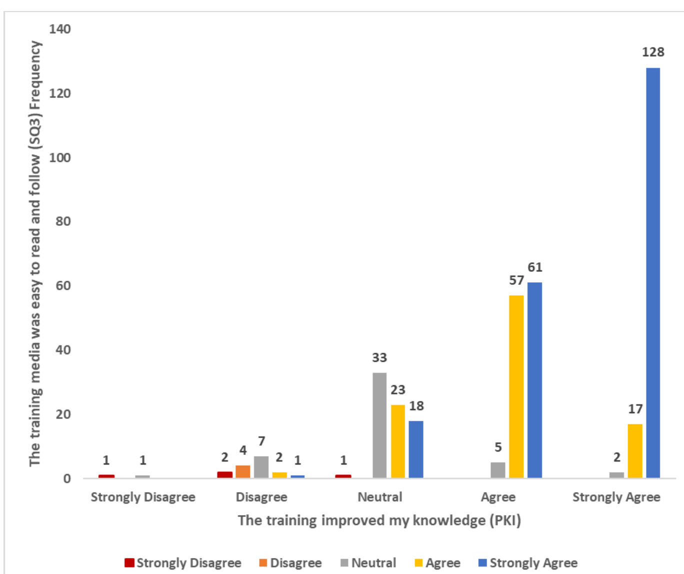

Figure 32: PKI vs SQ3 for case 3

4.3.2.4 PKI vs SQ4 for Respirable Crystalline Silica Training

Between the Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4) which was asking if the training objectives were clearly defined, 59 (16.25%), 45 (12.4%), 26 (7.16%) and 153 (42.15%) of the 363 trainees respectively agreed and strongly agreed about PKI and SQ4 **(**See **Table 21)**. It can be observed in **Figure 33** that none of the trainees had changed their answers from agreement to strongly disagreement. It is found that there is a significant association ($\chi2(16) = 567.193$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4).

Table 21: PKI vs SQ4 for case 3

		The training objectives were clearly defined (SQ4)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	0	0	0	0
	Disagree	0	1	3	0	0
	Neutral	0	5	28	10	5
	Agree	0	0	14	59	26
	Strongly Agree	0	1	9	45	153

a. PKI vs SQ4 χ^2 (16) = 567.193, p: 0.000

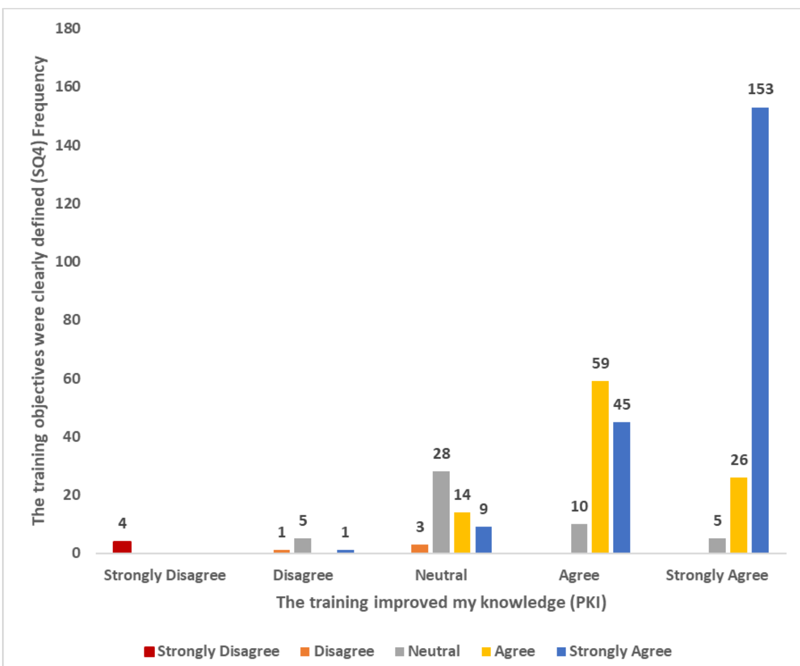

Figure 33: PKI vs SQ4 for case 3

4.3.2.5 PKI vs SQ5 for Respirable Crystalline Silica Training

For the cross tabulation result between the Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5) which was asking if the training topic was relevant to the trainee, 48 (13.22%), 47 (12.95%), 37 (10.2%) and 148 (40.77%) of the 363 trainees respectively agreed and strongly agreed about PKI and SQ5 **(**See **Table 22)**. In **Figure 34,** trainees counted for 24 (6.61%) remained neutral while 6 (1.65%) of them disagreed or strongly disagreed. It is found that there is a significant association ($\chi 2(16) = 311.220$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5).

Table 22: PKI vs SQ5 for case 3

		The training topic was relevant to me (SQ5)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	1	0	0	0
	Disagree	1	1	1	0	1
	Neutral	0	1	24	14	9
	Agree	0	3	11	48	37
	Strongly Agree	1	1	11	47	148

a. PKI vs SQ5 $\chi^2(16) = 311.220$, p: 0.000

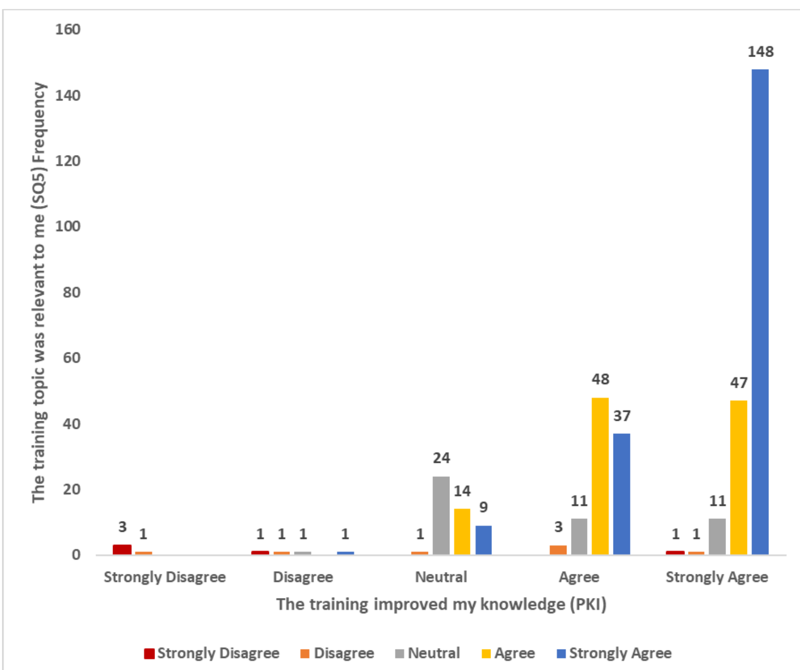

Figure 34: PKI vs SQ5 for case 3

4.3.2.6 PKI vs SQ6 for Respirable Crystalline Silica Training

The Survey Question six (SQ6) was asking if the training time allocation was sufficient. In **Table 23,** none of the trainees had changed their answers from strongly agree to strongly disagree. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question six (SQ6), 58 (15.98%), 54 (14.88%), 29 (7.99%) and 148 (40.77%) of the 363 trainees respectively agreed and strongly agreed about PKI and SQ6 **(**See **Figure 35)**. It is found that there is a significant association ($\chi 2(16) = 530.185$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question six (SQ6).

Table 23: PKI vs SQ6 for case 3

		The training time allocation was sufficient (SQ6)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	1	0	0	0
	Disagree	0	2	2	0	0
	Neutral	0	1	31	11	5
	Agree	0	2	10	58	29
	Strongly Agree	0	0	6	54	148

a. PKI vs SQ6 χ^2 (16) = 530.185, p: 0.000

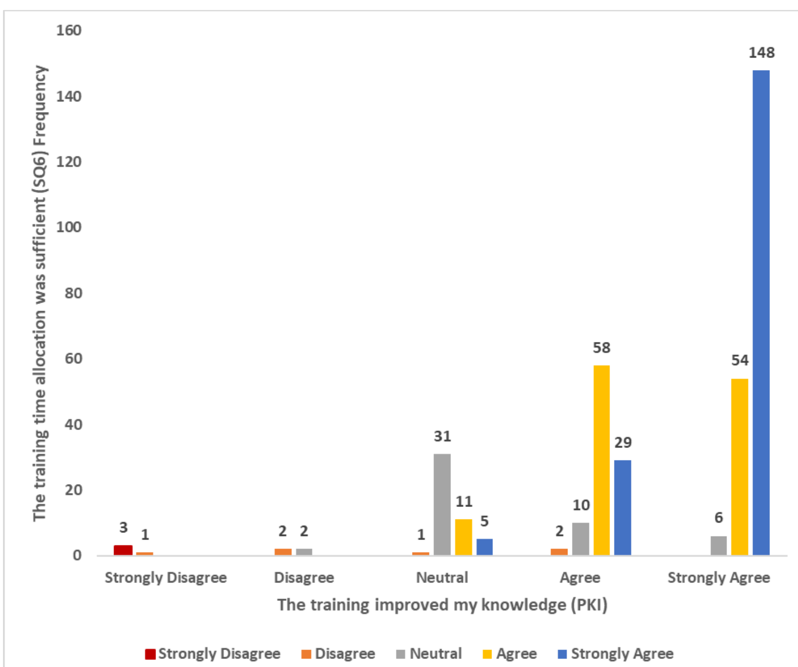

Figure 35: PKI vs SQ6 for case 3

4.3.2.7 PKI vs SQ7 for Respirable Crystalline Silica Training

Among the 363 trainees, 50 (13.77%), 24 (6.61%), 38 (10.47%) and 176 (48.48%) respectively agreed and strongly agreed about PKI and SQ7 (see **Table 24** and **Figure 36)**. The Survey Question seven (SQ7) was asking if the training would be useful in their work. Trainees counted for 24 (6.61%) of them remained neutral and 8 (2.2%) of them disagreed or strongly disagreed about their perception of knowledge improvement and training's usefulness. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question seven (SQ7), It is found that there is a significant association ($\chi2(16) = 534.356$, $p = 0.000$).

Table 24: PKI vs SQ7 for case 3

		The training will be useful in my work (SQ7)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	1	0	0	0
	Disagree	1	3	0	0	0
	Neutral	0	0	24	13	11
	Agree	0	0	11	50	38
	Strongly Agree	0	2	6	24	176

a. PKI vs SQ7 χ^2 (16) = 534.356, p: 0.000

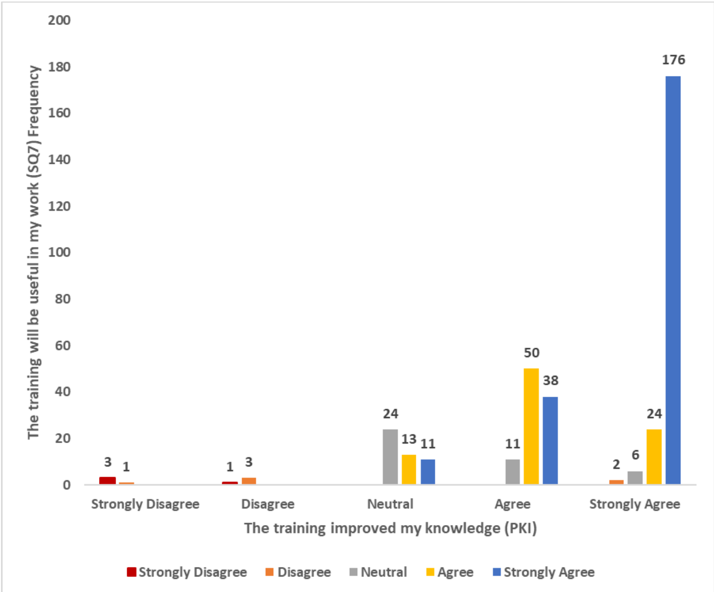

Figure 36: PKI vs SQ7 for case 3

4.3.2.8 PKI vs SQ8 for Respirable Crystalline Silica Training

The Survey Question eight (SQ8) was asking if the instructor was knowledgeable. Among the 363 trainees, 39 (10.74%), 57 (15.7%) and 193 (53.17%) of them respectively agreed and strongly agreed about PKI and SQ8 (see **Table 25** and **Figure 37).** Trainees counted for 21 (5.79%), 4 (1.1%), 3 (0.83%) of them respectively remained neutral, disagreed and strongly disagreed. None of the trainees had changed their answers from strongly agree to strongly disagree. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question eight (SQ8), It is found that there is a significant association ($\chi2(16) = 801.710$, $p = 0.000$).

