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Instructional Design Techniques Used to Develop Virtual Reality-Based Safety Training in an Industrial Environment

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Abstract

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MS, Walden University, 2012

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Dissertation Submitted in Partial Fulfillment

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Abstract

Instructional designers face the challenge of developing strong immersive virtual environments for education. However, there is very little research regarding the study of both the competence and practice of instructional design in the immersive virtual reality environment. The purpose of this qualitative Delphi study was to identify best practices that could be used by instructional designers when designing virtual reality-based safety training in order to improve safety competence and practice in the industrial environment. The conceptual framework for this study was based on the 3 primary groups of learning theory: behaviorism, cognitivism, and constructivism. Guiding questions were specific to the identification of instructional design elements, practices, and models that are used by instructional designers when developing virtual reality-based safety training. Participants were 4 expert panelists who were experienced instructional designers geographically dispersed across the United States with more than 10 years of experience. Data sources were 1 round of open-ended questionnaires and 2 rounds of rank-based questionnaires. After the 3 rounds, results revealed that best practices should include scenario-based instructional strategies that use psychomotor skills with competency-based assessments. The assessments should be clearly aligned to the learning objectives/outcomes and be demonstrative in scope. This study facilitates positive social change by providing instructional design insight regarding the use of virtual reality technology when merged with instructional theoretical considerations. The reflective nature of this study affords the instructional designer an opportunity to consider application of the technology specific to their individual projects.

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Dedication

This dissertation is dedicated to my parents, brother, daughter, grandchildren, family and friends for their moral support, encouragement, sacrifice and unending Love.

Acknowledgments

I am forever grateful to the expert panelists of this study for their individual support and overall contributions to the practice of instructional design. I would also like to acknowledge my employers, leaders, and mentors for providing a means by which to complete this dissertation.

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Chapter 1: Introduction to the Study

Instructional designers have had a profound impact on the bottom line of every corporate and industrial organization. *Training Magazine*'s 2016 Training Industry Report found that U.S.-based educational institutions and corporations with 100 or more employees spent 7.65 billion total training expenditures in 2016, flat from 7.6 billion in 2015. The top two priorities in the training industry for 2016 were increased training program effectiveness and reduced costs by improving efficiency (Training Magazine, 2016). Training expenditures per learner in 2016 was $814, which was up from $702 in 2015 (Training Magazine, 2016). However, actual hours of training per employee decreased from 53.8 in 2015 to 43.8 in 2016 (Training Magazine, 2016). Implementing technology-based training programs is more expensive but decreases the amount of time needed to train the employee.

Instructional designers are challenged every day to develop training that is more effective and efficient using emerging technology. Workplace instructional designers should focus more on a performance-based approach to training in order to improve transfer of skills and knowledge (Foshay, Villachica, & Stepich, 2014). Instructional designers must rely on theoretical knowledge to account for allowances and limitations of technology in order to determine if the level of effort to implement is worth the risk of possibly developing ineffective training. It is a delicate balancing act that could potentially cost the organization a great deal of money if the instructional designer misinterprets the technology use case. Virtual reality (VR) is but one of many technology options open to instructional designers.

This chapter provides a brief introduction and background to this study. In it I explain who instructional designers are and some of their challenges with incorporating emerging technology into learning activities. The problem statement and purpose speak specifically to difficulties with VR technology in learning and the industry's inability to adequately provide safety training. This chapter also provides a conceptual framework that addresses theories and models typically used in instructional design and VR. Finally, in this chapter I address the nature of the study, definitions, assumptions, scope, limitations, and significance of the study.

Background of the Study

There has been a great deal of interest using VR for the purpose of education (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). VR immerses the learner into a simulated environment that allows them to interact in a completely safe surrounding (Tanaka, et al., 2015). However, identifying beneficial instructional strategies and learning activities has been challenging for learning professionals. VR is an emerging technology (Hanson & Shelton, 2008), so there has been very little guidance from research-based best practices during implementation.

