STARS

University of Central Florida
STARS

Electronic Theses and Dissertations, 2004-2019

2015

A Framework for Safety Training Using Virtual Reality Software

Rana Riad
University of Central Florida

Part of the Industrial Engineering Commons
Find similar works at: https://stars.library.ucf.edu/etd
University of Central Florida Libraries http://library.ucf.edu

This Masters Thesis (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Electronic Theses and Dissertations, 2004-2019 by an authorized administrator of STARS. For more information, please contact STARS@ucf.edu.

STARS Citation

Riad, Rana, "A Framework for Safety Training Using Virtual Reality Software" (2015). *Electronic Theses and Dissertations, 2004-2019*. 1173.
https://stars.library.ucf.edu/etd/1173

University of Central Florida
STARS
Showcase of Text, Archives, Research & Scholarship

A FRAMEWORK FOR SAFETY TRAINING USING VIRTUAL REALITY SOFTWARE

by

RANA A. RIAD
B.S.I.E. University of Central Florida, 2014

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science in Industrial Engineering
in the Department of Industrial Engineering and Management Systems
in the College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Spring Term
2015

Major Professor: Luis C. Rabelo

© 2015 Rana A. Riad

ABSTRACT

Safety training is a vital component to the well-being of individuals in all industries. With technology advancing at the current pace, conventional training methods are no longer the most effective way to communicate information. There is a strong need for safety training that incorporates new methods and forms of communication to obtain higher levels of comprehension. Virtual reality systems offer a highly customizable and interactive form of delivering information to users. This research addresses major gaps in the field of safety training using virtual reality systems and provides a design framework for creating a virtual safety-training system. A model for the virtual environment is designed and developed and the process and justification is described. The environment and an applied use case for this model is developed and verified using a sample of trainees that would use the model. This exploratory framework provides a significant contribution to the field of safety education through virtual reality systems and can be expanded with further research.

Dedicated to my loving father Ashraf, my mother Riham, & my brother Aladdin

ACKNOWLEDGMENTS

First and foremost I would like to humbly thank the Almighty God. Without His grace and will, nothing would be possible. I pray that He continues to bless me and allow me to shine my light and contribute positively to humanity.

I would like to thank my advisor, Dr. Luis Rabelo. He has been my professor and mentor and I could not be more grateful for his guidance and support to my growth at UCF. Thank you to Dr. Gene Lee and Dr. Ana Ferreras for your supporting roles on my advisory committee. Thank you to the rest of my research team, Alexander Katsarsky and Connor Ford, as well as the members of the Simulation & Interoperability Lab. Thank you to the rest of the UCF professors for teaching me and pushing me to learn and succeed, including Dr. Ahmad Elshennawy, Dr. Jose Sepulveda, Dr. William Thompson, Dr. Waldemar Karwowski, and Dr. Michael Georgiopoulos. The team at UCF is gifted and I have truly learned from the best.

Thank you to President John Hitt, Dr. Nancy Marshall, Ms. Ana Petkov, as well as the rest of the Office of the President. I am grateful for your support and the opportunities I have had that helped shape me into a poised, polished, and professional leader. I cannot be more grateful for the wonderful UCF experiences that I have had. It has been an honor to learn from the best and brightest.

Thank you to my amazing friends and coworkers for your support. This has been a long journey and I could not have done it without your constant encouragement, patience, and belief in me.

Most importantly, thank you to my amazing family. First, thank you to my best friend and mother, Riham. My world would not be the same without you. You are always there for me, whether it be in a time of hardship or a time of happiness. You are my voice of reason and my words of encouragement. Thank you to my father, Ashraf. You have been my main inspiration in pursuing my engineering dreams since day one. Your confidence in me keeps me going, and I would not be the strong person I am today without your support. The unconditional confidence you both have in me is what keeps me going and allows me to accomplish anything I set my mind to. I hope I always continue to make you both proud of your little girl. Thank you to my brother, Aladdin. Your intelligence will never cease to amaze me. Thank you for always thinking the world of me and helping me whenever I need it. Seeing your passion in your work only makes me want to continue to better myself. The three of you are my main support system and I am truly blessed and fortunate to have you in my life.

With Love,

Rana Riad

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS/ACRONYMS

AIVTS	Artificial Intelligent Virtual Training System
CI	Confidence Interval
ENG2	Engineering 2 Building
IEEE	Institute of Electrical and Electronics Engineers
LVS	Live Virtual Simulation
LVC	Live Virtual Construction
MOSES	Military Open Simulator Enterprise Strategy
NEC	National Electrical Code
OSHA	Occupational Safety and Health Administration
PEVTS	Psycho-Educational Vocational Training System
SD	Standard Deviation
SL	Second Life
SKP	SketchUp Pro
STTC	United States Army Simulation and Training Technology Center
UCF	University of Central Florida
VR	Virtual Reality
VRS	Virtual Reality System
WSS	Wiimote Stereo Structure

CHAPTER ONE: INTRODUCTION

In this chapter, the background of safety training using virtual reality will begin. The problem statement of this research will be discussed as well as objectives, and research contributions. Furthermore, the distribution of this paper will be stated, laying out the synopsis of this work.

1.1: Background

Human nature is to excel and build. Since the beginning of time, humans have set out on a path of discovery, building and creating things as they see the need for them. During the Industrial Revolution, the evolution of industry became something that fascinated all. Machinery had become a way to improve on the systems humans put in place such as advances in agriculture, mining, textiles, manufacturing, and health.

With the advancement of humans' methods came issues that were never a problem before. Safety started to become a pressing matter for the common worker. The working conditions were atrocious. It seemed like the more advancements they made in manufacturing, the greedier industries became. Companies started accepting workers at all ages, with no regard for their well-being. There was no certain plan set forth for spontaneous fires, explosions, chemical spills, personal injuries, or other safety concerns that could occur.

The Occupational Safety and Health Administration (OSHA) in the United States was established in 1971 by the Department of Labor to improve workplace safety ("Timeline of OSHA's 40 Year

History,"). OSHA improved workplace safety by instilling rules and minimums that each company had to abide by. Today, OSHA still stands to be the greatest single improvement in ensuring that safety procedures are adhered to.

A large part of OSHA's job is to educate employers and employees about the best way to handle situations where safety may be a concern. Employers have the responsibility of properly conveying such things in the most effective manner. Traditionally, safety is taught to employees through conventional methods of board room meetings, presentations such as Keynote or PowerPoint slides, safety procedure books and pamphlets, or online modules that employees are required to read and answer simple questions to. All of these methods are acceptable for conveying facts, but one has to question their effectiveness. According to Dale's research on audio-visual methods in teaching, there are degrees and classifications of learning (Masters, 2013). Dale presented this to show that learning through audio, visual, and written examples is only a small part of learning. As seen in Figure 1, the greater support (the base of the cone) is based on direct experiences and use of the learning.

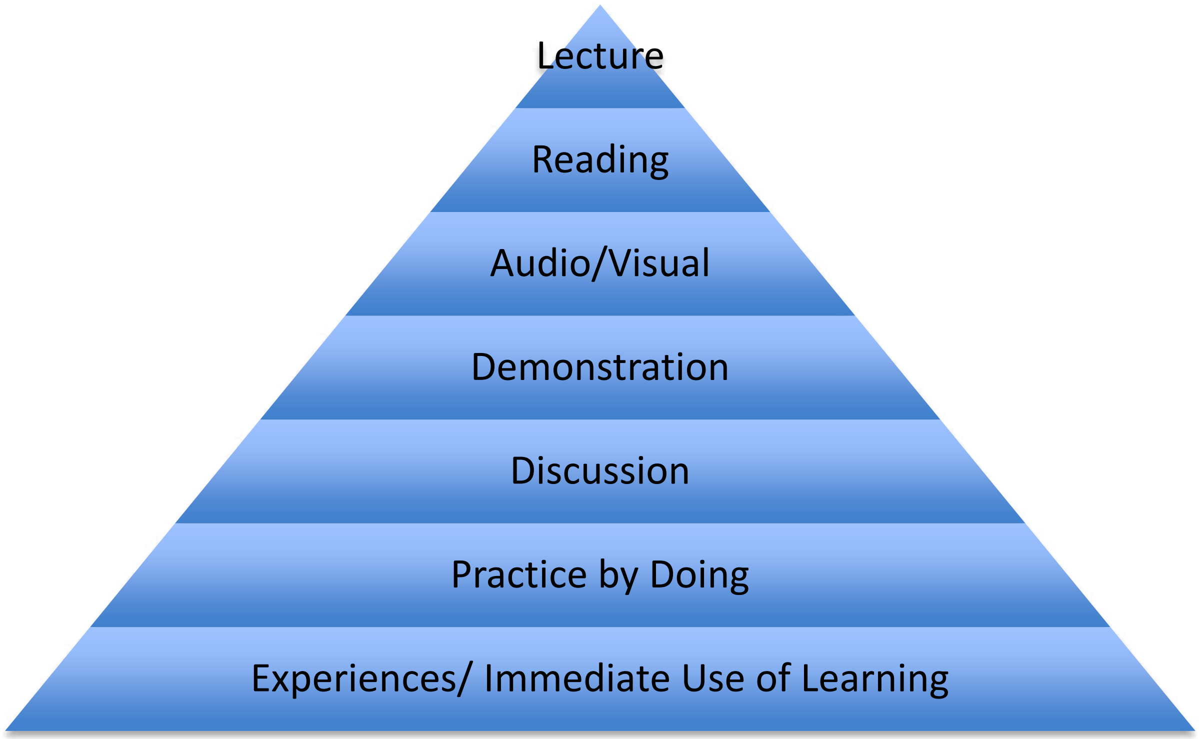


Figure 1: Pyramid of Learning

With this research on the proper methods of teaching and learning, it is safe to assume that learning a subject purely from the basis of PowerPoint and pamphlets may not be the best way to properly communicate safety protocol to employees in industry.

According to the Bureau of Labor Statistics (2014b), the number of fatalities recorded in 2012 was 4,628 from both private industries including goods and services, as well as government occupancies. The number of non-fatal injuries and illnesses for 2012 – 2013 hovers at an average of 3.35 per 100 full-time workers (Bureau of Labor Statistics, 2014a). You cannot place a value on a life, although many try to. With this understanding, any number of injuries, illnesses, or at worst, fatalities, is unacceptable in the workplace. OSHA aims to prevent injuries and control hazards by designing items and products for the workplace to teach hazard safety, however, they can only do so much (Shoji & Ge, 2015). The need for occupational safety training that can be delivered in an inexpensive and effective way exists, and the reasons lie in the numbers.

1.2: Problem Statement

Since safety is placed at such a high level of importance in industry, it is important to be confident in the content of the safety procedures that are being taught. What is possibly more important than the content is the method of delivery – one that ensures positive reception and future retention in high-risk situations, while remaining the most effective and least expensive method. While there has been many virtual reality systems produced, there is not a sufficient safety simulation environment that is interchangeable for use in instruction of safety procedures, specifically for a highly populated area such as a university setting. A simulation where users are able to interact with other users, or virtual avatar in a realistic environment with the proper stimuli is lacking. This research will work to address this problem by proposing a proper environment and preliminary platform for creating a simulation that can be used in a university setting to teach proper safety procedures to professors, students, and staff.

1.3: Objectives

The primary objective is to study what makes a sufficient environment for use in a safety procedure instruction tool. The framework for the simulation must be put in place. This includes creation of a realistic environment for simulation use. The University of Central Florida (UCF) engineering department will be the primary location for the use of the safety simulation. The Engineering 2 building will be the primary focus of creation of the environment. Creating an accurate representation of the environment is necessary for users of this simulation and will be the first objective of this research.

A secondary objective is to create a model of the environment that can be used within a virtual reality platform. It is important to ensure that the model is flexible enough to be adjusted for scenarios that are created in the future. The current environment is an academic building in a university; however, this building is creating a preliminary platform for any type of environment. It is important to keep close note of how this model is built and provide proper methodology for others to use in creating their specific environment setting.