Table 25: PKI vs SQ8 for case 3

		The instructor was knowledgeable (SQ8)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	0	0	1	0
	Disagree	0	4	0	0	0
	Neutral	0	0	21	15	12
	Agree	0	0	3	39	57
	Strongly Agree	0	0	6	9	193

a. PKI vs SQ8 χ^2 (16) = 801.710, p: 0.000

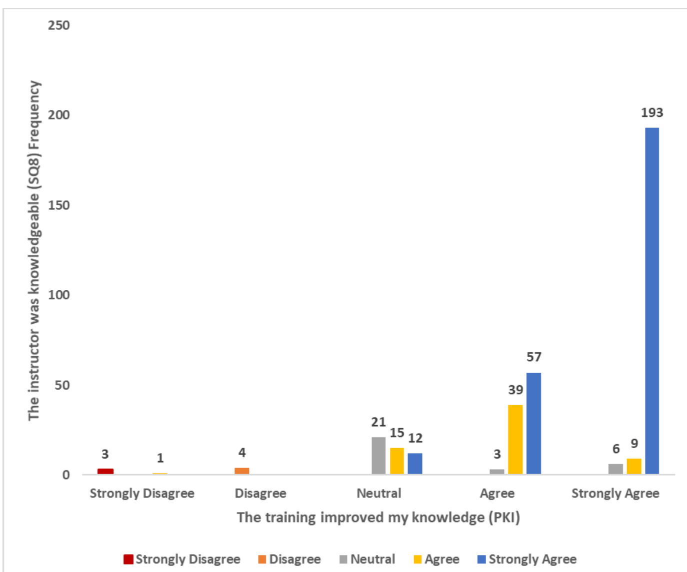

Figure 37: PKI vs SQ8 for case 3

4.3.3 Cross Tabulation Results for Pretest less than 72 and Posttest less than 72 for Respirable Crystalline Silica Training

4.3.3.1 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 26** indicate that among the 103 trainees, 26 (25.24%) and 34 (33%) increased their knowledge and they respectively agreed and strongly agreed that the training had improved their knowledge. Trainees counted for 10 (9.71%) remained neutral. As shown in **Figure 38**, none of the trainees who did not improve their knowledge had reported disagreement for their perception of knowledge improvement. It is found that there is no significant association ($\chi2(8) = 7.113$, $p = 0.525$) between KIR and PKI.

Table 26: KIR vs PKI for case 4

		The training improved my knowledge (PKI)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	<1	0	0	3	2	3
	=1	0	0	3	4	12
	>1	4	2	10	26	34

a. KIR vs PKI χ^2 (8) = 7.113, p: 0.525

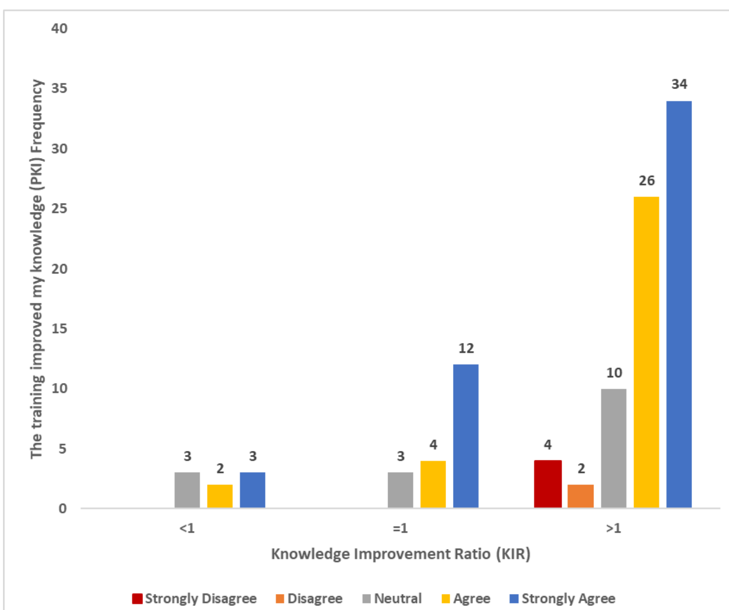

Figure 38: KIR vs PKI for case 4

4.3.3.2 PKI vs SQ2 for Respirable Crystalline Silica Training

The results of cross tabulation for Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2) which was asking if the training was easy to understand shown in T**able 27** indicate that 17 (16.5%), 15 (14.56%), 7 (6.8%), and 28 (27.18%) of the 103 trainees respectively agreed and strongly agreed about PKI and SQ2. It can be observed in **Figure 39** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association ($\chi 2(16) = 80.884$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question two (SQ2).

Table 27: PKI vs SQ2 for case 4

		The training was easy to understand (SQ2)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	1	1	2	0	0
	Disagree	0	1	1	0	0
	Neutral	1	2	13	0	0
	Agree	1	0	7	17	7
	Strongly Agree	0	0	6	15	28

a. PKI vs SQ2 χ^2 (16) = 80.884, p: 0.000

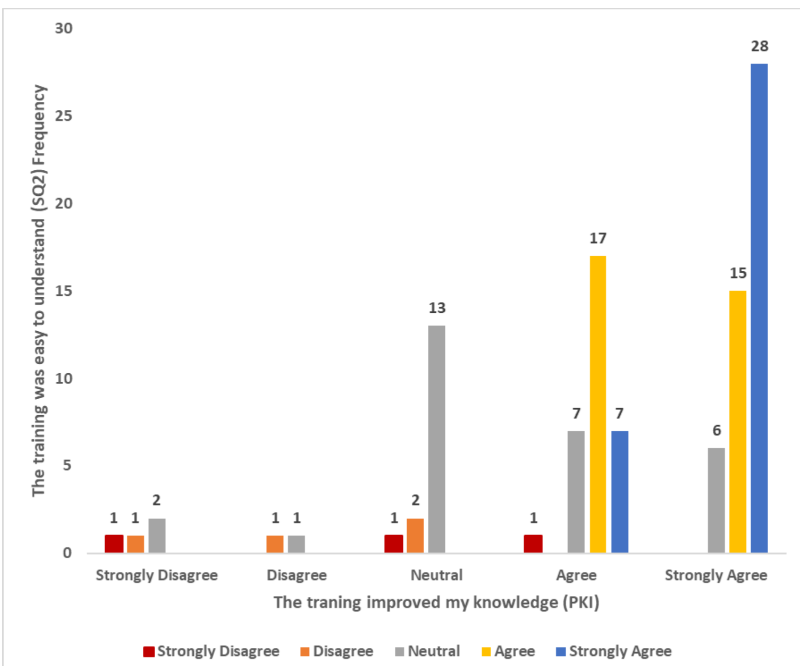

Figure 39: PKI vs SQ2 for case 4

4.3.3.3 PKI vs SQ3 for Respirable Crystalline Silica Training

For the cross tabulation results between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3) which was asking if the training media was easy to read and follow, 22 (21.36%), 17 (16.5%), and 31 (30.1%) of the 103 trainees respectively agreed and strongly agreed about PKI and SQ3. It can be observed in **Figure 40** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association (χ2(16) = 135.358, p = 0.000) between Perception of Knowledge Improvement (PKI) and the Survey Question three (SQ3).

Table 28: PKI vs SQ3 for case 4

		The training media was easy to read and follow (SQ3)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	2	0	2	0	0
	Disagree	0	1	0	1	0
	Neutral	1	1	13	1	0
	Agree	0	0	6	22	4
	Strongly Agree	0	0	1	17	31

a. PKI vs SQ3 χ^2 (16) = 135.358, p: 0.000

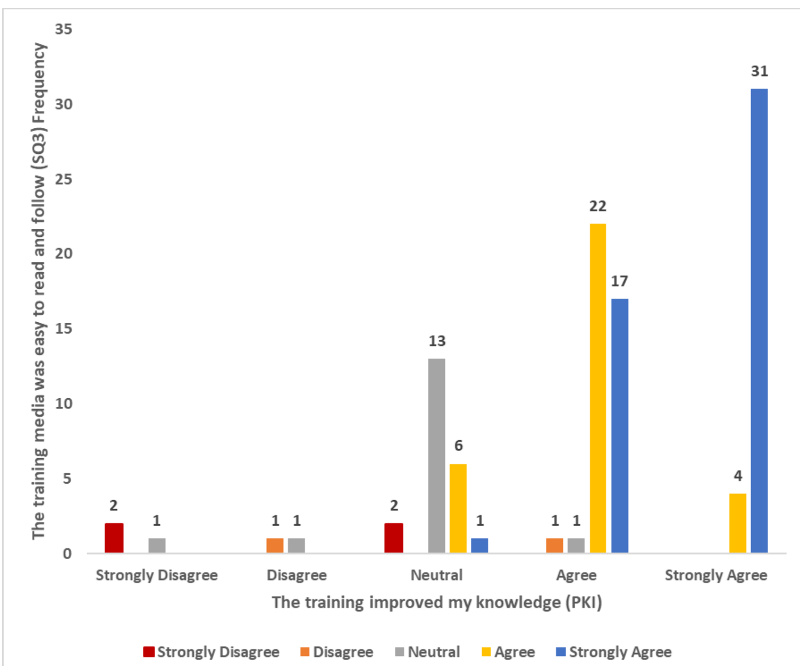

Figure 40: PKI vs SQ3 for case 4

4.3.3.4 PKI vs SQ4 for Respirable Crystalline Silica Training

Between the Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4) which was asking if the training objectives were clearly defined, 25 (24.27%), 11 (10.68%), 7 (6.8%) and 37 (35.92%) of the 103 trainees respectively agreed and strongly agreed about PKI and SQ4 **(**See **Table 29)**. It can be observed in **Figure 41** that none of the trainees had changed their answers from strongly agree to strongly disagree. It is found that there is a significant association (χ2(16) = 207.902, p = 0.000) between Perception of Knowledge Improvement (PKI) and the Survey Question four (SQ4).