There have been many instructional designers who lack the theoretical knowledge to effectively apply evidence-based instructional strategies to the courses they design (Ertmer & Newby, 2013). Instructional designers must not only understand or describe how learning occurs, but they must also prescribe the appropriate instructional strategy to ensure that learning has occurred (Ertmer & Newby, 2013). Instructional designers typically use a model to develop effective and efficient learning solutions. However, instructional design models must consider the increased levels of interactivity within the VR environment when designing VR-based learning activities (Reigeluth & Frick, 1999). In addition, the immersive and experiential natures of VR must complement each other for true learning to occur (Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010).

Research has failed to study both the competence and practice of instructional design in a fully immersive VR environment (Tracey & Boling, 2014). The VR environment should represent reality, or the real world, as much as possible in order to yield realistic results. However, the VR environment will be devoid of the typical hazards often found in the standard industrial environment. The goal of this study was to explore the considerations of instructional designers when designing VR -based safety training. This study was to provide instructional designer insights regarding design considerations specific to VR when designing safety training using this technology.

Problem Statement

There were 4,679 fatal work injuries in the United States in 2014, which was a 2% increase from 2013 with a 6% increase in the construction industry alone (US Department of Labor, 2015). Employers are required to provide a safe working environment for all employees (Occupational Safety and Health Administration, 2015). A strong safety training program helps employers identify and fix workplace hazards (Occupational Safety and Health Administration, 2015). Immersive VR provides a naturalistic environment for workers to physically experience the work environment without the associated risk.

VR has the potential to provide a risk-free environment while simulating the real-world environment. Research involving instructional design processes is limited and critically needed (Richey & Klein, 2014). There has been insufficient research regarding both the competence and practice of instructional design in a fully immersive VR environment (Tracey & Boling, 2014). Instructional designers could benefit from research that provides guidance by way of listing best practices towards implementing the use of VR technology.

Purpose of the Study

The purpose of this qualitative study was to identify best practices that could be used by instructional designers when designing VR -based safety training in order to improve safety competence and practice in the industrial environment. As instructional designers develop safety training for a variety of industrial environments, identification of high-level best practices should serve as guidance when developing such training.

Research Questions

This study focused on the following three central questions:

RQ1: What design elements do expert instructional designers believe should be considered when designing full immersion VR -based safety training?

RQ2: What practices do expert instructional designers use to overcome challenges experienced when designing full immersion VR as a medium for safety training?

RQ3: Which instructional design model do expert instructional designers believe would be most beneficial when designing full immersion VR -based safety training?

In addition to the research questions, I also answered the following subquestion based on participant responses.

SQ: Which learning and instructional design theories are reflected in best practices identified by expert instructional designers when designing full immersion VR -based safety training?

Conceptual Framework

The conceptual framework for this study was based on existing instructional design theories and models typically used during the practice of instructional design. In this study I also utilized prior research as a means by which to gather data regarding instructional design of VR-based training. This conceptual framework discussion first looks at multiple instructional design theories and models from which, as an interdisciplinary field, instructional design pulls . Instructional design draws theory from psychology, science, sociology, and education (Smith & Ragan, 2005). The primary research design of this study represented a design and development research (DDR) perspective. DDR is the systematic study of design and development and evaluation of instructional and noninstructional products and tools (Richey & Klein, 2007).

The primary types of theory used in instructional design are descriptive learning theories and prescriptive instructional theories (Smith & Ragan, 2005). Descriptive theory describes how learning occurs, and prescriptive theories prescribe methods that increase learning (Driscoll, 2005). There have emerged seven primary instructional design theoretical contributions in the field: behavioral learning theory (Skinner, 1987), information processing theory (Miller G. A., 1956), Gagné’s (1977) theory of instruction, general systems theory (Banathy, 1992), cognitive load theory (Sweller, van Merrienboer, & Paas, 1998), situated learning theory (Lave & Wenger, 1991), and constructivism (Merrill, 1992). Thus, theoretical research in instructional design spans from 1956 to the present, which makes it a new field that is just now beginning to define itself as an educational staple.

There are three primary groups of learning theory: behaviorism, cognitivism, and constructivism (Ertmer & Newby, 1993). Behaviorism is focused on observable behavior of the learner. Cognitivism is focused on psychological conditions as they relate to learning (Januszewski & Molenda, 2008). Constructivism is focused on the learner building their own knowledge (von Glasersfeld, 1995). These are the primary theories that guided this study, but more were considered when technology entered the equation.