A third objective is to contribute to the ongoing and evolving growth of virtual reality systems and their use by the general public. Technology is ever changing and the age of simulation is still in its infancy. While it is common for simulation to be used in industry for strategic planning or analysis, the involvement of humans in a virtual reality simulation is still a new idea. This study serves as a contribution to the virtual reality world and its ongoing development to be useful for society.

1.4: Contributions

After conducting initial research on the subjects of virtual reality platforms within the safety spectrum, research shows that there is not a proper software simulation that can be used for instruction of safety procedures for professors and students in an academic setting. By modeling the Engineering 2 Building of UCF, this can set precedence to any set of buildings for any area of industry interested in creating an interactive safety instruction tool. Setting the framework for the method to create the building and how to use it within a virtual reality system will contribute a new use for live virtual simulation for instructional use.

Live Virtual Constructive (LVC) simulations have been emerging at a quick pace due to the growing propensity of technology in human's daily lives. There are many forms of LVC that are currently being experimented with and created. Modeling tools also exist and there are many approaches that people take to populate their LVC environment. This research plans to contribute a method of creating a specific three-dimensional model that can be used within LVC and other virtual reality systems. This contribution can help others develop a platform for their own virtual reality training system. The accuracy and care taken to create a three-dimensional model that best recreates the actual real-world environment is crucial to helping aid in the immersive effect (Zhenbo, Jun, & Jauregui, 2009). Trainees must feel that their virtual environment is so similar to their live environment and virtual training enhances their experience.

1.5: Distribution

This thesis will be distributed as follows. Chapter One will discuss the background of using virtual reality systems in safety procedure training. It will discuss the importance of creating a realistic environment, the need for such, and the contributions to the field of study. Chapter Two will discuss a thorough literature review of safety training programs, virtual reality systems, and the combination of training safety using the virtual reality method. Chapter Three will discuss the methodology of how this research was conducted. Chapter Four will discuss the method for developing the modeling framework of the Engineering 2 environment. Chapter Five will discuss the research results by analyzing the model and providing an application of the model in a case study. Chapter Six will draw the conclusions as well as how this research can and will be expanded in future research.

CHAPTER TWO: LITERATURE REVIEW

In order to contribute to this field of study, it is important to conduct a thorough review of the current research and literature on the topics of safety simulation and virtual reality. To provide a holistic view of the research, a literature view was conducted to develop the knowledge and purpose discussed in Chapter One:

Section 2.1: Safety Training – This section presents current safety training programs, their uses, and the need to train safety in industries.

Section 2.3: Virtual Reality Systems – This section presents current virtual reality systems that have been developed or experimented with.

Section 2.4: Use of Virtual Reality – This section presents the need to combine training with virtual reality and the current examples and industries that have a need for such systems.

2.1: Safety Training

Before we begin to explore virtual reality, a thorough understanding of safety training and what makes a safety-training program effective must be explored. Safety training systems are catered to the audience that they are intended for. Several studies have been done on the effectiveness of safety training, the necessity of their specific industry, and the details that make a safety and hazard training legitimate.

A study sought to discover the best method for training in safety that would yield the most effective results. The study performed 95 experiments using three different classifications of engagement: least engaging using lectures and pamphlets; moderately engaging using programmed instruction; and most engaging using behavioral training (Burke et al., 2006). The study discovered that as training methods became more engaging, the subjects retained the information better and utilized what they learned to reduce accidents and injuries in the workplace. This supports the idea that in order for subjects to be engaged, the training must be rich in audience involvement and behavioral practice.

Another study was conducted on arcing fault hazards and their safety. The National Electrical Code (NEC) is responsible for assuring that electrical machinery to be used in the industry is installed and assembled in a certain way, but hazards such as equipment door openings or maintenance work error on arcing is not explained. The study sought out, with the Petroleum and Chemical Industry committee in IEEE to form a group to raise awareness of electrical personnel and the hazards associated with arcing faults. Arcing faults is described as "an unintended arc created by current flowing through an unplanned path,"(NEMA, 2015). This study used the group of experts in the field to run tests to quantify the hazards created by arcing faults. These subject matter experts' findings have resulted in safety training program materials and design considerations to create a safer work environment to help prevent arcing fault hazards (Crnko & Dyrnes, 2001). This study represents an opportunity where working conditions were thought to be safe, but was discovered that there is plenty of work to be done to reduce hazards. The study found safe working distances, incident energy that led to the arc faults, and list several new components that will reduce the hazards that electrical workers would experience. This new set of precautionary items and rules can be included in a safety-training program for electrical workers.

Another industry is the cement industry that has been shown to require closer attention to safety. The Florida Mining & Materials Corp. along with Moore McCormack Cement Inc. collaborated to describe a custom program devoted to safety and training for cement plant workers. They recognized that technical training and education is necessary, first and foremost, to improve morale in the cement workers. This study found that after administering an attitude survey, the Florida Mining cement plant workers had a strong desire to be more informed and better trained to excel at their job (Morgan, 1988). This study's training program included a required commitment by management; a training director; recognition by all parties that this new training program will be a new opportunity that they explore and will succeed as well as make mistakes from; and lastly will require a commitment from the trainees to learn. The study notes that the training program will be composed of diagrams and forms presenting technical and safety educational material. Training manuals and modules would be written and taught by an instructor. A training schedule would be created and all will be required to attend. Morgan (1988) further explains that "no company can afford not to train" and that just as machinery is quickly remedied when it is broken, the same should be done with their training programs. This paper shows the importance of a comprehensive safety-training plan.

Safety training is an important part of an organization. A paper published as recently as February 2015 states that organizations are moving towards using online training methods to educate their employees. This article discussed the need for occupational safety training as the number of fatal work accidents are at 3 million industrial injuries and over 4,000 fatalities (Shoji & Ge, 2015). Shoji and Ge (2015) continue to discuss the impact of industry costs as three to five times more than direct costs of injury related incidents that occur at work. Shifts in the mediums of training methods are happening especially as technology advancements continue to occur at an unspeakably fast pace. Technology continues to outgrow itself day by day and this paper discusses the importance of exploring alternative methods to deliver safety training to working individuals and the positive impacts this would have financially, ethically, and pathologically. Their study concludes by stating that further research is necessary to deem the impact of other forms of training.

Safety training programs have shown to be important at any age. In a recent study, children's pedestrian routes and their safety was researched. The study sought to determine the effectiveness of videos and websites in training children to choose safe pedestrian routes compared to active pedestrian safety control training and a no-contact control group (Schwebel & McClure, 2014). A sample of 231 young children participated in a study that trained them on safe pedestrian route selection. The study used training sessions compromised of videos and websites or street-side training, or virtual training. The study concluded that safe route selection is critical for pedestrian safety, but simply learning them from training videos is not the most effective way to teach children (Schwebel & McClure, 2014). This study is important to show that teaching safety is important in keeping even our younger generation safe. It is also important to conclude that the best method has yet to be discovered and further research with other delivery mediums must be presented.

On a more personal note, a study was conducted to determine what methods aid in forming an employee base that cares about safety and incident prevention as much as the organization does (Ford, 2014). The article describes a person who did not share safety values of his employer, Exxon. While performing a time consuming and tedious task, he neglected to wear the proper safety guards leading to several subsequent actions that nearly cost him his life and the company $5 million in damages. If his personality and perception of risk were stronger, it would have triggered this man to behave more diligently and carefully when performing even the most tedious of tasks. The article describes the importance of developing risk perception in employees and having them visualize the importance and weight that safety carries. The article concludes that while individual differences in personalities can predict workplace behavior, companies should work to ensure employees are placed in positions that make them happy and assess which of their employees need extra attention and special tools to help coach them (Ford, 2014). The need for a safety-training program even on an emotional level is needed to develop safer atmospheres for employees and their organizations.

2.2: Current Virtual Reality Systems

Safety training is considered predominantly as procedural training. A procedural task is a task that a person is supposed to follow based on a certain set of rules that were established (Mears, Hughes, & Moshell, 1988). Safety training programs rely heavily on ensuring that the population inhabiting a certain area knows how to react when certain situations that put them at risk are presented. Procedural training such as assembly work missile launching is too expensive to train on the actual system. Initial training as well as sustained training is what makes an inexpensive method of training necessary (Mears et al., 1988). Computer simulation is the answer for procedural training and this journal makes it clear that there is a gap for simulation-based training. This team developed a rehearsal system called PROSPR: Procedural Simulation Produced by Rehearsal. This prototype allows for a user to storyboard a procedural training system. This program fills in the gaps between the mental model of the real-world procedures and the way they are represented in the simulation.

Other research shows that virtual environments for training are becoming increasingly important enough that those in the field are creating their own training software and scripting language. Gerbaud, Mollet, Ganier, Arnaldi, and Tisseau (2008) first show that virtual environment training is inherently rare. It is still a relatively new concept to industry, and there are many lines of industry that still have not accepted it as a valid method of training individuals. They recognized that the first need is to study behavioral simulation and the proper way to develop three-dimensional models that will be accepted for training. Objects that are lower level need not be complex but complex objects will require an increased amount of time, stimulus response studies, and an increased amount of artificial intelligence. This research proposes the use of STORM and their coding language LORA to create a platform for general virtual training. The focus on this research was on reusability of the platform. The STORM engine focuses on treating a virtual human as a standard object in the environment and LORA allows those without a computer science background to create complex scenarios. This research focused on using computer science language and artificial intelligence engines to train virtual humans in an interactive virtual environment. This proves that there are other virtual reality systems and methods that are being researched and, as recognized, there is still great room for expansion and improvement.

There are many virtual reality software that exists and they all have their unique purpose. A major virtual reality system called Second Life (SL) was the software of choice in a research done with a three-dimensional multiple user environment. Molka-Danielsen and Chabada (2010) recognized the power of the multi-user virtual environment SL. Second Life has been used to simulate pedestrians, buildings, and scenarios involving such simulations. This research focused on the power of SL to be utilized as a scenario for an evacuation exit plan of a building. In the case of SL, this research did not investigate teaching humans how to navigate a certain building in case of emergency, but focused on how to design models of general buildings and see how humans would react in a scenario that they were unfamiliar with. This utilized SL's strength of having existing models and buildings available to utilize the software for such a task. The need for specific modeling of a building and educating humans on how to navigate their known surroundings was left open-ended, indicating there is still a gap for this field of study.

In the health field, it was recognized that people with traumatic brain injury caused by motor vehicle accidents, falls, wounds, or other injuries experience deficits in cognition including attention, memory, and problem-solving skills. In a study, Man, Poon, and Lam (2013) sought to examine the effectiveness of an artificial intelligent virtual reality to help those that have had such traumatic experiences re-develop their problem-solving and critical thinking skills that employment opportunities desire. Conventional memory training was done using psycho-educational interventions have shown improvements in rehabilitation for those with such traumatic injuries. However, computer-assisted training has always been in question. In this study, the researchers utilized artificial intelligent virtual reality-based training programs (AIVTS) to first, determine the correct level of difficulty that is necessary for each trainee that will be using this system and, second, to record the results of their training. The study also had a session using Psycho-educational vocational training system (PEVTS) that consisted of the conventional form of a training manual under the supervision of a trainer. Their statistical results did not show statistical significance between those who received AIVTS and those who received PEVTS, however, self-efficacy improved in those who used AIVTS, and in some specific categories, AIVTS showed higher results than in PEVTS. These results come to prove that while in this case, solid results were not proven as statistically significant, there are enough differences to indicate that further research must be done with using virtual reality as a training tool. With further research and analysis of this gap, training tools can be used to improve the cognition and problem-solving skills in the health industry as well.

Another interesting use-case of virtual reality training software was the use of position tracking technology. Yue and Wenhui (2013) decided to conduct a research study using three-dimensional position tracking methodology such as that used in a Nintendo Wii gaming console. In this study, they designed a three-dimensional interactive virtual reality system that they named Wiimote Stereo Structure (WSS) based on a Wiimote control. They determined that in order to be better immersed in such a virtual reality environment, a user must have a proper head mounted display, motion capture functionality, and other equipment that delivers 3D position tracking in a real scene. The key to their motion tracking system is their advanced camera calibration and tracking methods with their new WSS. After two previous attempts at calculating exact world position, they developed a structure that uses two Wiimote controls set in parallel to determine left and right camera coordinates. This pairing method is more accurate and robust than other methods they have tried before. This study shows the importance of accurate real-world representation and shows just another form of virtual reality that is being studied and developed.