Table 29: PKI vs SQ4 for case 4

		The training objectives were clearly defined (SQ4)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	1	0	0	0
	Disagree	0	0	0	2	0
	Neutral	0	0	13	2	1
	Agree	0	0	0	25	7
	Strongly Agree	0	0	1	11	37

a. PKI vs SQ4 χ^2 (16) = 207.902, p: 0.000

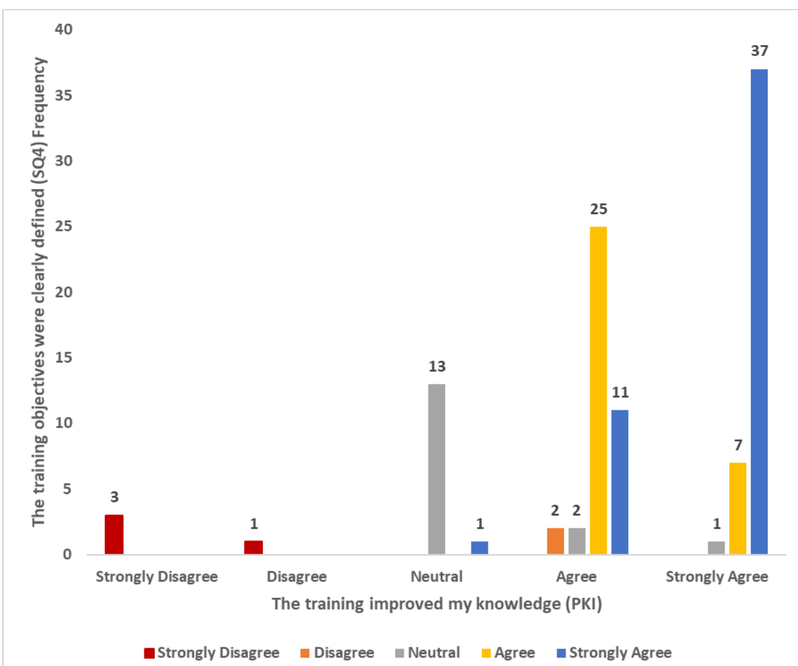

Figure 41: PKI vs SQ4 for case 4

4.3.3.5 PKI vs SQ5 for Respirable Crystalline Silica Training

In **Table 30,** none of the trainees had changed their answers from agreement to strong disagreement. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5) which was asking if the training topic was relevant to the trainee, 18 (17.48%), 7 (6.8%), 9 (8.74%) and 37 (35.92%) of the 103 trainees respectively agreed and strongly agreed about PKI and SQ5 **(**See **Figure 42)**. It is found that there is a significant association ($\chi2(16) = 218.007$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question five (SQ5).

Table 30: PKI vs SQ5 for case 4

		The training topic was relevant to me (SQ5)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	0	0	0	1
	Disagree	0	2	0	0	0
	Neutral	1	0	12	0	3
	Agree	0	0	5	18	9
	Strongly Agree	0	0	5	7	37

a. PKI vs SQ5 $\chi^2(16) = 218.007$, p: 0.000

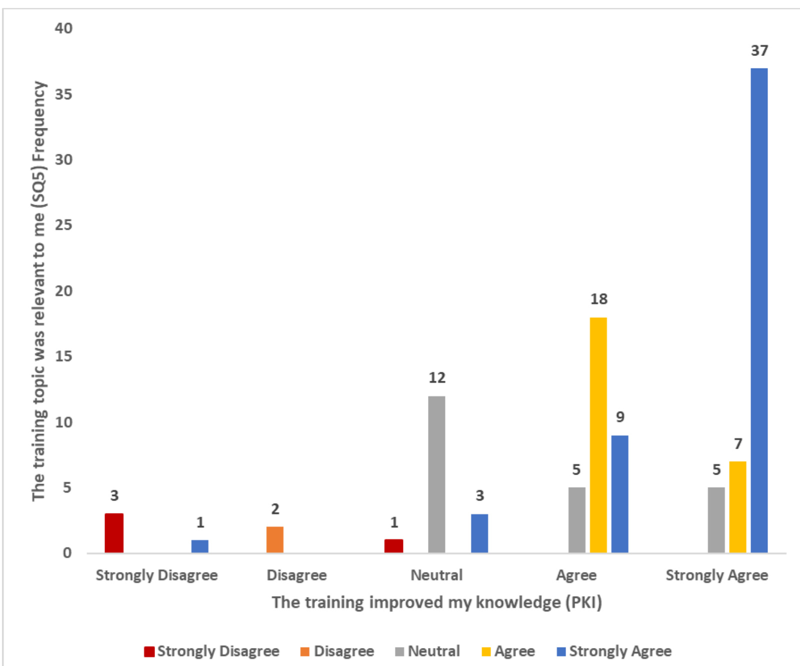

Figure 42: PKI vs SQ5 for case 4

4.3.3.6 PKI vs SQ6 for Respirable Crystalline Silica Training

The Survey Question six (SQ6) was asking if the training time allocation was sufficient. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question six (SQ6), 17 (16.5%), 7 (6.8%), 9 (8.74%) and 37 (35.92%) of the 103 trainees respectively agreed and strongly agreed about PKI and SQ6 **(**See **Figure 43)**. In **Table 31,** only 3 (2.91%) of the trainees strongly disagreed to both PKI and SQ6. It is found that there is a significant association ($\chi2(16) = 127.642$, $p = 0.000$) between Perception of Knowledge Improvement (PKI) and the Survey Question six (SQ6).

Table 31: PKI vs SQ6 for case 4

		The training time allocation was sufficient (SQ6)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	3	0	0	0	1
	Disagree	0	0	0	2	0
	Neutral	0	0	9	2	5
	Agree	0	3	3	17	9
	Strongly Agree	0	1	4	7	37

a. PKI vs SQ6 $\chi^2(16) = 127.642$, p: 0.000

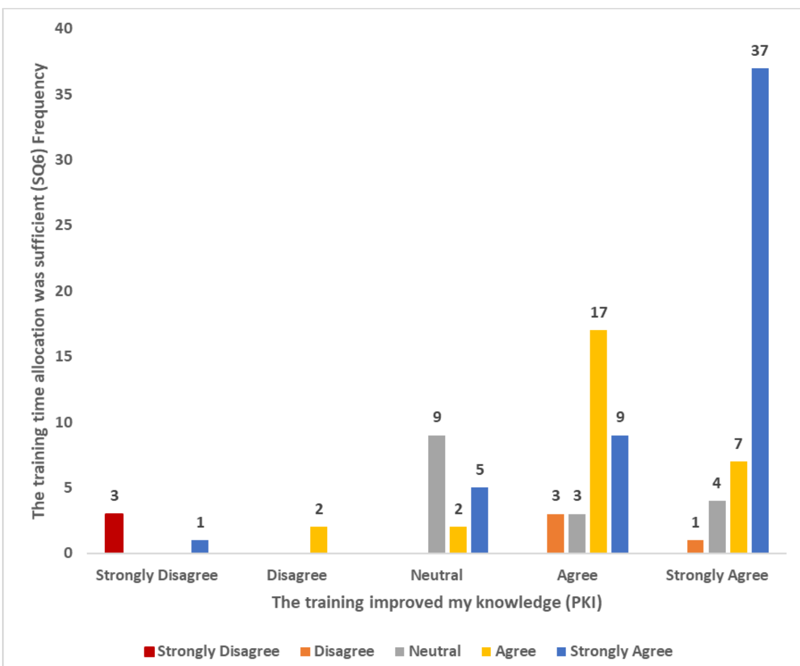

Figure 43: PKI vs SQ6 for case 4

4.3.3.7 PKI vs SQ7 for Respirable Crystalline Silica Training

Among the 103 trainees, 18 (17.48%), 6 (5.83%), 12 (11.65%) and 37 (35.92%) respectively agreed and strongly agreed about PKI and SQ7 (see **Table 32)**. The Survey Question seven (SQ7) was asking if the training would be useful in their work. Results shown in **Figure 44** indicate that 9 (8.74%) of the trainees remained neutral and 5 (4.85%) of them disagreed or strongly disagreed about their perception of knowledge improvement and training's usefulness. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question seven (SQ7), It is found that there is a significant association ($\chi2(16)$ = 147.744, p = 0.000).

Table 32: PKI vs SQ7 for case 4

		The training will be useful in my work (SQ7)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	0	0	0	0
	Disagree	0	1	0	1	0
	Neutral	1	0	9	3	3
	Agree	0	0	2	18	12
	Strongly Agree	0	2	4	6	37

a. PKI vs SQ7 χ^2 (16) = 147.744, p: 0.000

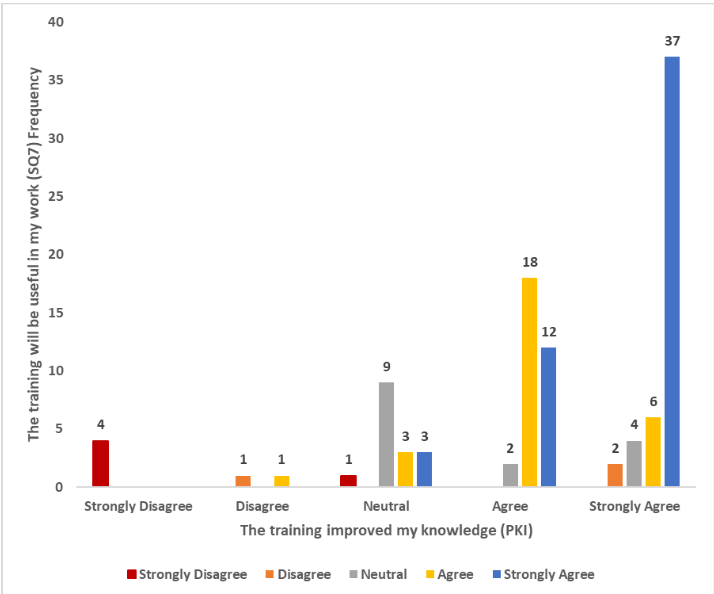

Figure 44: PKI vs SQ7 for case 4

4.3.3.8 PKI vs SQ8 for Respirable Crystalline Silica Training

The Survey Question eight (SQ8) was asking if the instructor was knowledgeable. Among the 103 trainees, 10 (9.71%), 5 (4.85%), 21 (20.39%) and 44 (42.72%) of them respectively agreed and strongly agreed about PKI and SQ8 (see **Table 33).** The result shown in **Figure 45** indicate that 8 (7.77%) of the trainees remained neutral while only 4 (3.88%) of them strongly disagreed. None of the trainees had changed their agreement into strong disagreement in their answers. For the cross tabulation results between the Perception of Knowledge Improvement (PKI) and The Survey Question eight (SQ8), It is found that there is a significant association ($\chi2(16)$ = 157.084, p = 0.000).