The technology of VR requires additional theories to define the concept towards applied learning. Experiential learning, as a subset of constructivism, plays a large role towards prescribing learning outcomes. Kolb (1984) indicated that experiential learning was based on the learner constructing knowledge by interpreting their learning experience. However, the realm of educational technology is even newer than instructional design and has embraced a newly developed theory called activity theory. Activity theory lends itself to the educational technology research (ETR) premise that learning is based more on learner activity than on the content being presented (Karakus, 2014). While cognitivism is an important learning theory, VR is mostly focused on behaviorism, constructivism, and experiential learning theories as they are more closely tied to the activities involved with VR-based learning. I discuss these theories more specifically in Chapter 2.

My approach to instructional design in this study followed Branch & Kopcha's (2014) perspective in that it was based on a systematic model driven by complex educational contexts. This research design served to organize the study and is similar to how instructional design models are practiced by instructional designers. Instructional design models are currently used to encourage learning during the instructional process (Spector, 2014). The instructional designer's selection of a particular model is often based on one of three factors: employer, education, and timing. Organizations and institutions often adopt a specific instructional system design (ISD) model that all employed instructional designers follow when designing corporate training or academic courses (Obizoba, 2015).

It is recommended that instructional designers use taxonomy to select an appropriate model based on instructional context (Branch & Kopcha, 2014). Aside from being mandated to use a specific model established by organizational requirements, designers were more prone to use their most comfortable model. The most commonly used model in the business environment is based on five core components: analysis, design, development, implementation, and evaluation (ADDIE; Branch & Kopcha, 2014; Chevalier, 2011; Lawson & Lockee, 2014). The fact that ADDIE contains foundational elements of all instructional design models implies that it could have been considered more concept than model (Branch & Kopcha, 2014). However, the ADDIE model addresses the constructive nature of building trade-specific skills within the industrial work environment.

Nature of the Study

This study was a qualitative study that used a modified Delphi method of inquiry directed to a panel of expert instructional designers. Delphi technique is typically used to gather and distribute expert insights and conclusions on a particular topic or problem, as well as encourage consensus towards a specific solution or solutions (Donohoe, Stellefson, & Tennant, 2012). I selected experts in the field of instructional design and requested that they participate in the study. They were asked their opinion regarding design considerations for full immersion VR-based safety training. I administered multiple rounds of questionnaires to build on patterns identified during the previous round of questioning.

After data collection, the focus of the study shifted to data analysis. The primary focus of qualitative study is to describe an event, phenomena, or feeling (Patton, 2002). This is not to imply that data collection and analysis of qualitative research is linear but instead it is more like a cyclical process (Creswell, 2014). It was for this reason that I relied on multiple rounds of questioning to increase the likelihood of identifying patterns and themes. It was very possible that the process of analysis would illuminate the need for additional data collection. From there, I critically reviewed the data to identify meaningful patterns through the use of computer software (Miles, Huberman, & Saldana, 2014). NVivo and other types of software served to help manage and organize the data.

Definitions

This section represents a listing of several terms that were frequently used by the industrial and educational technology industries, instructional designers, and the general VR-based training community.

Analysis, design, development, implementation, and evaluation (ADDIE): The most commonly used model in the business environment is based on five core components: analysis, design, development, implementation, and evaluation (Branch & Kopcha, 2014; Chevalier, 2011; Lawson & Lockee, 2014).

Consensus: Consensus is a set of convergent opinions from acknowledged experts (Davidson, 2013). Consensus is defined as 80% agreement (Pilcher, 2015).

Delphi technique: Delphi technique is typically used to gather and distribute expert opinions on a particular topic or problem, as well as encourage consensus towards a specific solution or solutions (Donohoe, Stellefson, & Tennant, 2012). The Delphi technique is beneficial in identifying and documenting contradicting opinions (Nworie, 2011)

Design and development research (DDR): The definition of DDR is "the systematic study of design, development, and evaluation processes with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development" (Richey & Klein, 2007, p. 1).