Designing virtual reality systems is expensive, but similar to how Yue and Wenhui (2013) utilized existing technology to enhance the virtual reality experience, Hongjian and Zhe (2013) developed an algorithm using Microsoft Kinect to recognize gestures. They also recognized the importance of immersion, interaction, imagination, and reality all coming together and they came to a conclusion that Kinect would properly synergize all these characteristics together creating an effective virtual reality system, at a low cost. They programmed Kinect with advanced algorithms for fingertip and convexity detection allowing a user to respond by selecting, picking up, rotating, zooming, moving, and releasing objects in the real world. By developing human-computer interaction with the Kinect, this research can help advance the realm of virtual reality systems.

As discussed, there are many studies and attempts at creating virtual reality systems from all angles including basic computer and unique coding languages to uses of existing technology such as the Wii and the Kinect. This research proves that there are several advances at creating virtual reality systems that would work for a variety of purposes and there is room in the industry for enhancing virtual reality systems, especially from the training perspective.

2.3: Use of Virtual Reality

After researching the need for safety training and the many approaches to creating virtual reality systems, the idea of combining these two needed to be explored. The combination of virtual reality and training has been attempted in many areas ranging from manual labor, health industry, and education.

The health industry is ever advancing and becoming more innovative. With interdisciplinary work and relationship between engineering and medicine growing, virtual reality was imminent in the health industry. Shao-Hua, Zeng-Gunag, Fan, Xiao-Liang, and Gui-Bin (2014) discuss research that attempts to utilize virtual reality to train heart surgeons before they ever operate on a live human. The study generated realistic three-dimensional vascular models from data collected from various patients. Furthermore, this study provides real-time feedback for the trainee. The system they propose uses the 3D vascular model, a physical catheter or wire model, a user interface for the trainee, and a human-machine interaction module. The vascular model is rendered as a three-dimensional simulation while a prototype of the haptic device system manipulates the catheter to provide proper feedback to the surgeon being trained. The trainee uses the user interface as its guide to what is happening, just as they would see in cardiovascular disease treatment (Shao-Hua et al., 2014). This advancement in the use of virtual reality is remarkable. The ability to have real-time interaction for training core skills proves great strides in the field of virtual reality training.

From a less physical standpoint, some research suggests mobile training is the desired new method of training health care professionals (Zarrad & Mahlous, 2014). Health care training systems help minimize risk to patient's lives and this study proposes that Mobile Health Care Training-based Systems (MHCTS) is the expected future trend of the health training industry (Zarrad & Mahlous, 2014). This study recognizes achievements done to increase three-dimensional rendering and graphical display as methods to train health care professionals, but the combination of network communication performance over ad-hoc networks has never been considered prior to this study. They propose a network-delay and bandwidth-sensitive application that allows interaction with the shared environment so critical information can be delivered to all stakeholders in a situation such as preparation of resuscitation area, medical staff, and laboratory and radiology staff when dealing with a critically injured patient requiring immediate intervention. The uniqueness of this study suggests turning the network of health care professionals into a virtual network to keep all people involved notified about current statuses of patients. Zarrad and Mahlous (2014) realize that there are still problems with this networking capability such as robustness and ability to keep nodes connected, but this multicast system has been studied before and while it is considered in its infancy, this can help to fill the gap between the health industry and advancements in technology.

While the health industry plays a major role in advances in technology, other industries have attempted to delve into the virtual reality world. Research has been done on the mining and construction industry and have shown great strides in utilizing virtual reality training systems to help manual labor workers with their procedural training and keep them safe (Li & Huang, 2010). In a study conducted by the School of Art and Design, Li and Huang (2010) discuss how designing a mining virtual reality system using a virtual human model, level of detail for multilayer model technology, crash detection, and the use of Vega application programmer development to create a system that can be supplemented to a miner safety education and technology training program. Furthermore, a similar study suggests the use of virtual training software to create animated scenarios to assist with teaching and training of off-shore miners (Zayas Perez, Marin, & Perez, 2007). When creating virtual reality systems that teach safety training methods, it is important that safety regulations and descriptions of proper procedures are displayed for the trainee as well as the development of that knowledge through practice (Zayas Perez et al., 2007). Virtual reality systems such as these are all still in their infancy and have much more development to go through. In the construction industry, research has shown that there has been a historical increase in high accident rates – almost twice the industrial average (Quang-Tuan & Chan-Sik, 2012). The aforementioned SL virtual reality system was utilized in this specific research study to simulate three-dimensional modeling to improve construction safety education. Quang-Tuan and Chan-Sik (2012) developed safety semantic templates that show specific scenarios, the proper communication to take when in those situations, hazard case analysis, and a result evaluation process. This construction safety education model based on SL has shown advantages, but even the study acknowledges it has not been evaluated to the extent necessary to prove that their methods were a success and further research on this topic must be done.

The general topic of education has also dabbled with the use of virtual reality in their curriculum. Zhenbo et al. (2009) conduct a research study that proposes building an e-learning environment using virtual reality technology. They discuss that virtual reality has been successful in real estate, entertainment, and urban planning among others so using it in education is entirely possible. They propose using a combination of social media methods such as Facebook along with virtual reality such as SL, to create three-dimensional virtual community where learning can take place. Their inputs would be through a data glove tracker and a head mount display. While their research is far from conclusive, their proposals spark conversation on bringing virtual reality into the classroom.

Other educational uses were analyzed from the child's perspective. Zhen and Shaohua (2009) propose using emotional based simulation to pique interest in a child's safety education and training. In this study, the researchers developed traffic safety education software for children using fuzzy sets to model variables of virtual characters. Their focus was on creating virtual characters that properly show emotional models based on decisions they make in the virtual reality system, in turn hoping that the children learn from the same virtual characters and that they are believable enough (Zhen & Shaohua, 2009). This research was very brief and was conducted to introduce the idea of using emotion simulation as a way to improve the real-world effect of virtual reality simulation.

2.4: Summary and Gap Analysis

With all the specific cases of utilizing virtual reality simulation, it is important to note that this is a general issue that is at the forefront of many engineering research facilities today. Sandoval et al. (2011) discusses that education systems through computing resources have "represented greater flexibility, accessibility, and adaptability to conventional education systems." Sandoval et al. (2011) also states that industry's increasing demands of quality, safety, environment, and economic management has necessitated a new way to train and teach humans in the most effective way possible. The research that has been conducted greatly shows the importance of safety training whether it is from a worker's perspective or a child's perspective. There have been strides in creating training software implementing virtual reality systems that already exist, or by creating new software using existing technology. The combination of safety training and virtual reality is an important field, but has proven that there are gaps in the studies.

The analysis of this current research has found three main gaps in the field.

1. While there are many specific use cases of virtual reality, there has not been a general case for training largely populated areas such as is found in an academic setting such as a major college or University.
2. Current safety training software does not focus on recreating the proper environment in the simulation that mimics the real-world environment that the trainees are accustomed to.
3. There is potential of using both virtual scripted avatar and prompts as well as other live characters in virtual reality software. Some research has touched on the use of virtual reality characters or the use of on-screen text alone or using live characters, but very few have shown the possibility of a synergy of the two.

Based on these observed gaps, this research will attempt to fill the gaps by providing a platform for a safety training simulation focused on recreating the proper environment for an academic setting with the potential of both scripted language as well as live human-machine interaction.

CHAPTER THREE: METHODOLOGY

A methodology is a justification system used in an area of study, as defined by Oxford University Press (2015). This chapter will discuss the three components of the methodology for this research.

3.1: Methodology Outline

This chapter outlines the methodology for this study. Figure 2 below defines the three phases of the methodology. Phase 1 defines the conceptualization phase. Phase 2 outlines the operationalization phase. Phase 3 discusses the premise for the conclusions.

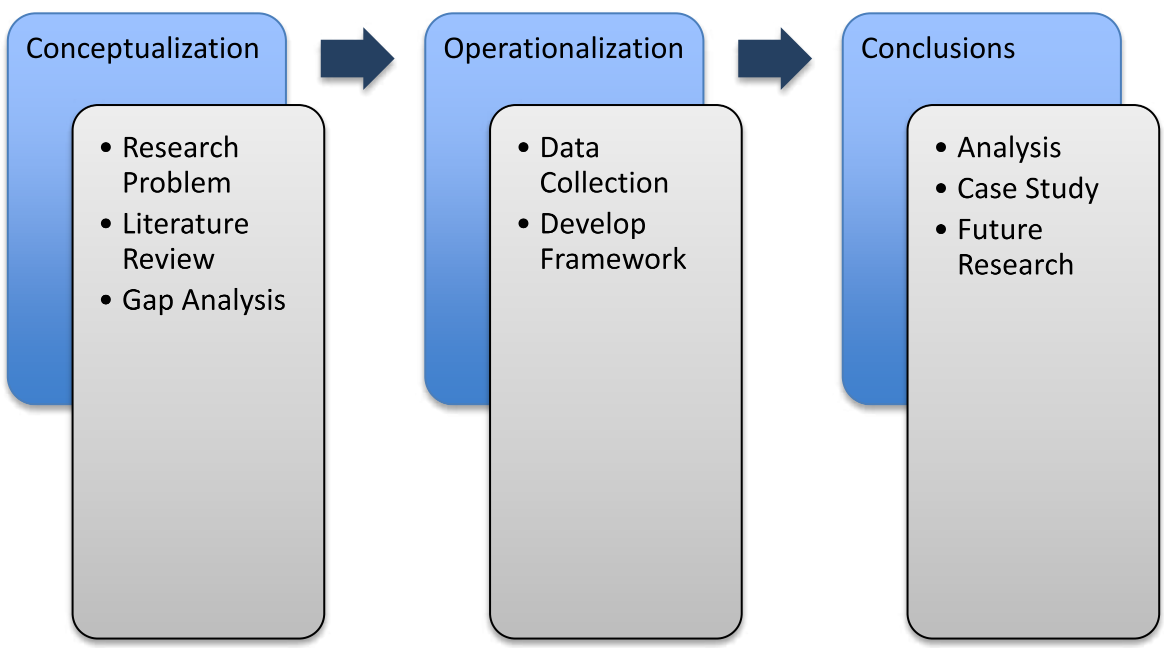


Figure 2: Methodology Phases and Flow

3.2: Conceptualization

Conceptualization discusses the research problem and questions, the literature review, and the gap analysis.

3.2.1: Research Problem

The research problem, as described in Chapter One, is that there is no sufficient virtual reality training systems framework that exists to be used to train safety procedures to those in a highly populated area such as a university setting while remaining effective and inexpensive. One of the most important aspects in such a training system is a proper framework with a recreation of the environment that the trainees can recognize.

3.2.2: Literature Review

The literature review consisted of researching academic journals, essays, and news articles. A thorough literature review was conducted on safety training systems and the effective elements of such training programs. Research was then focused on virtual reality systems and the existing experimentation as well as development of other live virtual simulation training systems. Research was found on live virtual simulation that has either been utilized or created using unique coding languages. A variety of methods of delivery of virtual reality systems was conducted and summarized. Third, research was focused on the combination of safety training using virtual reality systems. Research shows that while there were many attempts at training using virtual reality systems proving there is a need for sufficient training systems with proper methods of feedback that is both effective and inexpensive. Best to our knowledge, a variety of industries and systems lack accurate virtual environments to be used with virtual reality software.

3.2.3: Gap Analysis

Based on the literature review, there are three gaps that were discovered and discussed in Chapter Two. The first gap is that there has not been a general safety training model developed for training largely populated areas such as a university setting using virtual reality systems. The second gap is that current safety training software does not focus on recreating an accurate representation of the environment that safety training requires trainees be familiar with. A third gap is that there is potential for using both scripted avatars as well as other live characters in scenarios of a virtual reality system when training safety procedures.