Table 33: PKI vs SQ8 for case 4

		The instructor was knowledgeable (SQ8)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training improved my knowledge (PKI)	Strongly Disagree	4	0	0	0	0
	Disagree	0	0	1	0	1
	Neutral	0	1	8	1	6
	Agree	0	0	1	10	21
	Strongly Agree	0	0	0	5	44

a. PKI vs SQ8 χ^2 (16) = 157.084, p: 0.000

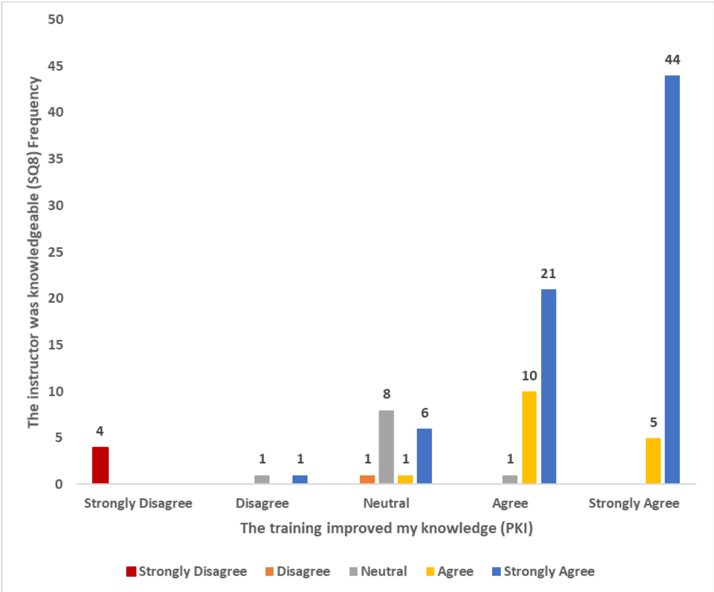

Figure 45: PKI vs SQ8 for case 4

4.4 Cross Tabulation for Self-Paced Independent Online Excavation and Trenching Training

Before performing cross tabulation on the data set, different cases were identified as shown in **Table 34**. Knowledge Improvement Ratio (KIR) was calculated by dividing the Posttest score with the Pretest score for each trainee. The results placed the trainees in the corresponding KIR for each case. A case could have one, two or three Knowledge Improvement Ratio (KIR). Knowledge Improvement Ratio (KIR) less than 1 or equal to 1 meant that the trainee's knowledge had degraded or remained at the same level after the training. The trainees improved their knowledge when the KIR was greater than 1.

Table 34: Self-Paced Independent Online Excavation Training Data Distribution

Online Excavation Training Cases	Knowledge Improvement Ratio (KIR)	Quantity of Trainee	Total
1) Pretest greater than or equal to 72 and Posttest greater than or equal to 72	< 1	1	97
	= 1	7	
	> 1	89	
2) Pretest greater than or equal to 72 and Posttest less than 72	< 1	2	2
3) Pretest less than 72 and Posttest greater than or equal to 72	> 1	117	117
4) Pretest less than 72 and Posttest less than 72	< 1	4	13
	= 1	1	
	> 1	8	
		Total	229

Univariate analysis gave us a general understanding of the whole dataset; however, it did not provide relationships between level 1 and level 2. Question number one in the survey was considered as metric for Perception of Knowledge Improvement (PKI) and was used as variables for level 1: Reaction. Knowledge Improvement Ratio (KIR) was used for learning - level 2. Only significant findings are presented in a tabulated form for the cross tabulation between knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI). Refer to sections 4.4.1 and 4.4.2.

4.4.1 Cross Tabulation Results for Pretest greater than or equal to 72 and Posttest greater than or equal to 72 for Self-Paced Independent Online Excavation and Trenching Training

4.4.1.1 Knowledge Improvement Ratio (KIR) for Self-Paced Independent Online Excavation and Trenching Training

The statistical results shown in **Table 35** indicate that the highest frequency among the total represented the trainees who had Knowledge Improvement Ratio (KIR) greater than 1. The number of trainees with KIR greater than 1 was 89 (91.75 %). Trainees who remained with the same KIR comprised 7.22 % and the percentage of trainees with KIR less than 1 was 1.03 % as shown in **Figure 46**. Most of the trainees had improved their knowledge from the self-paced independent online excavation training.

Table 35: Knowledge Improvement Ratio (KIR) for case 1

Knowledge Improvement Ratio (KIR)	Frequency	Percent	Valid Percent
<1	1	1.0	1.0
=1	7	7.2	7.2
>1	89	91.8	91.8
Total	97	100.0	100.0

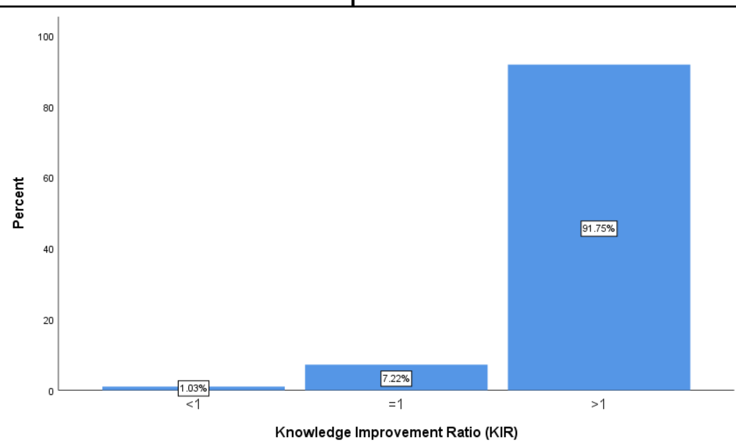

Figure 46: Knowledge Improvement Ratio (KIR) for case 1

4.4.1.2 Perception of Knowledge Improvement (PKI) for Self-Paced Independent Online Excavation and Trenching Training

The Perception of Knowledge Improvement (PKI) of the trainees was also evaluated. The statistical results shown in **Table 36** indicate that 4 (4.12%) of the trainees disagreed while 17 (17.53%) were neutral. Trainees counted for 53 (54.64%) agreed and 23 (23.71%) strongly agreed as shown in **Figure 47**. Most of the trainees had reported positively that the self-paced independent online excavation training had improved their knowledge.

Table 36: Perception of Knowledge Improvement (PKI) for case 1

The Training improvement my knowledge (PKI)	Frequency	Percent	Valid Percent
Strongly Disagree	4	4.1	4.1
Neutral	17	17.5	17.5
Agree	53	54.6	54.6
Strongly Agree	23	23.7	23.7
Total	97	100.0	100.0

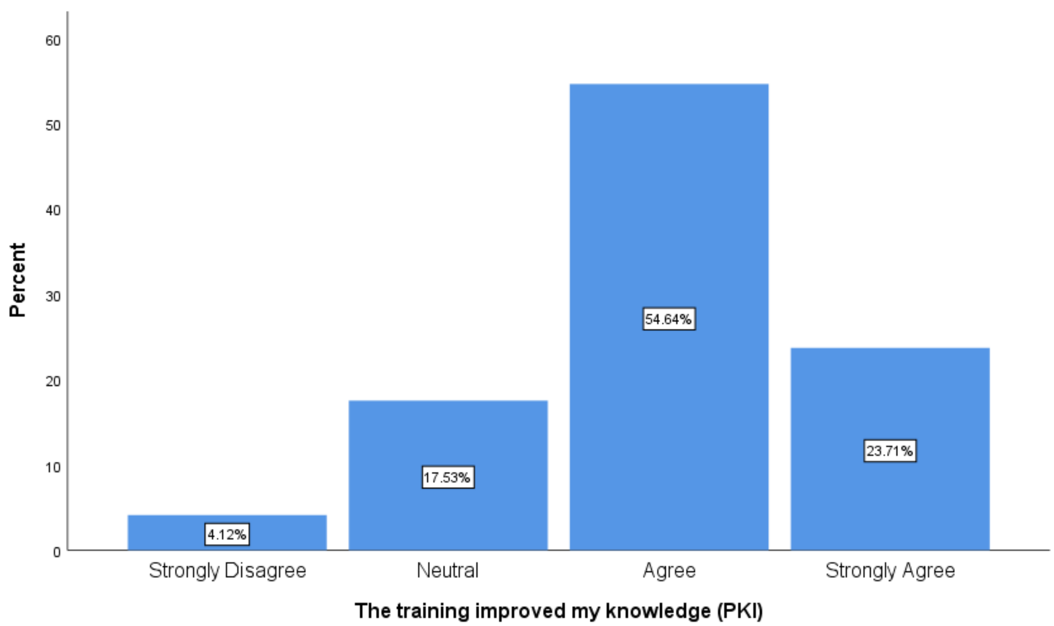

Figure 47: Perception of Knowledge Improvement (PKI) for case 1

4.4.1.3 Knowledge Improvement Ratio vs Perception of Knowledge Improvement for Self-Paced Independent Online Excavation and Trenching Training

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 37** indicate that among the 97 trainees, 49 (50.52%) and 19 (19.59%) respectively increased their knowledge and they agreed and strongly agreed that the training had improved their knowledge. Trainees counted for 17 (17.53%) remained neutral while 4 (4.12%) of them strongly disagreed for PKI even though their KIR was greater than 1. As shown in **Figure 48**, none of the trainees who did not improve their knowledge had reported disagreement for their perception of knowledge improvement. It is found that there is no significant association ($\chi 2(6) = 6.191$, $p = 0.402$) between KIR and PKI.

Table 37: KIR vs PKI for case 1

		The training improved my knowledge (PKI)			
		Strongly Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	<1	0	0	1	0
	=1	0	0	3	4
	>1	4	17	49	19

a. KIR vs PKI χ^2 (6) = 6.191, p: 0.402

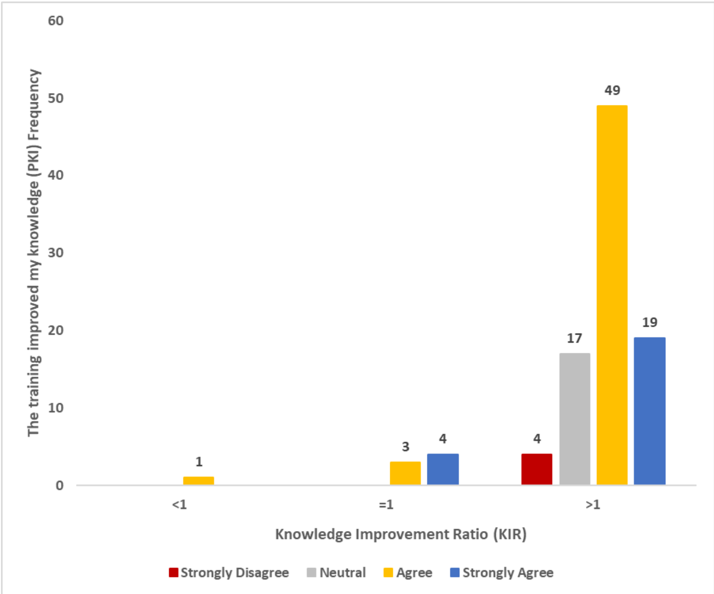

Figure 48: KIR vs PKI for case 1

4.4.2 Cross Tabulation Results for Pretest less than 72 and Posttest greater than or equal to 72 for Self-Paced Independent Online Excavation and Trenching Training

4.4.2.1 Knowledge Improvement Ratio (KIR) for Self-Paced Independent Online Excavation and Trenching Training

The statistical results shown in **Table 38** indicate that all the trainees had Knowledge Improvement Ratio (KIR) greater than 1. The number of trainees with KIR greater than 1 was 117 (100 %).