Educational design research (EDR): EDR refers to the study of educational interventions or the actual solution to an educational problem that yields new knowledge that informs the work of others (McKenney & Reeves, 2014). The goal of EDR is to improve education research specific to educational communications and technology (Barab & Squire, 2004; Burkhardt, 2009; Reeves, 2011; Schoenfeld, 2009; van den Akker, Gravemeijer, McKenney, & Nieveen, 2006).

Instructional design: Instructional design is a systematic method used to describe appropriate instruction, encourage learning, and apply educational descriptive and prescriptive theories (Smith & Ragan, 2005).

Virtual reality (VR): VR is the computer-generated simulation of a three-dimensional image or environment that interacts with a person by using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (Miller R. , 2014).

Assumptions

Assumptions in this study were tied to the expert panelists as Delphi studies rely on their opinions (Nworie, 2011). I assumed that panelists would be able to separate any bias towards the technology and view the data objectively throughout the study. I also assumed that panelists would not subsequently meet each other personally and divulge their participation as this study progressed.

Scope and Delimitations

The scope of this study addressed three utilities: instructional design, VR, and safety training. Instructional design was studied due to the challenges experienced by instructional designers when developing technology-based solutions. VR was studied due to the challenges experienced by instructional designers when implementing an emerging technology into learning environments. Safety training was studied due to the intense need of industrial environments to provide more effective and efficient training in a risk-free environment.

This study was a semistructured qualitative Delphi method of inquiry on the design elements used for VR-based safety training by a panel of expert instructional designers. The participants were carefully screened as practicing instructional designers to serve as the panel of experts. Multiple rounds of questionnaires were administered to build on patterns identified during the previous round of questioning. I used the panelist textual responses to identify patterns in order to identify themes. Findings were solely based on responses and ratings received from the panel of experts. Transferability is possible with this study but acquiring a different group of panel experts could yield similar or different results based on the selection criteria. The selection criteria used in this study is clearly defined in Chapter 3 and is easily transferred to various contexts.

Limitations

Limitations in using the Delphi technique included the amount of time required to complete the study and level of experience of the panelists (Nworie, 2011). The multiround nature of this methodology could result in attrition. In order to increase the number of participants, panelists were asked to provide recommendations for other participants as a process of snowball sampling (see Patton, 2015). The more participants in the study the more opinions, but at the same time, the more participants the harder it would have been to acquire consensus. It was recommended that 10-18 expert panelists be used for a Delphi study (Okoli & Pawlowski, 2004)

Participant selection criteria was based on the number of years of instructional design experience as well as the types of organizations where the experience was gained. The study was limited to participants who had (a) at least 10 years of instructional design experience; (b) completed more than 10 instructional design projects as the practicing instructional designer; (c) a degree/certificate in instructional design, education, or other business-related degree; (d) industrial-based safety training experience; and (e) incorporated various forms of technology into instructional design projects. As this research specifically involves safety training, participants were primarily selected from industrial organizations. Additional selection criteria also involved the types of courses designed by potential participants. All participants designed courses that involved various forms of technology. As this training is specific to the emerging technology of VR, it was important that participating instructional designers brought prerequisite knowledge regarding challenges consistent with similar types of technology-based learning.

Significance of the Study

Study of the instructional design aspects and models used to create VR-based safety training was important for several reasons. This research enhanced the fundamental understanding of designing fully immersive VR-based safety training. The results of this study helped fill a research gap as current studies primarily focused on developing desktop VR-based training. Fully immersive virtual environments added to worker experience by allowing workers to experience seemingly unsafe environments without risking their safety and potentially their lives. The results from the study could also be used to provide guidelines to design fully immersive virtual environments and thus provide a cost-savings to businesses by decreasing overall training development time.

Significance to Practice

The results of this study advanced the practice of instructional design by providing guidance for instructional designers when developing VR-based safety training. The results yielded a listing of best practices to be used when designing safety training using VR technology. Identification of best practices decreased the amount of analysis typically performed by instructional designers during the early stages of instructional design.