3.3: Operationalization

Operationalization defines the data collection period and the development of the framework.

3.3.1: Data Collection

The research began by collecting the data necessary to develop a proper environment for a safety training simulation. In order to model a highly populated area, ENG2 was chosen to be the preliminary model for building a virtual environment. In order to recreate the building, data on the building was collected. It was determined that collecting data on safety aspects of the building, commonplace items, and textures – in that order of importance – was necessary in recreating the building. Both qualitative and quantitate data on the building was vital and necessary to ensure an accurate representation of the real-world environment.

3.3.2: Development of Framework

There were seven main steps that occurred when developing the design for the framework of the model. The steps are as follows and will be discussed further below.

1. Select modeling software.
2. Determine a proper scale based on available floor plans.
3. Create the frame of the building i.e. walls, floors, ceilings, and doors.
4. Add the primary details that pertain to safety.
5. Fill in commonplace details to help create as realistic of a model as possible.
6. Add textures to match the real-world environment.
7. Piece together all components into a cohesive environment.

Once these steps were completed, the framework was considered developed and it was time to move onto verification, validation, and final analysis of the framework.

3.4: Conclusions

The conclusion phase consists of a case study, analysis of the results, and discussion of future research.

3.4.1: Case Study

An application of the use of this model is necessary to provide a case study for further research. For this research, a case study was conducted by importing the SKP model into virtual reality software. The virtual reality software was called Military Open Simulator Enterprise Strategy (MOSES) was chosen for this purpose. The case study portion takes the model and applies it to MOSES to see the outcome of such a use-case of the model. This use-case is used to validate the researched model and help answer any integration and test questions that may come of such software-based research.

3.4.2: Analysis

After the model is completely designed, it is important to analyze, verify, and validate the model. The verification and validation step is vital to any simulation model and can be done in a variety of techniques. Some informal techniques for verification and validation include inspections, audits, and documentation testing, among man others (Balci, 1997). While these forms are considered "informal", they are calculated and well structured (Balci, 1997).

In order to validate and verify this model, this research surveyed a sample consisting of 22 participants affiliated with UCF. These participants were given instruction to review the model. Once they have spent time interacting with the virtual model, the participants answered a set of questions designed to verify and validate the current virtual model.

The analysis stage is a vital part of the end of the research study as it is the basis of whether the research can be concluded. This stage compares the findings to that of the information found in current literature. The gaps that were discovered at the beginning of the research are answered. The model has been applied to a sample virtual reality system. Conclusions can be drawn based on the steps conducted in the conceptualization and operationalization phases of the methodology.

3.4.3: Future Research

Future research explains the possible directions that the research may continue in. Discussing future research is usually the outcome of areas that were out of scope of the current research study, complications that were met along the way, or paths that were explored but not tested. This research should give a solid test-bed for future researchers to explore, learn, and gain insight on other areas where they can contribute to this field of study. There is a dire need for safety training in the industry, so future research is not only a suggestion, but also a firm pathway to expansion and improvement on these ideas.

CHAPTER FOUR: THE FRAMEWORK

This chapter will explain the results of the three-dimensional modeled environment. It will explain the method to creating the model providing a design that can be replicated. A case study consisting of inputting the model into existing virtual reality software is discussed. In order to verify and validate the model, a survey is given to a sample set of participants. This method was used to ensure that our model is valid and can be used as a framework for creating an environment for safety training software.

4.1: Data Collection

The first step was to gather quantitative and qualitative data of ENG2 in order to have proper information to use as references for recreating the building as a three-dimensional model. Floor plans, various images, and details on the building were taken as part of this data collection.

Floor plans of each level of the building was obtained and converted to images. Figure 3, Figure 4, Figure 5, and Figure 6 below show the plans of floors one, two, three, and four, respectively, of ENG2. Each floor plan has proper scaling and dimensions of each floor.