Table 38: Knowledge Improvement Ratio (KIR) for case 3

Knowledge Improvement Ratio (KIR)	Frequency	Percent	Valid Percent
>1	117	100.0	100.0
Total	117	100.0	100.0

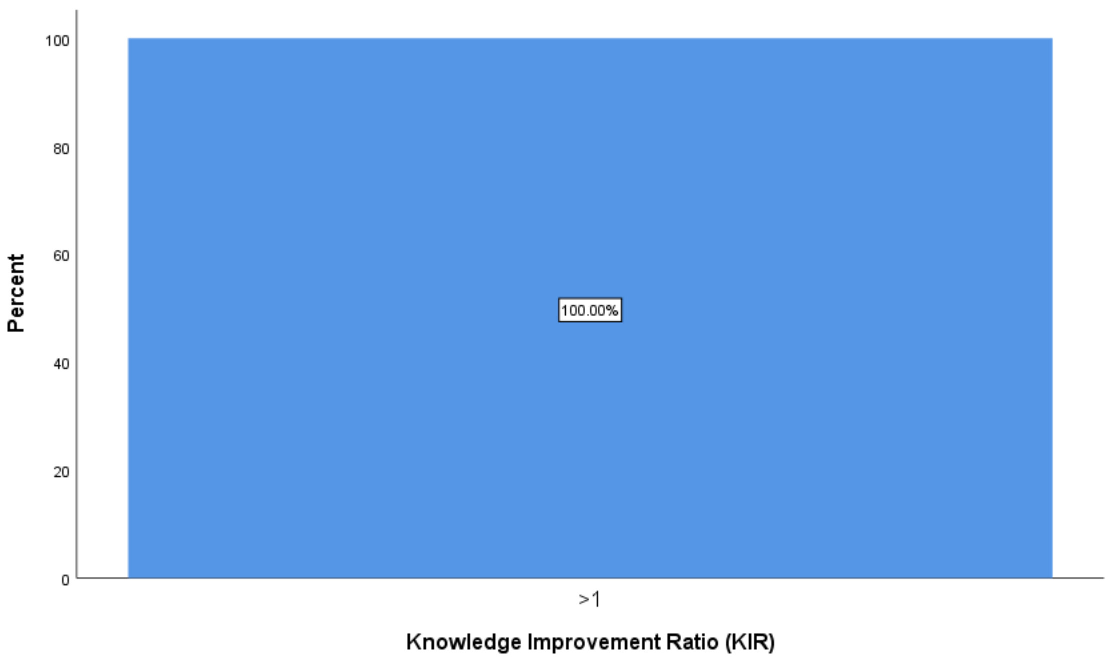

Figure 49: Knowledge Improvement Ratio (KIR) for case 3

4.4.2.2 Perception of Knowledge Improvement (PKI) for Self-Paced Independent Online Excavation and Trenching Training

The Perception of Knowledge Improvement (PKI) of the trainees was also evaluated. The statistical results shown in **Table 39** indicate that 9 (7.69%) of the trainees strongly disagreed and

1 (0.85%) of them disagreed while 20 (17.09%) were neutral. Trainees counted for 40 (34.19%) agreed and 47 (40.17%) strongly agreed as shown in **Figure 50**. Most of the trainees had reported positively that the self-paced independent online excavation training had improved their knowledge.

Table 39: Perception of Knowledge Improvement (PKI) for case 3

The Training improvement my knowledge (KI)	Frequency	Percent	Valid Percent
Strongly Disagree	9	7.7	7.7
Disagree	1	.9	.9
Neutral	20	17.1	17.1
Agree	40	34.2	34.2
Strongly Agree	47	40.2	40.2
Total	117	100.0	100.0

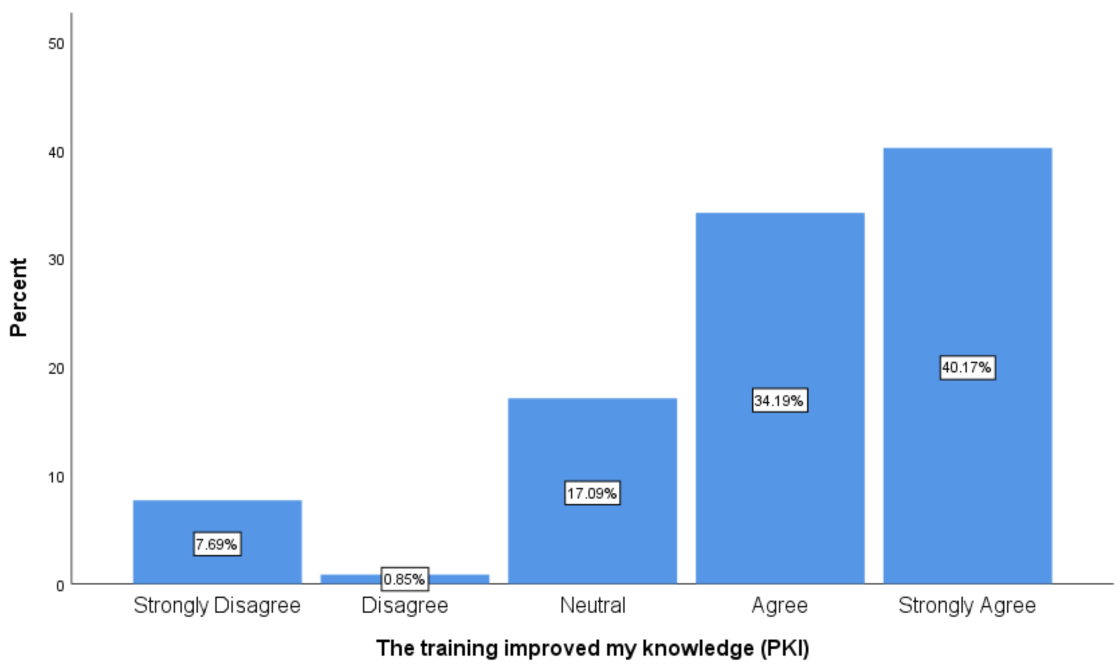

Figure 50: Perception of Knowledge Improvement (PKI) for case 3

4.4.2.3 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 40** indicate that among the 117 trainees, 40

(34.19%) and 47 (40.17%) respectively increased their knowledge and they agreed and strongly agreed that the training had improved their knowledge. Trainees counted for 20 (17.09%) remained neutral while 9 (7.69%) and 1 (0.85%) of them respectively strongly disagreed and disagreed for PKI even though their KIR was greater than 1. No statistics are computed because Knowledge Improvement Ratio is a constant.

Table 40: KIR vs PKI for case 3

		The training improved my knowledge (PKI)				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	>1	9	1	20	40	47

a. No statistics are computed because Knowledge Improvement Ratio is a constant.

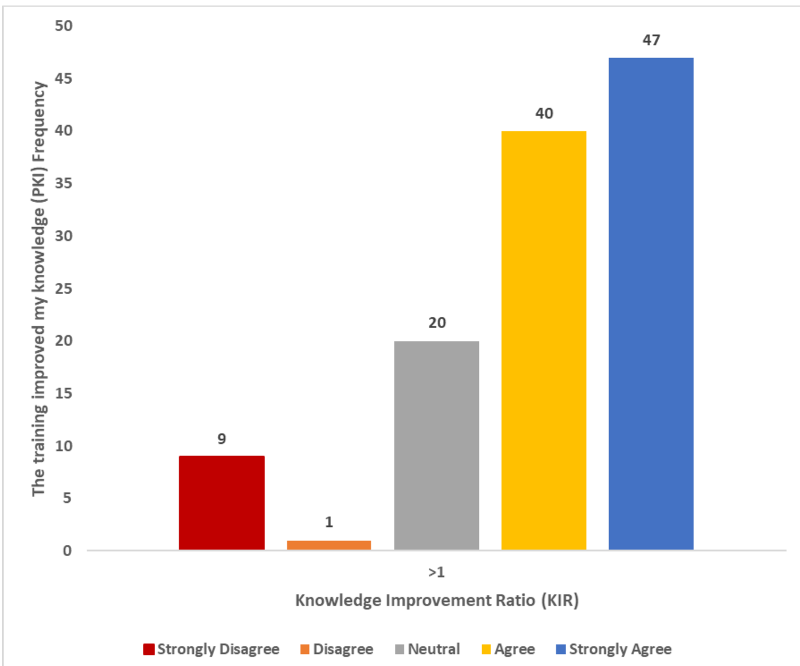

Figure 51: KIR vs PKI for case 3

4.5 Cross Tabulation for Instructor Led Traditional Excavation and Trenching Training

Before performing cross tabulation on the data set, different cases were identified as shown in **Table 41**. Knowledge Improvement Ratio (KIR) was calculated by dividing the Posttest score with the Pretest score for each trainee. The results placed the trainees in the corresponding

KIR for each case. A case could have one, two or three Knowledge Improvement Ratio (KIR). Knowledge Improvement Ratio (KIR) less than 1 or equal to 1 meant that the trainee's knowledge had degraded or remained at the same level after the training. The trainees improved their knowledge when the KIR was greater than 1.

Table 41: Instructor Led Traditional Excavation Training Data Distribution

Traditional Excavation Training Cases	**Knowledge Improvement Ratio (KIR)**	**Quantity of Trainee**	**Total**
1) Pretest greater than or equal to 72 and Posttest greater than or equal to 72	< 1	2	100
	= 1	6	
	> 1	92	
2) Pretest greater than or equal to 72 and Posttest less than 72	< 1	0	0
3) Pretest less than 72 and Posttest greater than or equal to 72	> 1	68	68
4) Pretest less than 72 and Posttest less than 72	< 1	0	8
	= 1	1	
	> 1	7	
		Total	176

Univariate analysis gave us a general understanding of the whole dataset; however, it did not provide relationships between the cases of level 1 and level 2. Question number one in the survey was considered as a metric for Perception of Knowledge Improvement (PKI) and was used as variables for level 1: Reaction. Knowledge Improvement Ratio (KIR) was used for learning - level 2. Only significant findings are presented in a tabulated form for the cross tabulation between knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI). Refer to sections 4.5.1 and 4.5.2.

4.5.1 Cross Tabulation Results for Pretest greater than or equal to 72 and Posttest greater than or equal to 72 for Instructor Led Traditional Excavation and Trenching Training

4.5.1.1 Knowledge Improvement Ratio (KIR) for Instructor Led Traditional Excavation and Trenching Training

The statistical results shown in **Table 42** indicate that the highest frequency among the total represented the trainees who had Knowledge Improvement Ratio (KIR) greater than 1. The number of trainees with KIR greater than 1 was 92 (92 %). Trainees who remained with the same KIR comprised 6 % and the percentage of trainees with KIR less than 1 was 2 % as shown in **Figure 52**. Most of the trainees had improved their knowledge from the instructor led traditional excavation and trenching training.