Significance to Theory

The usage of the term "theory" in this study was geared more in a nonstandard context. In this study the term "theory" was more in line with Maxwell's (2013) explanation which leaned more towards "a set of concepts or ideas and the proposed relationship" (p. 48). Theory in this study was used more to provide explanation towards the practical application of instructional design during the development process. However, this study was not considered grounded theory in that theory was not developed inductively during the study and did not drive the collection of data (see Maxwell, 2013).

Significance to Social Change

Positive social change was achieved through this study by providing an understanding of critical design elements that should be considered by instructional designers when designing VR-based safety training. Ultimately, this information can be used as a guide in designing VR-based safety training that will improve learner knowledge by allowing them to experience seemingly unsafe environments without actually risking their safety and potentially their lives, thereby decreasing the number of safety-related accidents in the industrial environment.

Summary and Transition

This chapter introduced the study and provided specifics including background information, problem and purpose statements, research questions, theoretical foundation, conceptual framework, nature of the study, definitions, assumptions, scope and delimitations, limitations, and significance of the study. This chapter served as both an introduction to the study as well as an abridged version of how the study was conducted.

This chapter spoke to the fact that instructional design is the application by which descriptive learning theories and prescriptive instructional theories are used to develop educational programs that guide instruction and increase learning. Instructional designers have a profound impact on the bottom line of every corporate and industrial organization. *Training Magazine*'s Training Industry Report (2016) found that U.S.-based educational institutions and corporations with 100 or more employees spent 7.65 billion total training expenditures in 2016; flat from 7.6 billion in 2015. Instructional designers were challenged every day to develop training that was more effective and efficient through the use of emerging technology. Workplace instructional designers should have focused more on a performance-based approach to training in order to improve transfer of skills and knowledge (Foshay, Villachica, & Stepich, 2014).

This chapter also spoke to industrial challenges with implementing effective safety training. After receiving 8-10 hours of nonimmersive safety training, workers were frequently placed on the jobsite with zero experience in an unsafe environment. The primary challenge involved with safety training was the inability of American organizations to create an unsafe training environment per federal Occupational Safety and Health Administration regulations (2011). However, learning experiences of job-specific environmental conditions required practice within an unsafe environment (Neville, 1998). VR had the potential to provide a risk-free environment while simulating the real-world environment.

After providing the conceptual framework of the study, this chapter provided details explaining how the study was conducted. This study was a qualitative study using a modified Delphi method of inquiry by a panel of expert instructional designers. I administered multiple rounds of questionnaires to build on the patterns identified during the previous round of questioning. Lastly, based on the method of study, this chapter provided specifics identifying project scope and delimitations, limitations, and significance. Chapter 2 provides a literature review of noted research strongly related to this study.

Chapter 2: Literature Review

Chevalier (2007) indicated that 80% of work-related performance problems are tied to the environment and not necessarily the actual training received by the worker. Implementing training that provides a realistic but safe VR industrial environment will allow trainees to experience the setting while at the same time learn the required job. The number of safety regulations is confusing and typically does not afford the worker an opportunity to apply what is learned (Mincks & Johnston, 2009). After receiving 8-10 hours of nonimmersive safety training, workers are frequently placed on the jobsite without any experience in an unsafe location. The primary challenge with safety training is to provide learning in safe surroundings. However, job-specific learning experience requires realistic practice, which maintains an associated level of risk (Neville, 1998).

A review of literature indicated that VR-based training can simulate a real-world environment with risk-free scenario-based safety concerns (Backus, Keegan, Gluck, & Gulick, 2010). VR immerses the learner into a simulated industrial environment that allows them to interact in a completely safe surrounding. However, identifying beneficial instructional strategies and learning activities is challenging for learning professionals. VR is an emerging technology (Hanson & Shelton, 2008), and there is very little guidance by way of research-based best practices. Instructional designers typically use a model to develop effective and efficient learning solutions. However, instructional design models must consider the increased levels of interactivity in the VR environment when designing VR-based learning activities (Reigeluth & Frick, 1999). In addition, the immersive and experiential natures of VR must complement each other for true learning to occur (Freitas et al., 2010). There has been insufficient research regarding both the competence and practice of instructional design in a fully immersive VR environment (Tracey & Boling, 2014). The desire to conduct emerging technology research in a naturalistic setting instead of a more controlled lab-like environment implies that the technology is designed into learning solutions without the benefit of adequate research (Bishop & Elen, 2014).