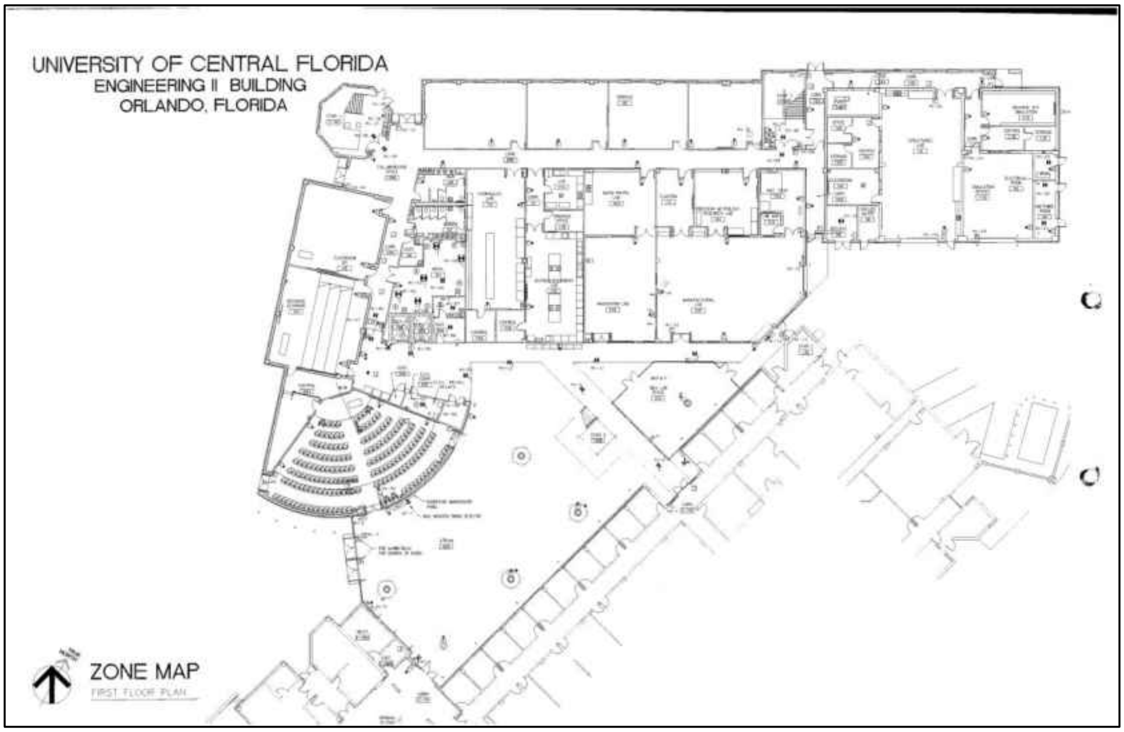


Figure 3: Engineering 2, Floor 1

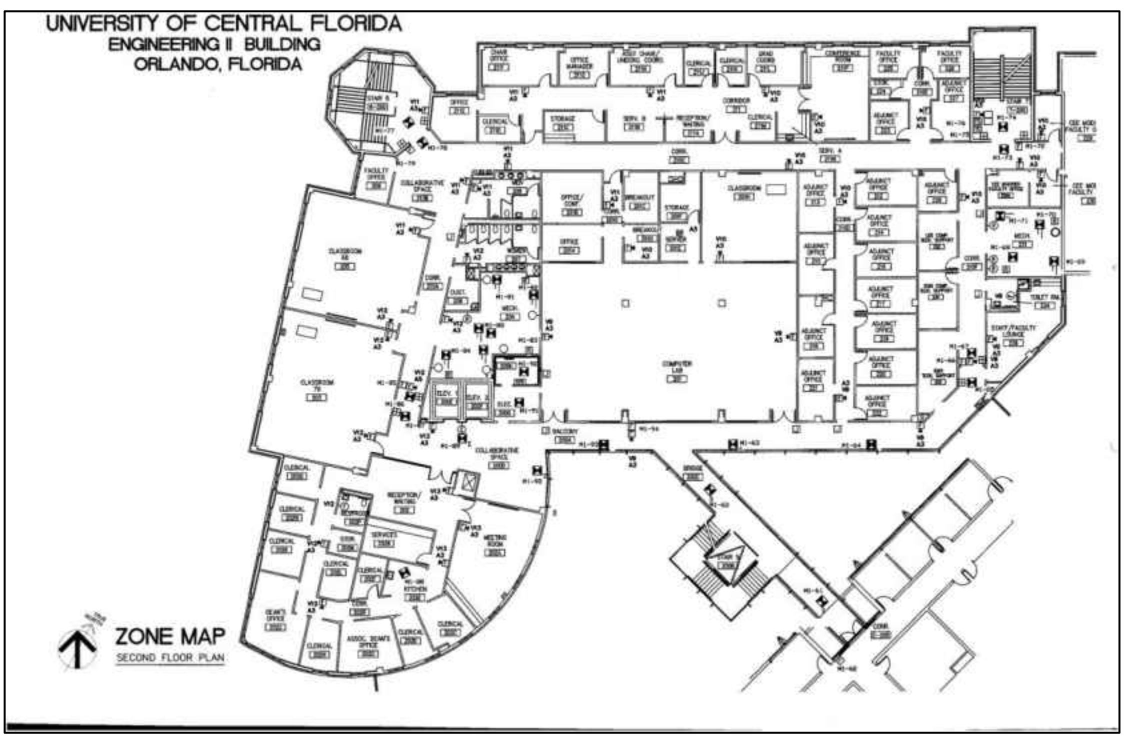


Figure 4: Engineering 2, Floor 2

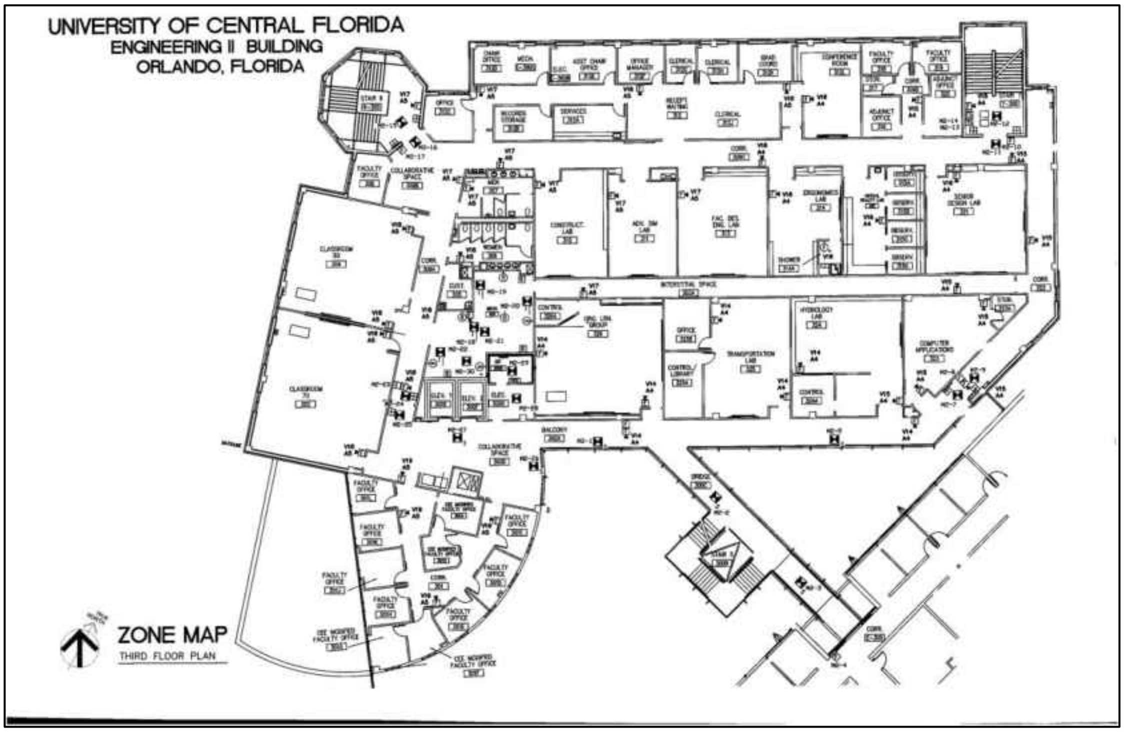


Figure 5: Engineering 2, Floor 3

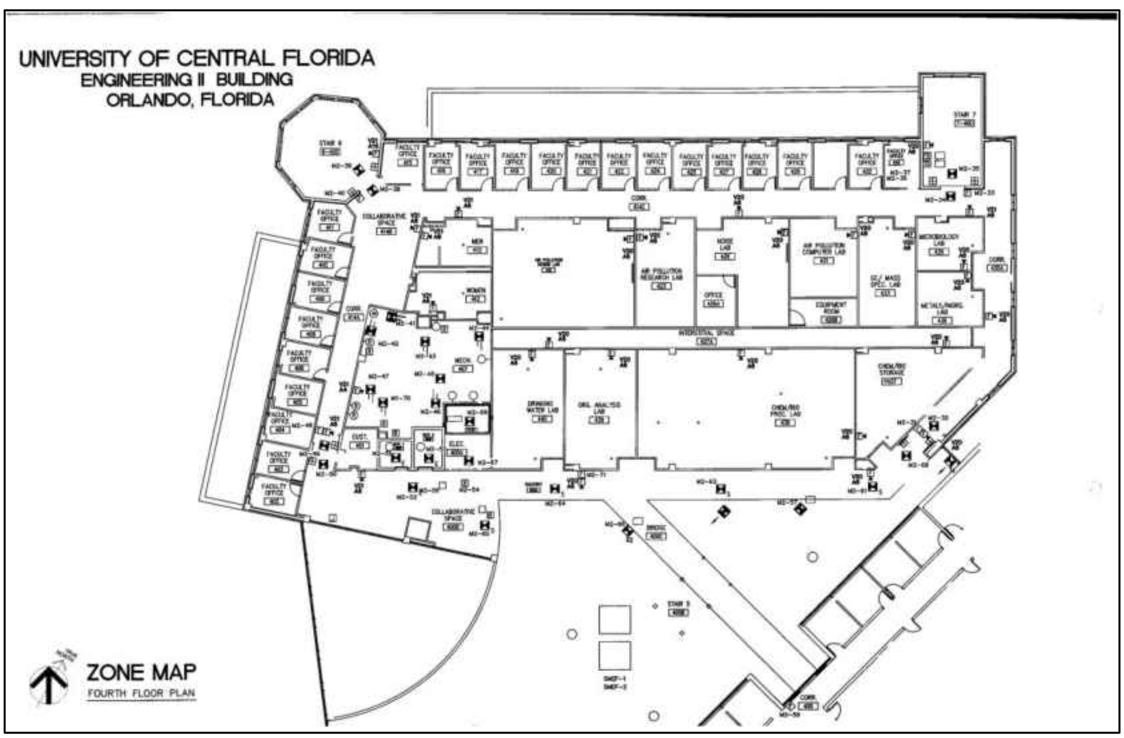


Figure 6: Engineering 2, Floor 4

Each floor plan has specific symbols that aided in notifying where the main doorways, exits, fire alarms, smoke detectors, and other important aspects of the building were located. The floor plans were a vital component to creating the most accurate representation of ENG2.

For the purpose of the framework, the focus was placed on recreating a plan for floor one and floor four. The fourth floor was chosen as the most safety prone floor in this building due to its proximity to the exterior of the building as well as the number of laboratories located on this floor. Table 1 below shows the safety concerns of the two floors and the quantitative data collected on each.

Table 1: Quantitative Information on Floor 1 and 4

Item	ENG 2, Floor 1, Quantity	ENG 2, Floor 4, Quantity
Room Numbers	100-183	400-442
Exit Signs	14	7
Fire Extinguishers	5	4
Double Doors	19	4
Single Doors	21	41
Stairways	2	2
Windows	2	5
Elevators	2	2
Emergency Instruction Signs	5	11
First Aid Kit	1	1
Fire Alarms	15	6

By collecting the floor plans of the building and the quantitative data associated with the safety concerns of these floors, the framework can now be developed and modeling the building may begin.

4.2: Modeling Tool Selection

After collecting qualitative and quantitative data on ENG2, the framework for the safety training simulation began. A three-dimensional modeling tool was researched and selected. A variety of modeling software was preliminary tested under four criteria: relevance, ease of use, flexibility, and cost. Each of these criteria was given a score between 1 and 5. A score of 1 meant the software met the criteria the least and a score of 5 meant the software met the criteria the most. Table 2 below shows the method for choosing the proper 3D modeling tool.

Table 2: Modeling Software Selection

Software	Relevance	Ease of Use	Flexibility	Cost	Score
3ds Max	5	3	4	5	4.3
AutoCAD	2	1	3	5	2.8
Blender	4	1	1	1	1.8
Inventor	1	2	3	5	2.8
Maya	4	1	3	5	3.3
MOSES	5	1	2	5	3.3
Revit	2	3	2	5	3.0
SketchUp Pro	5	5	5	3	4.5
SolidWorks	1	2	3	1	1.8
Unity 3D	4	3	4	5	4.0

The clear winner was SketchUp Pro (SKP) with the highest score of 4.5 based on relevance, ease of use, flexibility, and cost.

SketchUp Pro, formerly produced by Google and now owned and developed by Trimble, is “like a pencil with superpowers” (Trimble, 2013). It offers the versatility of simply drawing desired features of a floor plan with the level of detail and power that is needed from a three-dimensional CAD modeling software. The design element allows for texture editing and scaling, both of which are easily changeable features. Finally, SKP offers a multitude of file formats that can be imported and exported to be compatible with other virtual reality software. For this research, SKP proved to be the best software to model ENG2 and create a successful virtual three-dimensional recreation.

4.3: Developing the Model

With the selection of the model, the environment for the safety training software was created. The floor plans were imported into SKP as PDF files. These were used as the layout for modeling the building. Each floor was designed, drawn, and extruded to the specifications defined in the floor plan. A 5 to 1 scale was chosen for all dimensions in SKP.

Once each of the floors was built, the details were added. It was important to add all the qualitative details collected at the beginning of the study pertaining to safety. The model contained all exit signs, emergency signs, first aid kits, fire alarms, smoke detectors, and motion detectors, as is demonstrated in Figure 7. Adding all of the safety elements was the highest priority in order to ensure that the model contained the beneficial and easily recognizable elements to a safety-training model.

Figure 7: Doorway on ENG2, Floor 1

All commonplace items were then added. These secondary items included chairs, water fountains, and other accessories that help add detail to the environment. These details are what help with the immersive component of the environment. It is important that ensuring the trainees feel immersed in the training environment so that they take the safety training as seriously as possible. Figure 8 shows an example of a professor's office that can be found on the fourth floor of ENG2.

Figure 8: Sample Office on Fourth Floor of ENG2

Textures were then added to the environment. Another reason why SKP was chosen is the ability to add detail to surfaces quickly. Textures such as carpet, brick, drywall, and other surface area details can be added to models at a relatively fast pace. This feature adds to the flexibility of the software. This ensures that changes can be made to models as they come without having to recreate the entire section that needs to be updated. Figure 9 shows an example of how the ceiling and floor tiling was created by taking pictures of the actual ceiling and floor tiles on the first floor of ENG2. These images were converted to textures and used to create the celling and floor tiling.

Figure 9: Sample Floor and Ceiling Textures on First Floor of ENG2

SKP also allows for components to be built and then pieced together as needed. This enables the model to be considered interchangeable and customizable. Each room can be made separately and then combined together to make a hallway of rooms. Every room can be identical or unique, however, this feature enabled the accuracy of each floor. For example, each floor has identical makeups of classrooms and bathrooms. These components were made once and were then duplicated and combined to ensure uniformity between the floors.

Figure 10 and Figure 11 show completed sample images of the two floors of ENG2. Appendix C shows full exterior images of the modeled floors.

Figure 10: First Floor of ENG2

Figure 11: Fourth Floor of ENG2

CHAPTER FIVE: RESULTS

This chapter discusses the results of this research. The framework has been clearly defined and developed. The environment has been modeled and can be imported in a variety of virtual reality software. The platform and test-bed has been created and this design can be used as a researcher sees fit. A case study is presented using MOSES as the virtual reality software of choice. The research is analyzed using a survey of a sample set of participants to verify and validate the model. The results of the analysis are also presented in this chapter.

5.1: Case Study

In order to provide a use-case for the developed model, a virtual reality software was chosen to demonstrate the effectiveness of taking this model and importing it into a current virtual reality software that can be further developed into a full training simulation program. The virtual reality software chosen was the Military Open Simulator Enterprise Strategy (MOSES). MOSES was a project developed by the United States Army Simulation and Training Technology Center (STTC) based on the framework of OpenSimulator. It was developed as a tool to train military personnel before they go into live-training simulations. Virtual reality simulation was a cheaper and more effective route to take in order to supplement the education of basic protocol to soldiers.

MOSES was chosen to use as a use-case because of its relevance to virtual reality and the fact that it has built in avatars that trainees can use in the virtual world. MOSES is open-source virtual reality software with the ability to create scenarios from scratch using environments created by various users. This makes it a perfect case study for the ENG2 environment that was modeled. It is important to note that taking the proactive measures to ensure that the modeling software used is compatible with the virtual reality software makes it extremely important when creating a training simulation. SKP has the ability to export models in a variety of different formats. MOSES can only read collada files, so that was a limitation that had to be dealt with. A collada file is an XML hybrid file. Like many modeling software, collada is just one of many formats that a modeling file is available in. Other file formats include OBJ, XSI, 3DS, and many more.

Initially, it was instinctive to export directly from SKP to MOSES, but after an initial trial, it was realized that the model must first undergo some "modeling cleanup". All software is created differently from each other and the way they are created largely depends on the way they can interact. Exporting SKP files directly as collada files did not contain the textures in the proper format needed for importing into MOSES. Therefore, the model was first exported as an OBJ file which tends to export models much cleaner, with less vertices and triangles, and packages up texture files as a separate entity. The OBJ file was then opened in Blender, another modeling software, and then exported as a collada file. This process allowed for successful export of both the model file and of the texture files.

Finally, the model was ready for MOSES. The environment of ENG2 was successfully imported and uploaded into MOSES. Trainees can now explore the ENG2 environment through the eyes of an avatar using MOSES. This case study uncovered certain issues that others may need to keep in mind for future research. It is important to choose both modeling software and virtual reality software that are compatible. Importing models into virtual reality software can take some adjusting to the model. While MOSES was the software of choice, there are many virtual reality software that can be used, or developed, for this same purpose. This is a major milestone in bridging the gap between conventional training and virtual reality training and the options are endless.

5.2: Verification and Validation

In order to verify and validate this model, a survey was used as the method of choice. While this research showed that the model could successfully be used to create environments and a test-bed for virtual reality training, the process was also verified and validated by a group of 22 participants who interacted with the model and gave input on their interaction.

The study was conducted as follows. The participants were each provided with the proper consent to participate in such a study. Participants were chosen on two bases. The first was that the participant must be affiliated with UCF in some way, whether they were a student, faculty, or staff. The second was that they spoke English so that there could be no language barriers and the results would not be misconstrued due to misinterpretation.

Participants were provided two videos and four sets of images to view and answer questions relating to them. The students answered based on a 7-scale Likert scale. A Likert scale is a scale that consists of equal number of favorable and unfavorable choices concerning the attitude of a subject (Gliem & Gliem, 2003). The participants were not told what the environment was of, or what the model portrayed. The first video was a fly-through of ENG2 first floor. The second video was a fly-through of ENG2 fourth floor. After watching each video, the participant was asked to rate their similarity to the actual ENG2 floors, respectively. Next, the four sets of images were shown one set at a time. Each set contained a picture taken in the actual ENG2 juxtaposed with a screenshot from the model. The investigators did not sway the participants and the process was objective in that the investigator did not answer any questions the participants had about the model or survey while they were participating in the study. Follow up questions to rate their likelihood of using such a model for safety training as well as the level of ease of recognizing the areas in the building after using the model were asked and noted at the end of the study. The entire study can be found in Appendix B. There were a total of 13 questions: 5 were characteristic and 8 pertained to the study. The results were analyzed as follows. Figure 12 shows the mean interval plot of all questions conducted in the survey.