Table 42: Knowledge Improvement Ratio (KIR) for case 1

Knowledge Improvement Ratio (KIR)	Frequency	Percent	Valid Percent
<1	2	2.0	2.0
=1	6	6.0	6.0
>1	92	92.0	92.0
Total	100	100.0	100.0

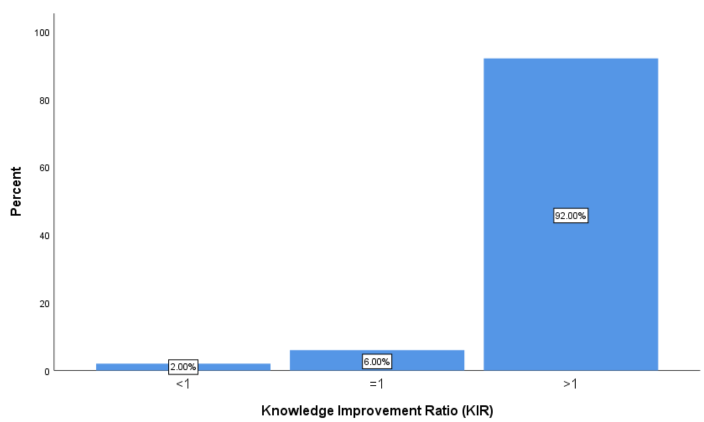

Figure 52: Knowledge Improvement Ratio (KIR) for case 1

4.5.1.2 Perception of Knowledge Improvement for Instructor Led Traditional Excavation and Trenching Training

The Perception of Knowledge Improvement (PKI) of the trainees was also evaluated. The statistical results shown in **Table 43** indicate that 4 (4%) of the trainees disagreed while 10 (10%) were neutral. Trainees counted for 40 (40%) agreed and 46 (46%) strongly agreed as shown in **Figure 53**. Most of the trainees had reported positively that the instructor led traditional excavation and trenching training had improved their knowledge.

Table 43: Perception of Knowledge Improvement (PKI) for case 1

The Training improvement my knowledge (PKI)	Frequency	Percent	Valid Percent
Disagree	4	4.0	4.0
Neutral	10	10.0	10.0
Agree	40	40.0	40.0
Strongly Agree	46	46.0	46.0
Total	100	100.0	100.0

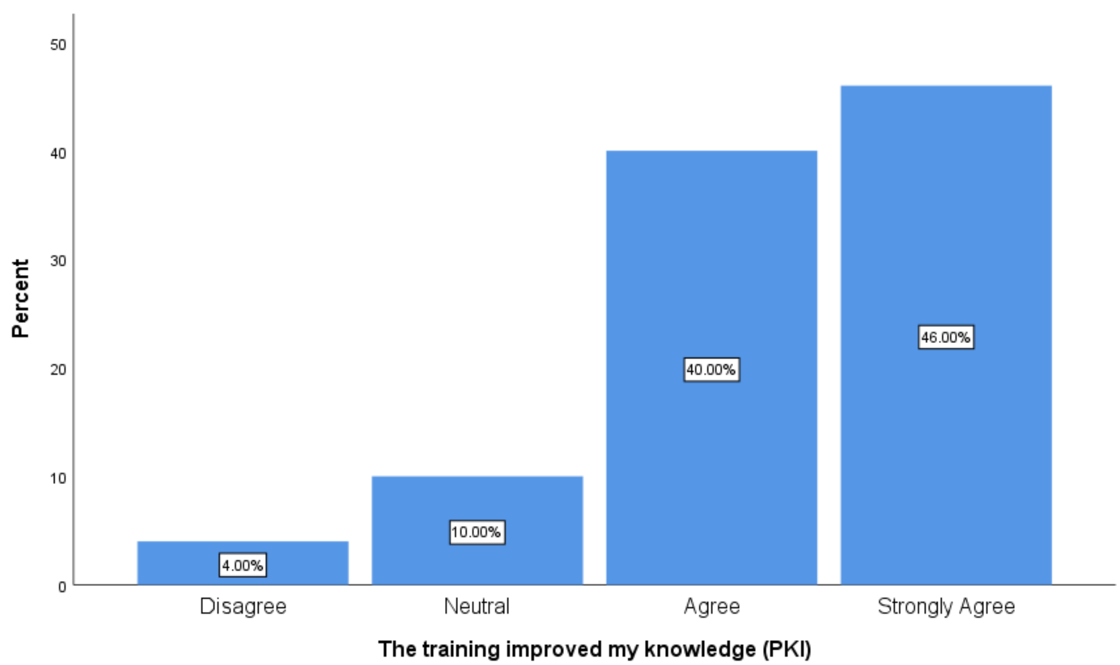

Figure 53: Perception of Knowledge Improvement (PKI) for case 1

4.5.1.3 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 44** indicate that among the 100 trainees, 38 (38%) and 43 (43%) respectively increased their knowledge and they agreed and strongly agreed that the training had improved their knowledge. Trainees counted for 8 (8%) remained neutral while 3 (3%) of them disagreed for PKI even though their KIR was greater than 1. As shown in **Figure 54**, only 1 (1%) of the trainees who remained with the same Knowledge Improvement Ratio (KIR) had reported disagreement for his or her perception of knowledge improvement. It is found that there is no significant association ($\chi2(6) = 7.368$, $p = 0.288$) between KIR and PKI.

Table 44: KIR vs PKI for case 1

		The training improved my knowledge (PKI)			
		Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	<1	0	0	1	1
	=1	1	2	1	2
	>1	3	8	38	43

a. KIR vs PKI χ^2 (6) = 7.368, p: 0.288

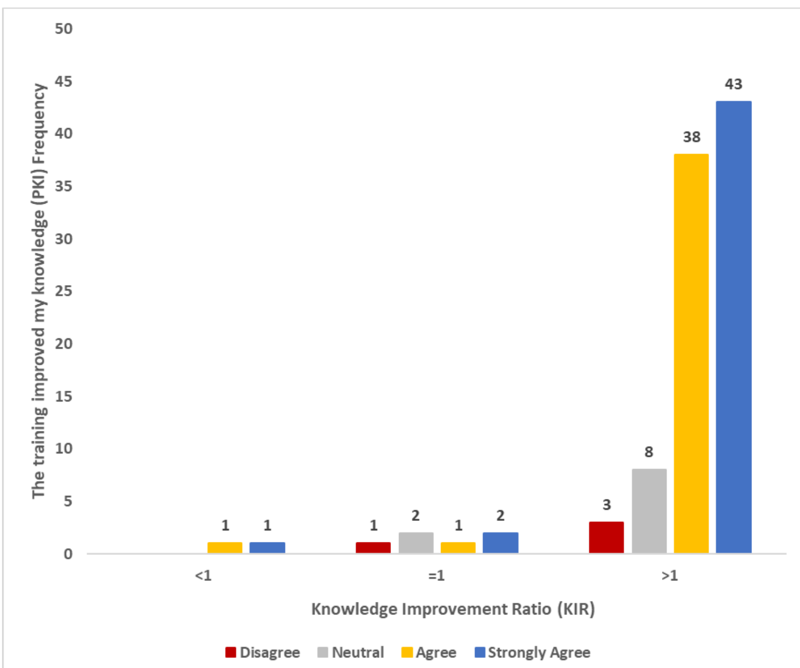

Figure 54: KIR vs PKI for case 1

4.5.2 Cross Tabulation Results for Pretest less than 72 and Posttest greater than or equal to 72 for Instructor Led Traditional Excavation and Trenching Training

4.5.2.1 Knowledge Improvement Ratio for Instructor Led Traditional Excavation and Trenching Training

The statistical results shown in **Table 45** indicate that all the trainees had Knowledge Improvement Ratio (KIR) greater than 1. The number of trainees with KIR greater than 1 was 68 (100 %).

Table 45: Knowledge Improvement Ratio (KIR) for case 3

Knowledge Improvement Ratio (KIR)	Frequency	Percent	Valid Percent
>1	68	100.0	100.0
Total	68	100.0	100.0

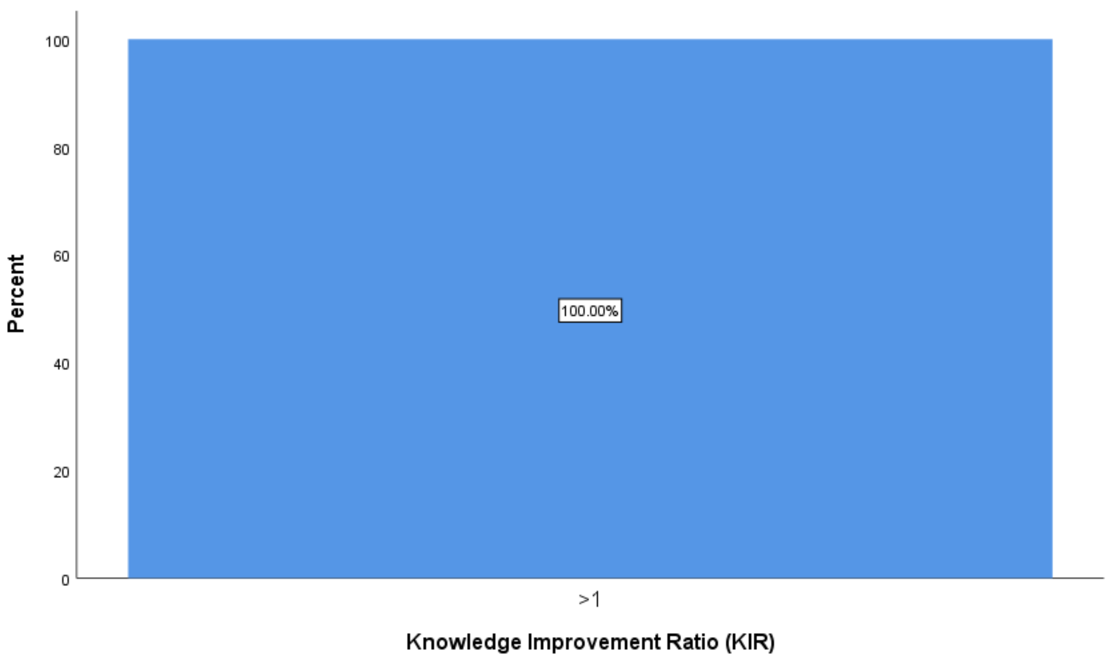

Figure 55: Knowledge Improvement Ratio (KIR) for case 3

4.5.2.2 Perception of Knowledge Improvement for Instructor Led Traditional Excavation and Trenching Training

The Perception of Knowledge Improvement (PKI) of the trainees was also evaluated. The statistical results shown in **Table 46** indicate that 2 (2.94%) of the trainees disagreed while 4 (5.88%) were neutral. Trainees counted for 21 (30.88%) agreed and 41 (60.29%) strongly agreed as shown in **Figure 56**. Most of the trainees had reported positively that the instructor led traditional excavation and trenching training had improved their knowledge.