The goal of this study was to explore instructional designer considerations used when designing VR-based industrial safety training. The subsections of this literature review include literature search strategy, theoretical foundation, conceptual framework, literature review, and conclusion. Each section is focused on the following themes: instructional design, VR, and safety training. With VR and instructional design as the primary focus, this review provided theoretical foundations and conceptual frameworks for both. With VR as an emerging technology, it was also important to review current literature regarding commonly used research designs for educational technology studies. Therefore, there was also a section that includes details regarding EDR and DDR.

Literature Search Strategy

This review begins by identifying studies that involved the use of VR-based training or VR simulators and then systematically covers instructional design, ETR, and safety training. The studies detailed in this literature review were derived from various industries and serve to build on the scope of this topic, which was required due to the limited amount of research. The publication dates of the literature cited ranged from 1913 to 2016, with older literature serving as foundational measures. According to

Dawidowicz (2010), the goal of a literature review is to examine current literature on the topic unless there are extenuating circumstances, such as emerging technology. Dawidowicz recommended that researchers search for literature that involves similar technology. With limited research regarding VR in the industrial environment, this literature review details research on VR in other industries. Considering the emerging technology used in this research, the ratio between foundational and current literature is acceptable.

Current literature encompassed studies published within the last 3 to 5 years that not only determined the current level of knowledge in the field but also the gap specific to collaborated instructional design practices when designing VR-based training. However, it was necessary to include background studies in order to communicate introductory details regarding the various topics. The conclusion of this literature review provides a summary of the literature search strategy, theoretical foundation, conceptual framework, and recent literature review, and how they related directly to the goal of this study.

As with most studies, this literature search strategy began in a school library. Walden University’s online library includes 104 databases, 199,297 Ebooks, 67,749 full-text journals, and 3,841,002 dissertations (Walden University, 2015). With such a vast repository of literature, it was important to approach the search with an explicit strategy in mind. The initial plan included starting from a broad perspective and then narrowing down to specific topics such as VR and safety training. The literature search began as a review of the “Database by Subject” listing with “Education” as the identified subject.

The initial database used was the "Education Research Starters" to attain a listing of introductory literature on four themes: VR-based training, instructional design, related theories, and safety training.

The search continued with a keyword search of the previously stated themes using the EDITLib, ProQuest Central, Academic Search Complete, and PsycINFO databases. After a general keyword search on *virtual reality, instructional design, safety training, behaviorism*, *constructivism*, and *experiential learning*, another search was conducted on keyword title phrases such as *instructional design, virtual reality-based training*, and *safety training*. After I reviewed the articles, I took notes of the reference listings from each article, with attention to recent studies and those related to the overall goal of this study. Considering the emerging technology of VR, this literature review strategy included a frequent review of literature to identify newly published articles for possible inclusion.

Conceptual Framework

The usage of the term theory in the context of conceptual framework is intended in a nonstandard context. Theory in this literature review is used more to provide explanation of the practical application of instructional design during the development process. I also used prior research to help identify keywords, patterns, and themes (see Maxwell, 2013). There are many instructional designers who lack the theoretical knowledge to effectively apply evidence-based instructional strategies to the courses they design (Ertmer & Newby, 2013).

Instructional designers must not only understand or describe how learning occurs, but also prescribe the appropriate instructional strategy to ensure learning has occurred (Ertmer & Newby, 2013). Instructional design, as an interdisciplinary field, draws theory from psychology, science, sociology, and education (Smith & Ragan, 2005). The primary types of theory used in instructional design are descriptive learning theories and prescriptive instructional theories (Smith & Ragan, 2005). Descriptive theory involves how learning occurs, and prescriptive theories offer methods that increase learning (Driscoll, 2005). There have emerged seven primary instructional design theoretical contributions in the field: behavioral learning theory (Skinner, 1987), information processing theory (Miller G. A., 1956), Gagné's (1995/1996) theory of instruction, general systems theory (Banathy, 1992), cognitive load theory (Sweller, van Merrienboer, & Paas, 1998), situated learning theory (Lave & Wenger, 1991), and constructivism (Merrill, 1992). Thus, theoretical research in instructional design spans from 1956 to the present, which makes it a fairly new field that is just now beginning to define itself as an educational staple.