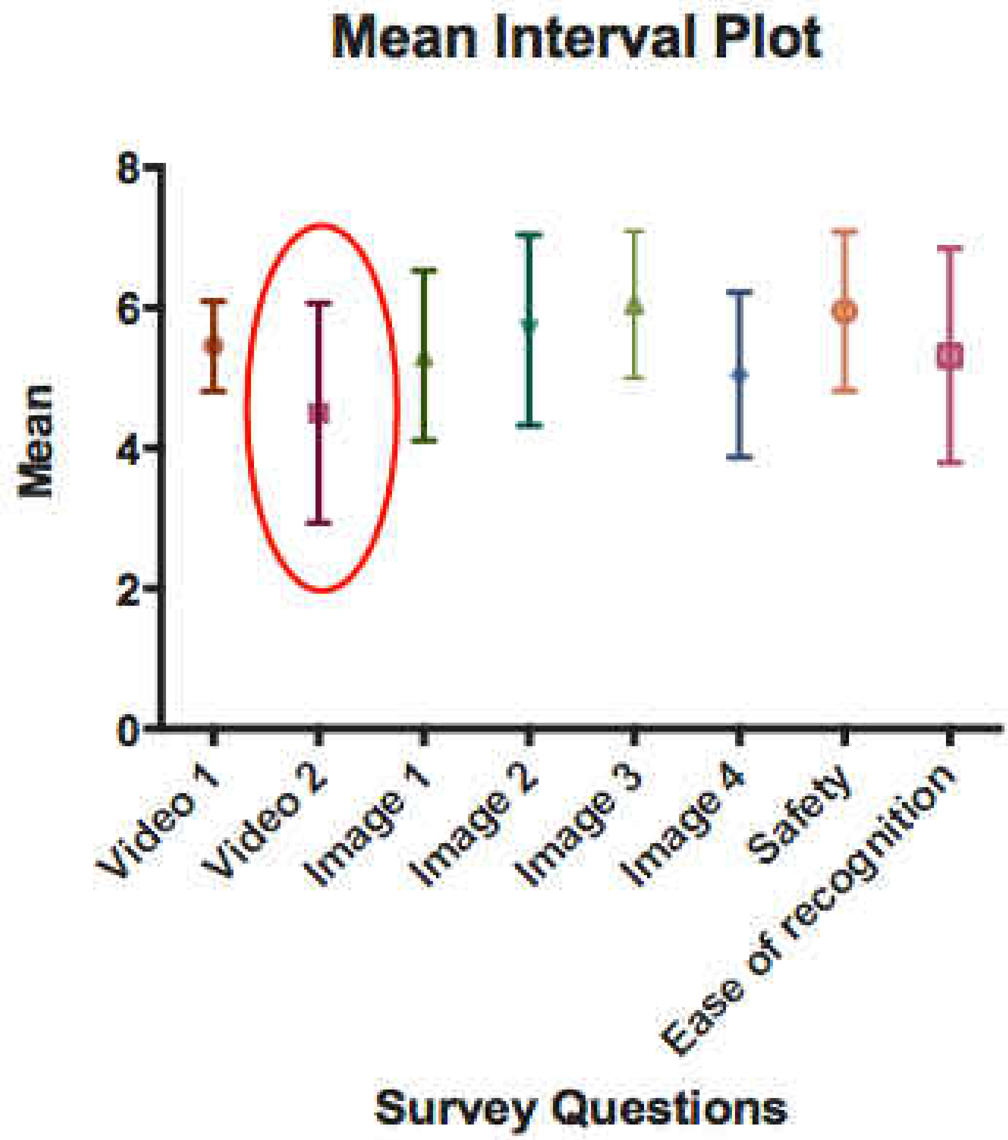


Figure 12: Mean Interval Plot of all Questions

The survey's validity was determined through calculation of Cronbach's alpha. Cronbach's alpha Cronbach's alpha is a statistic that measures the internal consistency of a set of items (Gliem & Gliem, 2003). A multivariate analysis to determine the Cronbach's alpha was conducted and

Cronbach's alpha was deemed to be 0.5890. If the question pertaining to video 2 was omitted, the alpha increases to 0.6556, which is more reliable resulting in the mean interval plot found in Figure 13 below.

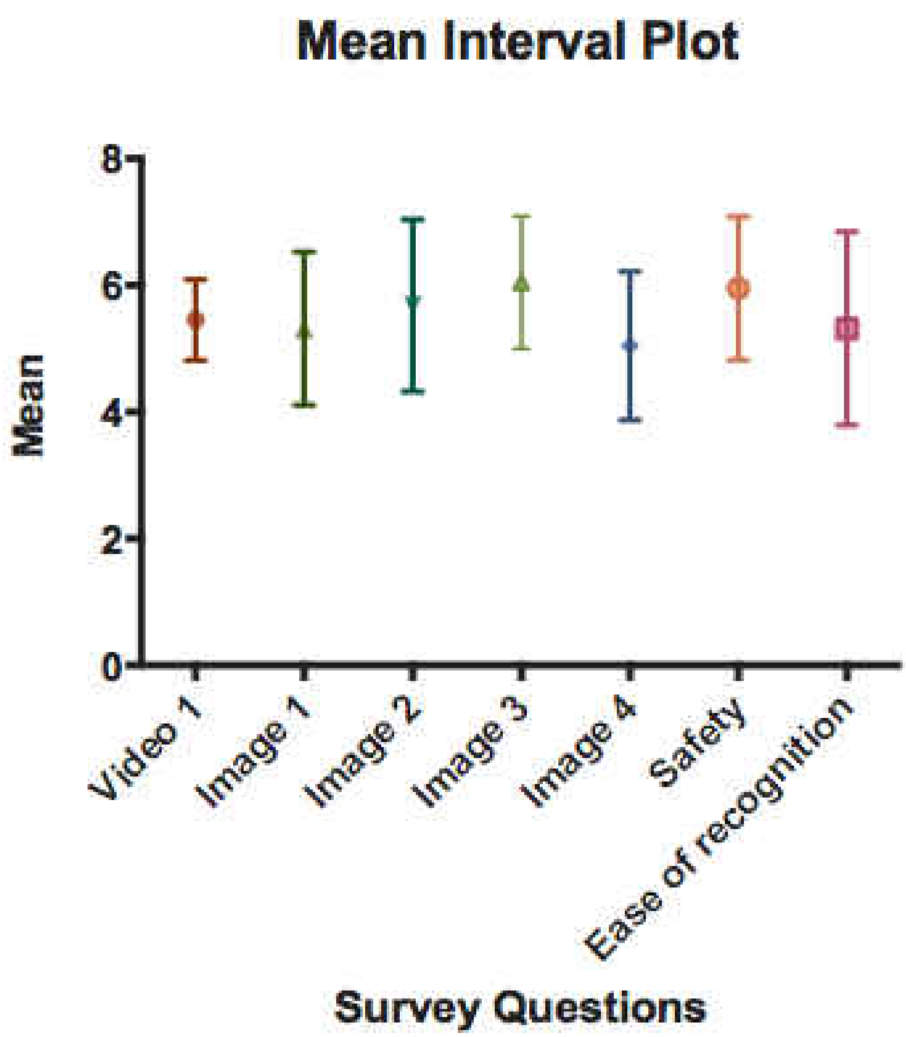


Figure 13: Mean Interval Plot of Reliable Data

Typically, a value of 0.6 or more is considered to be a reliable measure of consistency between the survey construct and what the survey is investigating. Video 2 showed a fly-through of the fourth floor. From the situational observations of conducting the survey, Video 2 seemed like it would not be a reliable question. A great number of students were confused by the fact that the engineering atrium was not part of ENG2, resulting in a possibility of skewed answers when asked about the similarity of the simulation and the real environment. Therefore this question could have improperly skewed the results of the survey, and the alpha value attests to that. This information can also assist with the development of this model in further research.

Figure 14 displays a collection of histograms of the participants' survey results, including a mean value displayed at the top of each histogram.

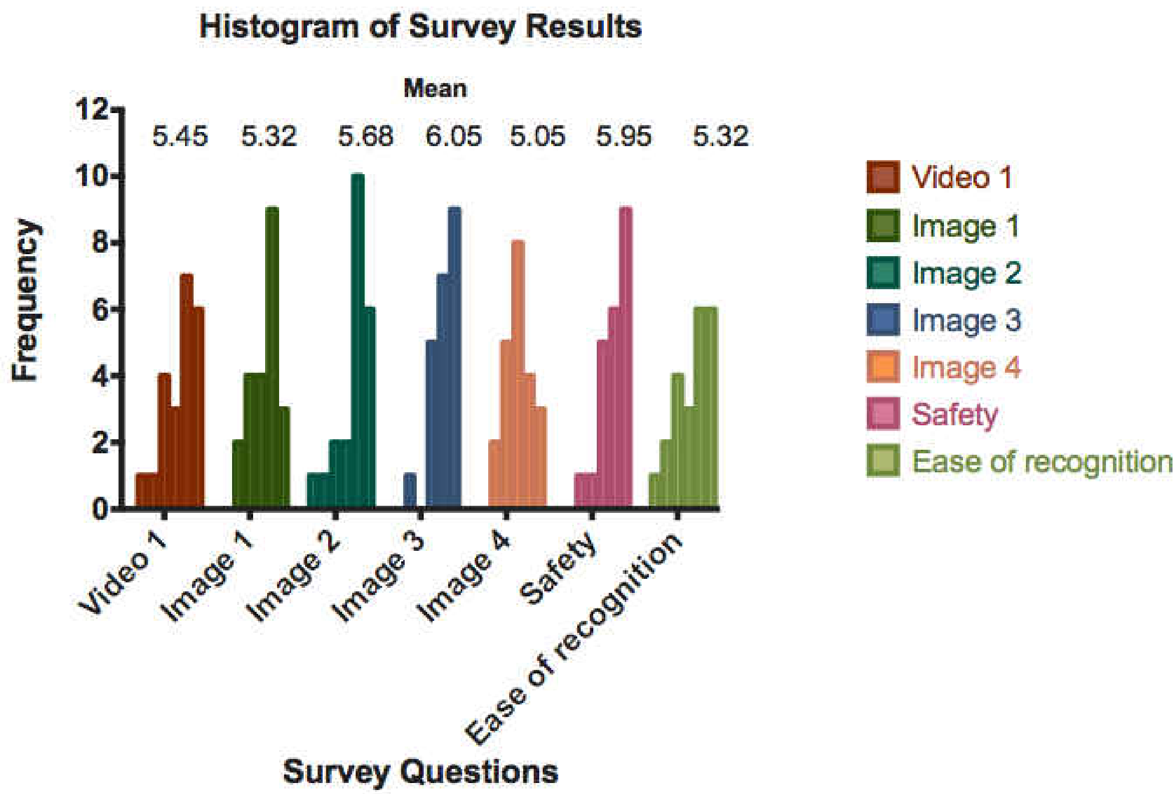


Figure 14: Histogram of Survey Results

The average of all the questions testing for similarity between the actual environment and the model is 5.45. This places the average at the favorable end of the 7-scale similarity Likert scale as shown in Figure 15.

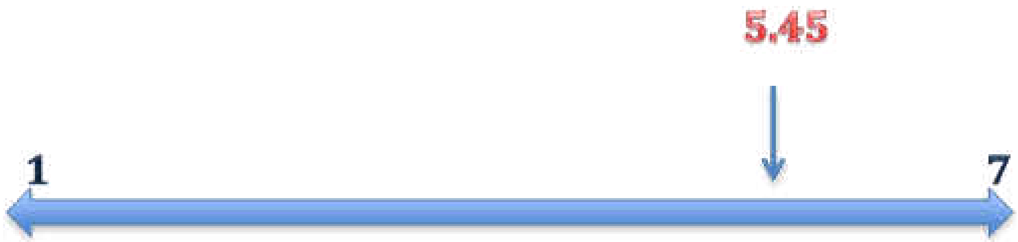


Figure 15: Likert Scale of Similarity

The analysis explored a possibility of correlation between how familiar the participants thought they were with the building and the resulting similarity scale that was calculated. The correlation analysis concluded that there was no correlation between the two measures. This shows that whether or not the student was familiar with ENG2 does not skew their ability to recognize that the model is similar to the actual environment. This knowledge can be used to assist in the future development of the model in further research.