Table 46: Perception of Knowledge Improvement (PKI) for case 3

The Training improvement my knowledge (KI)	Frequency	Percent	Valid Percent
Disagree	2	2.9	2.9
Neutral	4	5.9	5.9
Agree	21	30.9	30.9
Strongly Agree	41	60.3	60.3
Total	68	100.0	100.0

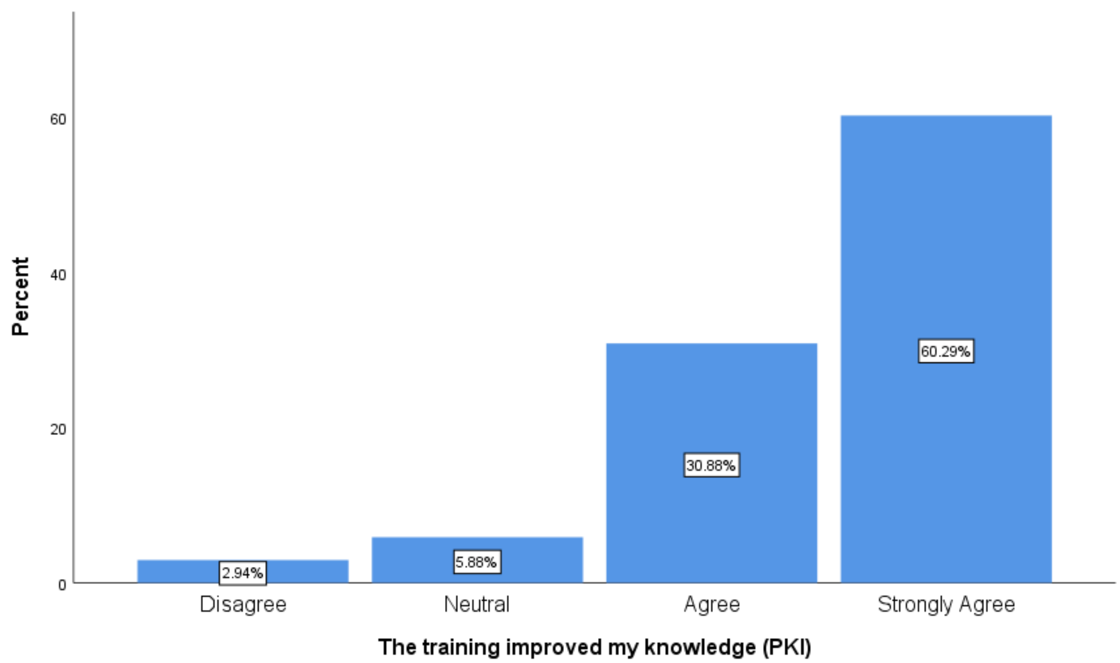

Figure 56: Perception of Knowledge Improvement (PKI) for case 3

4.5.2.3 Knowledge Improvement Ratio vs Perception of Knowledge Improvement

The cross tabulation results for Knowledge Improvement Ratio (KIR) and Perception of Knowledge Improvement (PKI) shown in **Table 47** indicate that among the 68 trainees, 21 (30.88%) and 41 (60.29%) respectively increased their knowledge and they agreed and strongly agreed that the training had improved their knowledge. Trainees counted for 4 (5.88%) remained neutral while 2 (2.94%) of them disagreed for PKI even though their KIR was greater than 1. No statistics are computed because Knowledge Improvement Ratio is a constant.

Table 47: KIR vs PKI for case 3

		The training improved my knowledge (PKI)			
		Disagree	Neutral	Agree	Strongly Agree
Knowledge Improvement Ratio (KIR)	>1	2	4	21	41

a. No statistics are computed because Knowledge Improvement Ratio is a constant.

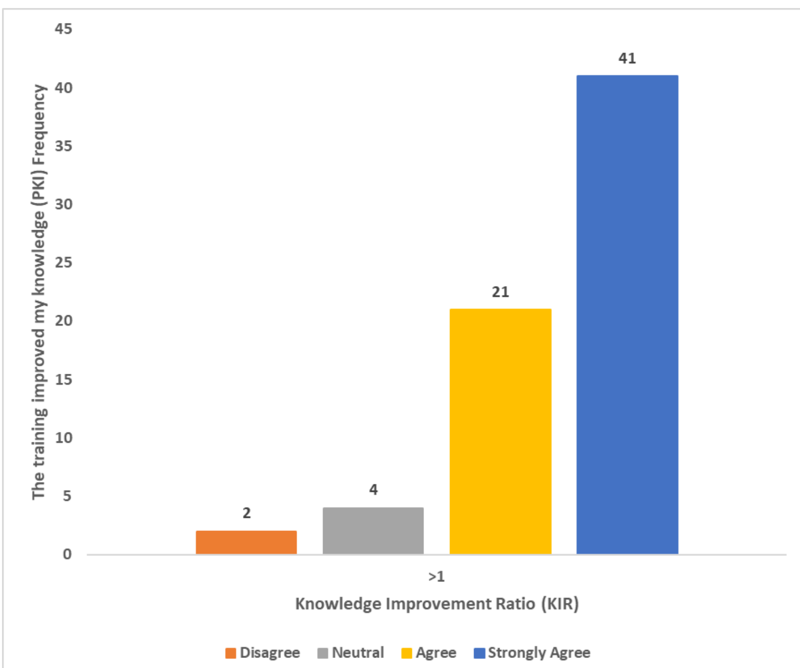

Figure 57: KIR vs PKI for case 3

CHAPTER 5: SUMMARY, CONCLUSIONS, LESSON LEARNED AND RECOMMENDATIONS

5.1 Summary

The objective of the study was to identify a new metric to measure learning effectiveness, to find the factors affecting Reaction: level 1 - Perception of Knowledge Improvement (PKI), to find the statistically significant correlation of level 1 and level 2 and how Reaction: level 1 - Perception of knowledge Improvement (PKI) affects Learning: level 2 - Knowledge Improvement Ratio (KIR).

The analyses are conducted by following the Kirkpatrick model of training effectiveness evaluation. Data collected from two grants, Respirable Crystalline Silica (29 CFR 1926.1153) and Excavation and Trenching (29 CFR 1926 Subpart P), are used as case studies to apply the Kirkpatrick model of training effectiveness evaluation. The findings are used to improve the overall training systems.

5.2 Conclusions

As part of the proposals, level 1: Reaction and Level 2: Learning have been determined to be variables to evaluate the trainings effectiveness. The reaction of the trainees has been collected from the survey questions one (1) through eight (8). Their answers show that most them have agreed or strongly agreed to the training components. The knowledge improvement of the trainees has been considered as level 2. We have found that most them have improved their knowledge on the topics or standards.

For the instructor led traditional respirable crystalline silica training, the reaction: level 1 of the trainees has reported that most of them have strongly agreed and agreed that the training has improved their knowledge when their Perception of Knowledge Improvement (PKI) has been evaluated. In addition, the level 2: learning measured by the Knowledge Improvement Ratio (KIR) has been greater than 1 for most of the trainees. It has also been found that most of the trainees who have reacted more in favor of the training and its components also have better Knowledge Improvement Ratio (KIR).

For the self-paced independent online excavation and trenching training, most of the trainees strongly agree or agree when their reaction: level 1 has been evaluated. The knowledge Improvement Ratio (KIR) greater than 1 represented the majority of the trainees. Most of the trainees who have reacted very well to the training have the highest Knowledge Improvement Ratio (KIR).

For the instructor led traditional excavation and trenching training, we have also found that most of the trainees have had an agreeable perception of the training and its components and they have increased their knowledge. Furthermore, most of the trainees who have agreed and strongly agreed to the training and its components have obtained Knowledge Improvement Ratio (KIR) greater than 1.

It is further concluded that trainees who have had the perception that the training they have gone through improved their knowledge on the subject have performed better on the posttests; therefore, their knowledge improvement ratio has shown greater improvement.

When we have compared the results of level 1 and level 2 between two different trainings which have used two different delivery methods, we have found a better reaction: level 1 as well as a better learning: level 2 for the self-paced independent online excavation and trenching training than the instructor led traditional respirable crystalline silica training.

When we have compared the results of level 1 and level 2 between two different trainings which have used the same delivery method, we have found a better reaction: level 1 as well as a better learning: level 2 for the instructor led traditional excavation and trenching training than the instructor led traditional respirable crystalline silica training.

The reason for a such result is supported by the fact that the respirable crystalline silica training has been developed on the new occupational exposure to respirable crystalline silica standard published on March 25, 2016 while the excavation and trenching training has been developed on an old and revised standard which has been more familiar to the trainees.

For the same subject, i.e. excavation and trenching, the instructor led traditional delivery method has been more effective than the self-paced independent online delivery method. The reaction: level 1 of the trainees has been optimal. And they have achieved higher percentage of Knowledge Improvement Ratio (KIR); level 2: learning, in the instructor led traditional delivery method of the excavation and trenching training.

Based on Kirkpatrick Level 1 – reaction training effectiveness evaluation, it is found that in both training subjects as well as in both training delivery methods (traditional and online); the trainings have been effective due to the fact that majority of the trainees have shown agreement or strongly agreement to the question measuring their perception of knowledge improvement.

When we have further analyzed what may have effect on the perception of the trainees, we have found that when the training materials are easy to understand per their literacy level, and the module is easy to read and follow it helps the trainees to improve their knowledge.

Moreover, it is important that the training facilitator defines and communicates the objectives of the training to the trainees. Our analysis has revealed that when trainees agree that the training's objectives are clearly defined, their perception on knowledge improvement also increase based on the Likert scale.

Other factors that have shown statistically significant association with the trainee's knowledge improvement perception have been identified as relevance of the topic, time allocation, the instructor's knowledge on the subject. Furthermore, trainees' perception on knowledge improvement significantly increase when they can relate the training subject to their job applications.

5.3 Lessons Learned and Recommendations

People believe that participants who are dissatisfied with the training (level 1) and failed to demonstrate that they have assimilated the subject matter (level 2) are unlikely to then demonstrate effective transfer (level 3) leading to undesired results (level 4).

The study recommends to go further to focus also on the change of behavior (Level 3 of Kirkpatrick Model) of trainees after receiving a specific training and level 4 (Return on Expectation - ROE and Return on Investment – ROI). … Level 1, 2, 3 and 4 of evaluation are linked or interconnected. Future papers will be focused on the continuity of this study which evaluated only level 1 and 2 of safety training on respirable crystalline silica and excavation and trenching training topics.

APPENDIX

A. Opinion Survey

Please answer the questions below by assigning ratings from 1 to 5. One being strongly disagree, and five being strongly agree. All answers are completely confidential.

1) This safety training improved my knowledge and understanding.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

2) Overall, the safety training materials presented were easy to understand.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

3) The PowerPoint presentation was easy to read and follow.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

4) The objectives of this training were clearly defined.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

5) The topic covered was relevant to me.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

6) The time allotted for this training was sufficient.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

7) This training experience will be useful in my work.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

8) The instructor was knowledgeable on the training subjects.

STRONGLY DISAGREE 1 2 3 4 5 STRONGLY AGREE

B. Sign-Up

Please answer the following questions. All answers are completely confidential. Circle correct answer(s). In some cases, you need to circle only one correct answer; in some other cases, you can circle all answers that apply (i.e. more than one answer).