The new variable called “Total Similarity” was created based on the 7 valid questions from the survey. This value was analyzed against participants’ major through a two-sample t-test. With a p-value of 0.355, it can be concluded that there is no difference whether the participant’s major was Engineering or not. This supports the idea that whether or not they have more opportunities to go to the building does not necessarily means they can recognize the building better. Similarly, when comparing the participants’ class standing as upperclassmen versus lowerclassmen, a p-value of 0.487 proves that there is no difference of determining the similarity of the model when it came to years spent at UCF. These conclusions help eliminate the notion of any potential bias from the survey.

In conclusion, the statistical analysis shows that the 3D virtual model was validated and verified. An initial study with 22 participants shows that on a scale of 1 to 7, 1 being extremely dissimilar and 7 being extremely similar, the mean says that the model similarity is at 5.454, proving that the model has favorable results. The following table summarizes the findings of the analysis:

Table 3: Analysis Summary

Item	Values
Cronbach's Alpha	0.6556
Mean, SD, (95% CI)	5.454, 0.731, (5.222,5.869)
Class Standing	p-value = 0.355; reject null
Major	p-value = 0.487; reject null

CHAPTER SIX: CONCLUSIONS

This chapter provides closure to the research. Conclusions are discussed and any future research pertaining to this study is explored.

6.1: Conclusions

Through initial literature review, it was determined that safety training is vital to our present world. In the literature review, it was established that there are many great safety-training programs that exist, and the needs is evident. Virtual reality is a new field that is being actively explored and researched with. In many fields, there has been experimentation and implementation with training using virtual reality. However, based on the research, there were gaps in that there was not a proper three-dimensional virtual environment developed for highly populated areas such as an engineering building, current safety training software does not focus on recreating an accurate representation of the environment, an finally that there is potential for a wide variety of safety training delivery methods using virtual reality software.

The framework design for creating a modeled environment of the UCF ENG2 was developed. This model was tested through a case study where it was imported into MOSES. This virtual reality software contains avatars and was a valid form of testing the use-case of using this 3D model for creating training scenarios in a virtual reality system. The model was finally verified and validated using a nominal technique that surveys a group of participants who acted as a first-hand team of testers of the model. A survey based o a 7-scale Likert scale concluded that the model is in fact similar to the actual environment and could be a viable model to use for safety training of ENG2.

Training in safety is only growing as humans continue to interact and evolve with the world. Similarly, while virtual reality is new, it is not a passing technology and it is here to stay. It has been used in a variety of fields and its role and importance in safety training cannot be denied. Safety training using virtual reality software proposes an entire new field of study where humans can be trained using an inexpensive and effective method. The possibilities are endless when it comes to safety training using virtual reality software.

6.2: Future Research

This research is extremely important in that it presents a design framework for a virtual reality environment to be used for safety training simulation. The general platform of this study allows it to be versatile and customizable for a variety of industries and virtual reality systems. This field of study is on the forefront of technology so it is ever-changing, allowing it to be a key component in growth and exploration for safety training using virtual reality software.

The validation step of this research proposed many areas that need to be explored when further researching the creation of a 3D virtual model. During the research study, the investigator took note of all comments and observations of the participants while taking the study and there were many interesting points that were discovered. The biggest concern from a great majority of the participants were that small yet important details were missing such as familiar student posters and pictures on the walls. Many participants said that having familiar details would help them recognize the areas better in an emergency situation. The validity of these suggestions needs to be explored. The participants also noted that even though the colors were similar, exact colors, tile patterns, and ceiling material would also aid them when learning from a safety training simulation. One participant in particular noted that being able to look out the window and recognize their outdoor surroundings would aide in safety training. This proposes the question that the exterior environment will need to be modeled as well in order to have the full-immersion effect. Other small details such as the fire extinguisher doors and doorways being open did not resonate well with the participants, who often see doors to these fire extinguishers and offices closed. These comments from the participants are important when further researching the best methods for creating a virtual environment.

With this established framework, an important next step would be to conduct future research on specific scenarios using virtual reality software. Placing scenarios in the simulation and using those to test the effectiveness of safety training is a big portion of advancing the field of simulation-based training. These scenarios can be using strictly scripted virtual avatars, live characters in the scenario, or a combination of both. There is a big market for live, virtual, and constructive simulation studies. In the medical field, studies have shown that those who trained using a virtual reality software prior to performing surgery remembered the rules better than those who conventionally learned the surgery procedures (Dede, 2009). Dede (2009) goes on to note that those who have used virtual training software have shown enhancement in perspective, situated learning, and transfer of knowledge.

Alternative forms of virtual reality could be another step in expansion of this research. An immersion study by Gutierrez et al. (2007) not only explored virtual reality systems on a computer screen (known as partial immersion), but it also studied full immersive simulation trainers that included head mounted displays. Both the full and partial immersive trainers showed significant improvement in training first year medical students. Such a study can be expanded to the safety realm in order to test better uses of virtual reality to train safety procedures to individuals in various industries.

Taking this research even a step further would be to conduct research on the level of immersion of the safety training software. While conducting training using the virtual reality software has shown improvements in retaining knowledge as opposed to conventional training methods, further testing on how seriously a trainee takes it is necessary. It has been proposed to measure the level of immersion of such training simulation by using head mounted displays to measure brainwaves of involvement. For example, if the training software has placed the trainee's avatar in a situation where a fire has broken out, brainwaves can be measured to see how involved the trainee is. If they are not taking the training seriously, this can be detrimental to the learning process. This could also lead to discussions of how to make the training scenarios more realistic for trainees.

Other expansions of the research could be using the safety training simulation in scenarios where the actual environment has not been built yet. For example, if a new hospital is being built and all the doctors, nurses, and staff will be hired from several different areas, a virtual reality simulation training system can enable them to be familiar with the surroundings of the new building including learning where all the different labs, offices, and wards are located as well as to receive safety training procedures. This will allow them to be extremely familiar with their future environment before they ever step through the front doors.

Safety training systems using virtual reality simulation software can be expanded and taken in many different directions. Providing the design framework for creating a valid environment was just the first step to an entire new field of study.

APPENDIX A: UCF IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Rana Ashraf Riad**

Date: **March 26, 2015**

Dear Researcher:

On 3/26/2015, the IRB approved the following human participant research until 03/25/2016 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	Simulation Training Platform within the Safety Industry
Investigator:	Rana Ashraf Riad
IRB Number:	SBE-15-11174
Funding Agency:	
Grant Title:	
Research ID:	N/A
Grant ID:	*<Delete if none or manually enter>*
IND or IDE:	*<Delete if none or manually enter>*

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 03/25/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 03/26/2015 12:30:50 PM EDT

IRB manager

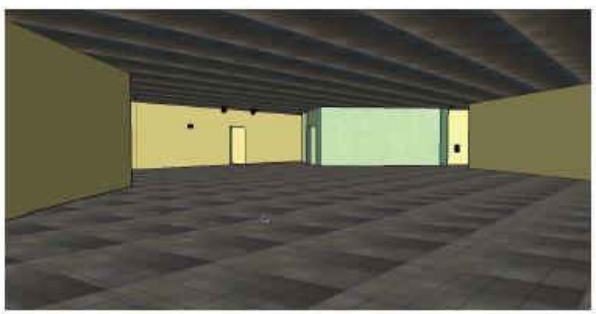
APPENDIX B: SURVEY

Virtual Reality Environment

Verification and Validation Study

Please Answer Questions 1-5:
1. Are you a student, faculty, or staff?
2. What is your age?
3. What is your major?
4. What is your class standing?
5. On a scale of 1 to 7, 1 being extremely unfamiliar and 7 being extremely familiar, how familiar are you with the Engineering 2 Building?

Watch the following video called Video 1:



6. Based on Video 1, how similar is this to the Engineering 2 1st floor on a scale of 1 to 7, 1 being extremely dissimilar and 7 being extremely similar?

Watch the following video called Video 2:

7. Based on Video 2, how similar is this to the Engineering 2 4th floor on a scale of 1 to 7, 1 being extremely dissimilar and 7 being extremely similar?

Compare the following sets of pictures and rate their similarity on a scale of 1 to 7, 1 being extremely dissimilar, 7 being extremely similar.

Image 1

Screenshot 1

8. On a scale of 1 to 7, how similar is Image 1 to Screenshot 1?

Image 2

Screenshot 2

9. On a scale of 1 to 7, how similar is Image 2 to Screenshot 2?

Image 3

Screenshot 3

10. On a scale of 1 to 7, how similar is Image 3 to Screenshot 3?

Image 4

Screenshot 4

11. On a scale of 1 to 7, how similar is Image 4 to Screenshot 4?

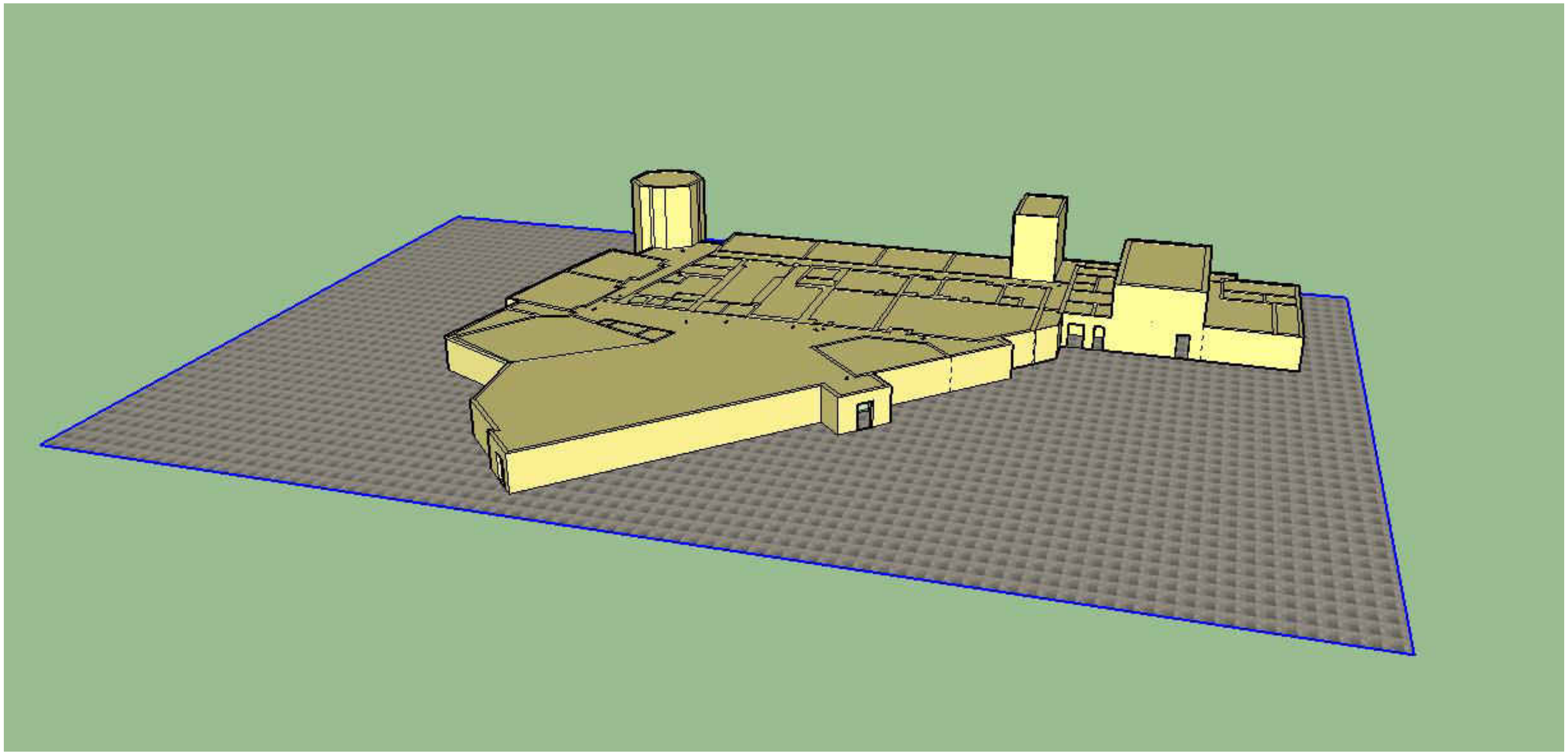
12. On a scale of 1 to 7, 1 being extremely unlikely and 7 being extremely likely, how likely are you to learn safety procedures from a simulation using this model? Safety procedures can be considered as evacuation plans, pathways, routes, exit signs, etc.