FIRST NAME: ***LAST NAME:***

1. What is your level of education?
   a) High School/GED
   b) Some college
   c) Associate degree
   d) Bachelor’s degree
   e) Graduate degree
   f) Other _____________

2. What is your job classification?
   a) Operating Engineer
   b) Mason
   c) Bricklayer
   d) Laborer
   e) Other (Please specify) ___________

1. How long have you been in construction industry?
   a. 1-5
   b. 6-10
   c. 11-15
   d. 16-20
   e. 20+

2. Do you have any of the safety training certifications listed below, please select all that apply?
   a. None
   b. M.U.S.T Safety
   c. OSHA 10/ MIOSHA 10
   d. OSHA 30/ MIOSHA 30
   e. Other____________________________

REFERENCES

1. United States Department of Labor. Bureau of Labor and Statistics “Injuries, Illnesses and Fatalities Data”. Website: https://www.bls.gov/iif/oshsum.htm
2. US Department of Labor. Bureau of Labor Statistics. News Release. “National Census of Fatal Occupational Injuries in 2017”. Website: https://www.bls.gov/news.release/pdf/cfoi.pdf
3. US Department of Labor. Bureau of Labor Statistics. “Census of Fatal Occupational Injuries Summary, 2017”. Website: https://www.bls.gov/news.release/cfoi.nr0.htm
4. United States Department of Labor. Occupational Safety and Health Administration (OSHA). “Safety and Health topics - Incident Investigation”. Website: https://www.osha.gov/dcsp/products/topics/incidentinvestigation/index.html
5. United States Department of Labor. Occupational Safety and Health Administration (OSHA). Susan Harwood Training Grant Program. Program Statistics. Website: https://www.osha.gov/dte/sharwood/statistics.html
6. U.S. Bureau of Labor Statistics. Self-employment in The United States - Steven F. Hipple and Laurel A. Hammond (MARCH 2016).
7. US Department of Labor. Occupational Safety and Health Administration (OSHA). “Respirable Crystalline Silica”. Website: https://www.osha.gov/dsg/topics/silicacrystalline/
8. US Department of Labor. Occupational Safety and Health Administration (OSHA). “Excavation and Trenching”. Website: https://www.osha.gov/SLTC/trenchingexcavation/
9. Jim Kirkpatrick and Wendy Kayser Kirkpatrick “The Kirkpatrick Four Levels: A Fresh Look After 50 Years, 1959 – 2009”. Kirkpatrick partners LLC. (2009-2011).
10. Kirkpatrick Partners. The One and Only Kirkpatrick. Kirkpatrick Foundational Principles. Website: https://www.kirkpatrickpartners.com/Our-Philosophy/Kirkpatrick-Foundational-Principles

11. Kirkpatrick Partners. The One and Only Kirkpatrick. The New World Kirkpatrick Model. Website: https://www.kirkpatrickpartners.com/Our-Philosophy/The-New-World-Kirkpatrick-Model
12. Dr Gog Soon & Joo Seet Jun Feng, March 2017. “THE KIRKPATRICK MODEL: The end is the beginning”. Website: https://www.ial.edu.sg/content/ialeads/pdfs/The_Kirkpatrick_Model.pdf
13. Example of Handout “Kirkpatrick’s Four Level of Training Evaluation in Detail”. Website: http://www.ct.gov/ctdn/lib/ctdn/ttt_14_m5_handouts2.pdf
14. Winfrey, Elaine C. "Kirkpatrick's four levels of evaluation." Encyclopedia of educational technology 1.1 (1999): 1-6.
15. La Duke, Phil. "How to Evaluate Training: Using the Kirkpatrick Model." Professional Safety 62.8 (2017): 20.
16. M. McLain. “Evaluating Long-Term Training Effectiveness.” DAI Solutions May, 2017. Website: http://www.dai-solutions.com/evaluating-long-term-training-effectiveness/
17. P. Tamkin, J. Yarnall, M. Kerrin “Kirkpatrick and Beyond: A review of models of training evaluation.” Institute Employment Studies (2002).
18. T. Brewer. “Use of Phillip’s Five Level Training Evaluation and Return on Investment Framework in the U.S. Non-Profit Sector” University of North Texas. August, 2007. Dissertation Prepared for the Degree of DOCTOR OF PHILOSOPHY.
19. Handbook of Training Evaluation and Measurement Methods by Jack J. Phillips. 3rd Edition. Website: https://www.taylorfrancis.com/books/9781136010422
20. Simplify Training “Learn, Comply, Succeed”. Ensure your training is effective. Website: http://trainingtoday.blr.com/article/ensure-your-training-is-effective/
21. MindTools “Kirkpatrick's Four-Level Training Evaluation Model - Analyzing Learning Effectiveness”. Website: https://www.mindtools.com/pages/article/kirkpatrick.htm

22. Kazan, Esref Emrah, "Analysis Of Fatal And Nonfatal Accidents Involving Earthmoving Equipment Operators And On-Foot Workers" (2013). Wayne State University – Dissertations. Paper 731.
23. Amin Akhavan Tabassi, Mahyuddin Ramli and Abu Hassan Abu Bakar, “Effects of training and motivation practices on teamwork improvement and task efficiency: The case of construction firms”, International Journal of Project Management 30 (2012) 213–224.
24. Dong-X; Entzel-P; Men-Y; Chowdhury-R; Schneider-S, “Effects of safety and health training on work-related injury among construction laborers”. J Occup Environ Med 2004 Dec; 46(12):1222-1228.
25. Chun-Ling Ho, Ren-Jye Dzeng, “Construction safety training via e-Learning: Learning effectiveness and user satisfaction”. Computers & Education. Volume 55, Issue 2, September 2010, Pages 858-867.
26. Aziz Rahimizadeh, Mohammad Hasan Basirinezhad, Akram Olmolok Lahijanian, Reza Arjmandi, “Effectiveness of Health, Safety, and Environment Training Courses Using the Kirkpatrick Model and Providing Managerial Solutions for the Staff of Sinadarou Company”. Biomedical and health, 3, 1, (2018), 54-61.
27. Eduardo Salas, Katherine A. Wilson, Heather A. Priest, and Joseph W. Guthrie. “DESIGN, DELIVERY, AND EVALUATION OF TRAINING SYSTEMS”. University of Central Florida, Orlando, Florida.
28. Kaya, Serhan, "Effect Of Construction Worker Demographic On E-Learning With Hazard Communication Standard" (2014). Wayne State University - Thesis. Paper 381.
29. Hasse Nordlöf, Birgitta Wiitavaara, Hans Högberg, Ragnar Westerling “A cross-sectional study of factors influencing occupational health and safety management practices in companies”. Safety Science 95 (2017) 92–103.
30. Sang D. Choi “Aging Workers and Trade-Related Injuries in the US Construction Industry” Safety and Health at Work 6 (2015) 151-155.

31. James Avis, Ann-Marie Bathmaker & John Parsons (2002) Communities of practice and the construction of learners in post-compulsory education and training, Journal of Vocational Education and Training, 54:1, 27-50, DOI: 10.1080/13636820200200186.
32. Yangho Kim, Jungsun Park, Mijin Park “Creating a Culture of Prevention in Occupational Safety and Health Practice”. Safety and Health at Work 7 (2016) 89-96.
33. Thanet Aksorn, B.H.W. Hadikusumo “Critical success factors influencing safety program performance in Thai construction projects”. Safety Science 46 (2008) 709–727.
34. Michael J. Burke, Suzanne Chan-Serafin, Rommel Salvador, Alexis Smith & Sue Ann Sarpy (2008) The role of national culture and organizational climate in safety training effectiveness, European Journal of Work and Organizational Psychology, 17:1, 133-152, DOI: 10.1080/13594320701307503.
35. Emrah Kazan, Mumtaz A. Usmen “Worker safety and injury severity analysis of earthmoving equipment accidents”. Journal of Safety Research 65 (2018) 73–81.
36. Gulgun Mistikoglu, Ibrahim Halil Gerek, Ercan Erdis, Mumtaz Usmen, Hulya Cakan, Emrah Esref Kazan “Decision tree analysis of construction fall accidents involving roofers”. Expert Systems with Applications 42 (2015) 2256–2263.
37. YINGGANG WANG, PAUL M. GOODRUM, CARL HAAS, ROBERT GLOVER and SHARAM VAZARI “Analysis of the benefits and costs of construction craft training in the United States based on expert perceptions and industry data”. Construction Management and Economics (December 2010) 28, 1269–1285.
38. Rafiq M. Choudhry “Behavior-based safety on construction sites: A case study”. Department of Civil and Environmental Engineering, College of Engineering, King Faisal University, Al-Hofuf, Al-Ahsa 31982, Saudi Arabia.
39. Chun-Ling Ho, Ren-Jye Dzeng “Construction safety training via e-Learning: Learning effectiveness and user satisfaction”. Computers & Education 55 (2010) 858–867.

40. Glenn Trout "E-Learning & Online Training Keeping Up with the Evolving Workplace". Training Tips. Professional Safety. (JUNE 2016) (www.asse.org)

41. Iraj Mohammadfam, Mojtaba Kamalinia, Mansour Momeni, Rostam Golmohammadi, Yadollah Hamidi, Alireza Soltanian "Evaluation of the Quality of Occupational Health and Safety Management Systems Based on Key Performance Indicators in Certified Organizations". Safety and Health at Work 8 (2017) 156-161.

42. Wendy E. A. Ruona, Michael Leimbach, Elwood F. Holton III and Reid Bates "The relationship between learner utility reactions and predicted learning transfer among trainees". International Journal of Training and Development 6:4. ISSN 1360-3736.

43. Hun Myoung Park "Univariate Analysis and Normality Test Using SAS, Stata, and SPSS". Ph.D. Indiana University (2008).

ABSTRACT

TRAINING EFFECTIVENESS ANALYSIS OF OSHA SILICA AND EXCAVATION SAFETY STANDARDS FOR CONSTRUCTION

by

BEDEL DESRUISSEAUX

May 2019

Advisor: Dr Mumtaz Usmen

Major: Civil Engineering

Degree: Master of Science

As construction safety and health standards evolve due to changing industry practices and stakeholder expectations, and as the mandates get stronger for compliance with these standards, the need for training programs becomes more pronounced. The proposed paper covers the training material development and program delivery and evaluation efforts associated with two OSHA standards applicable to construction; one on Respirable Crystalline Silica (29 CFR 1926.1153) and other on Excavation and Trenching (29 CFR 1926 Subpart P). The work reported was undertaken through federally funded grants under the auspices of OSHA's Susan Harwood program. The training materials developed consisted of PowerPoint instructional modules; pretests and posttests to measure incremental knowledge gain; exercises to support better understanding of the training contents; and survey instruments to evaluate the effectiveness of the training materials and training delivery systems used in implementing the programs. Trainees included employees and employers representing various trades (operating engineers, laborers, masons, facilities personnel and others). The delivery was performed by an instructor led traditional lecture method for the Silica standard, while a combination of instructor led traditional lecture and independent self-spaced online methods was implemented for the Excavation and Trenching standard. Training material and program delivery details and the acquisition and

analysis of all the data pertaining to training effectiveness analysis and evaluation based on Kirkpatrick levels 1 and 2 are described and discussed in this thesis.

AUTOBIOGRAPHICAL STATEMENT

Bedel Desruisseaux joined Wayne State University for the first time in Winter 2014. It was the last semester to complete his Bachelor of Sciences degree. He was able to come to Wayne State University because of a scholarship he had received from World Learning and Department States of America via the embassy of the United States of America in Haiti. At the end of his first adventure, he came back to Haiti and transferred the credits earned to the American University of the Caribbean (AUC) - Les Cayes, Haiti; from which he graduated and obtained a Bachelor of Science in Civil Engineering in 2014. He was the best student of his class in the Civil Engineering Department and the salutatorian during the commencement ceremony.

Bedel Desruisseaux worked in private construction companies, telecommunication company, non-governmental organizations as well as personal construction jobs in Haiti. He was involved in construction of road, hospital, residential housing for private owners and government. He worked with a lot of pioneer engineers who implanted in him the best skills a Civil Engineer should possess. He served as a teaching assistant to the American English teacher during his study at the American University of the Caribbean. He had the privilege to introduce the first-year students to the Civil Engineering career in September 2017 at the American University of the Caribbean. In January 2018, his second adventure at Wayne State University started and he is obtaining a Master of Science degree in Civil Engineer specializing Construction Management, on May 2nd, 2019. He has been serving as a Graduate Student Assistant and Graduate Teaching Assistant at Wayne State University during his graduate education.