13. On a scale of 1 to 7, 1 being extremely difficult and 7 being extremely easy, how would you rate the level of ease of recognizing areas in the Engineering 2 Building after using this model?

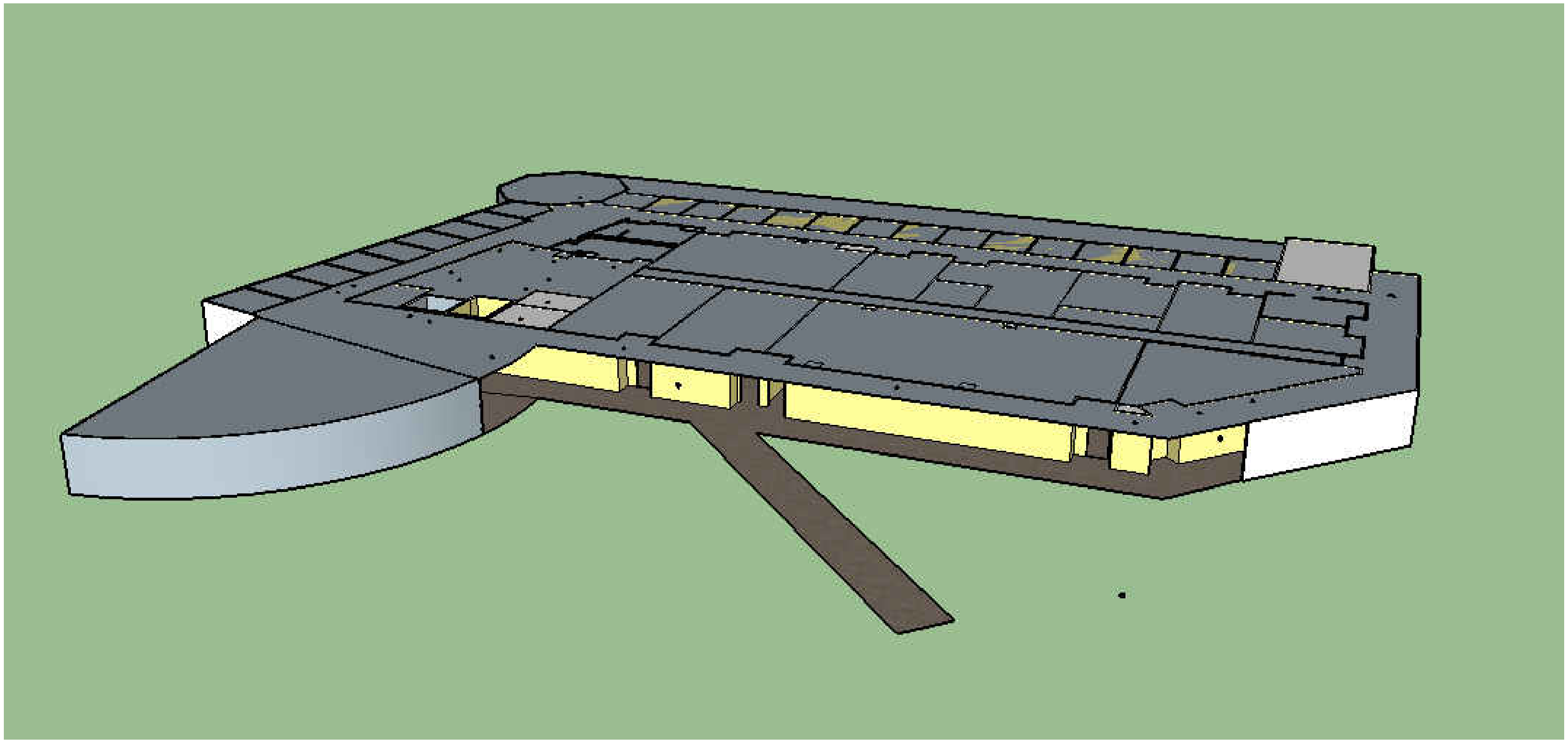
Comments? Questions? Concerns?

Thank you!

APPENDIX C: IMAGES OF FIRST AND FOURTH FLOORS OF ENGINEERING 2



This is an image of the exterior of ENG2 Floor One as it was modeled in SketchUp Pro.



This is an image of the exterior of ENG2 Floor Four as it was modeled in SketchUp Pro.

REFERENCES

Balci, O. (1997, 7-10 Dec. 1997). *Verification, Validation And Accreditation Of Simulation Models.* Paper presented at the Simulation Conference, 1997., Proceedings of the 1997 Winter.

Bureau of Labor Statistics. (2014a). Employer-Reported Workplace Injuries and Illnesses - 2013 [Press release]. Retrieved from http://www.bls.gov/news.release/archives/osh_12042014.pdf

Bureau of Labor Statistics. (2014b). National Census of Fatal Occupational Injuries in 2013 [Press release]. Retrieved from http://www.bls.gov/news.release/archives/cfoi_09112014.pdf

Burke, M. J., Sarpy, S. A., Smith-Crowe, K., Chan-Serafin, S., Salvador, R. O., & Islam, G. (2006). Relative Effectiveness of Worker Safety and Health Training Methods. *American Journal of Public Health, 96*(2), 315-324. doi: 10.2105/AJPH.2004.059840

Crnko, T., & Dyrnes, S. (2001). Arcing fault hazards and safety suggestions for design and maintenance. *Industry Applications Magazine, IEEE, 7*(3), 23-32. doi: 10.1109/2943.922447

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science, 323*(5910), 66-69. doi: 10.1126/science.1167311

Ford, G. (2014). UNDERSTANDING PEOPLE HELPS REDUCE SAFETY RISKS IN THE WORKPLACE. *Hydrocarbon Processing, 93*(8), 84-86.

Gerbaud, S., Mollet, N., Ganier, F., Arnaldi, B., & Tisseau, J. (2008, 8-12 March 2008). *GVT: a platform to create virtual environments for procedural training.* Paper presented at the Virtual Reality Conference, 2008. VR '08. IEEE.

Gliem, J. A., & Gliem, R. R. (2003). Calculating, Interpreting, And Reporting Cronbach's Alpha Reliability Coefficient For Likert-Type Scales: Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education.

Gutierrez, F., Pierce, J., Vergara, V. M., Coulter, R., Saland, L., Caudell, T. P., . . . Alverson, D. C. (2007). The effect of degree of immersion upon learning performance in virtual reality simulations for medical education. *Stud Health Technol Inform, 125*, 155-160.

Hongjian, L., & Zhe, Q. (2013, 20-22 Dec. 2013). *Virtual experiment system for electrician training based on Kinect and Unity3D.* Paper presented at the Mechatronic Sciences, Electric Engineering and Computer (MEC), Proceedings 2013 International Conference on.

Li, C., & Huang, X. (2010, 10-11 July 2010). *The study on mining virtual reality system.* Paper presented at the Industrial and Information Systems (IIS), 2010 2nd International Conference on.

Man, D. W. K., Poon, W. S., & Lam, C. (2013). The effectiveness of artificial intelligent 3-D virtual reality vocational problem-solving training in enhancing employment opportunities for people with traumatic brain injury. *Brain Injury, 27*(9), 1016-1025. doi: 10.3109/02699052.2013.794969

Masters, K. (2013). Edgar Dale's Pyramid of Learning in medical education: a literature review. *Med Teach, 35*(11), e1584-1593. doi: 10.3109/0142159X.2013.800636

Mears, J. E., Hughes, C. E., & Moshell, J. M. (1988, 10-12 Oct 1988). *Designing training scenarios by rehearsal.* Paper presented at the Visual Languages, 1988., IEEE Workshop on.

Molka-Danielsen, J., & Chabada, M. (2010, 5-8 Jan. 2010). *Application of the 3D Multi User Virtual Environment of Second Life to Emergency Evacuation Simulation.* Paper presented at the System Sciences (HICSS), 2010 43rd Hawaii International Conference on.

Morgan, C. B. (1988, 24-26 May 1988). *Implementing training programs-operation, maintenance and safety.* Paper presented at the Cement Industry Technical Conference, 1988. Record of Technical Papers., 30th IEEE.

NEMA. (2015). AFCISafety.org. *What is an AFCI? (Q&A).* 2015, from http://www.afcisafety.org/qa.html

Oxford University Press. (Ed.) (2015) Oxford Dictionaries. Oxford University Press.

Quang-Tuan, L., & Chan-Sik, P. (2012, 20-23 Aug. 2012). *Construction safety education model based on second life.* Paper presented at the Teaching, Assessment and Learning for Engineering (TALE), 2012 IEEE International Conference on.

Sandoval, T. C. L., Quintero, M., x, rmol, M. E., Lo, x, . . . Cervantes, H. J. (2011, Feb. 28 2011-March 2 2011). *Virtual process lab.* Paper presented at the Electrical Communications and Computers (CONIELECOMP), 2011 21st International Conference on.

Schwebel, D. C., & McClure, L. A. (2014). Children's pedestrian route selection: Efficacy of a video and internet training protocol. *Transportation Research: Part F, 26*, 171-179. doi: 10.1016/j.trf.2014.07.005

Shao-Hua, M., Zeng-Gunag, H., Fan, Y., Xiao-Liang, X., & Gui-Bin, B. (2014, 26-30 Aug. 2014). *A 3D virtual reality simulator for training of minimally invasive surgery.* Paper presented at the Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE.

Shoji, N., & Ge, J. (2015). Safety Training. *Professional Safety, 60*(2), 34-38.

Timeline of OSHA's 40 Year History. 2015, from https://http://www.osha.gov/osha40/timeline.html

Trimble. (2013, 2015). SketchUp Pro. Retrieved August 23, 2015, from http://www.sketchup.com/products/sketchup-pro

Yue, L., & Wenhui, Z. (2013, 28-29 Oct. 2013). *3D Interactive Virtual Reality System Based on Wiimote Stereo Structure.* Paper presented at the Computational Intelligence and Design (ISCID), 2013 Sixth International Symposium on.

Zarrad, A., & Mahlous, A. R. (2014, April 29 2014-May 1 2014). *A comprehensive case study of the impact of multicast routing protocols on mobile health care training systems.* Paper presented at the e-Technologies and Networks for Development (ICeND), 2014 Third International Conference on.

Zayas Perez, B., Marin, M. M., & Perez, E. I. (2007, 25-28 Sept. 2007). *Developing a Virtual Environment for Safety Training.* Paper presented at the Electronics, Robotics and Automotive Mechanics Conference, 2007. CERMA 2007.

Zhen, L., & Shaohua, H. (2009, 14-16 Aug. 2009). *Emotion Simulation in Interactive Virtual Environment for Children's Safety Education.* Paper presented at the Natural Computation, 2009. ICNC '09. Fifth International Conference on.

Zhenbo, L., Jun, Y., & Jauregui, D. A. G. (2009, 14-16 Aug. 2009). *A new virtual reality environment used for e-Learning.* Paper presented at the IT in Medicine & Education, 2009. ITIME '09. IEEE International Symposium on.