There are three primary groups of learning theory: behaviorism, cognitivism, and constructivism (Ertmer & Newby, 1993). Behaviorism is focused on observable behavior of the learner; cognitivism is focused on psychological conditions as they relate to learning (Januszewski & Molenda, 2008); constructivism is focused on the learner building their own knowledge (von Glasersfeld, 1995); and experiential learning, which is where the learner transforms their own knowledge through actual experience (Kolb, 1984).

The technology of VR requires additional theories to define the concept towards applied learning. Experiential learning, as a subset of constructivism, plays a large role towards prescribing learning outcomes. Kolb (1984) indicated that experiential learning is based on the learner constructing knowledge by interpreting their learning experience. However, the realm of educational technology is even newer than instructional design and has embraced a newly developed theory called activity theory. Activity theory lends itself to the ETR premise that learning is based more on learner activity than on the content being presented (Karakus, 2014). While cognitivism is an important learning theory, VR is mostly focused on behaviorism, constructivism, and experiential learning theories as they are more closely tied to the activities involved with VR-based learning.

Behaviorism

Schunk (2012) defined learning as "an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience" (p. 3). This definition clearly links learning to behavior in that it expresses two forms of the word "behavior" as well as considers the experience of activity. Driscoll (2005) defined learning as "a persisting change in performance or performance potential that results from experience and interaction with the world" (p. 1). The terms "performance," "experience," and "interaction" lead the instructional designer towards behaviorist and activist principles, which are both characteristics of VR-based training.

Van Merrienboer and Bruin (2014) defined behaviorism as the theory where all learning is guided by the laws of classical or operant conditioning. Classical conditioning refers to neutral stimuli leading to automatic response and operant conditioning is based on reinforcement and more easily attained (van Merrienboer & Bruin, 2014). Despite the ensuing debate and misinterpretation of the definition of behaviorism (Moore, 2011), the majority of early instructional design models are based on the theory of behaviorism (Gustafson & Branch, 2007).

Another behaviorist law is operant conditioning which is based on associating stimulation with a positive or negative outcome, (Thorndike, 1911). Skinner (1938) made the most profound distinction between classical and operant conditioning by indicating that classical conditioning is programmed and results in automatic response while operant conditioning is a voluntary response. As an operant conditioning example, if the dog presses a button and is given meat powder, then this is a positive outcome that the dog will voluntarily continue to do. However, if the dog hits a bell and receives an electric shock, then this would be a negative outcome of which the dog would voluntarily refrain from doing. Both operant conditioning and classical conditioning are grounded by how learning is tied to physical behavior, or performance of the learner based on the definitions of learning provided by Schunk (2012) and Driscoll (2005) respectively.

The grounded premise surrounding VR is based on behaviorism which was initially presented by Watson (1913). Watson was the first to point out that learning objectives should truly be objective; instead of subjective by which to explain the student’s expected behavior. Watson also indicated that observing the behavior of an “animal” not only displays current knowledge but also the animal’s previous experience. For example, someone who learns how to tie a shoestring must first learn how to tie a knot and make loops in order to be successful. The action of tying a shoestring includes multiple learning objectives which serve of previous experience.

The purpose of workforce training programs is to improve the trainee's behavior and individual performance on the job. A skilled workforce is constructed by completing required tasks or acquiring the skills to complete the required tasks. Before the emerging technology of VR, trainees were focused more on gaining the knowledge but were unable to physically apply/translate this knowledge from a behavioral perspective in the industrial setting until participation in on-the-job training. VR affords the worker an opportunity to experience their own behavior while at the same time allowing others to observe the learner's behavior. It represents the practical application of a learned behavior which strongly ties VR to the theory of behaviorism.

As a learning theory, behaviorism speaks directly to VR in that the simulated setting allows for "hands-on" learning in a virtual environment that matches the real-world where the behavior will be performed. According to Skinner (1938), behaviorism is the philosophy where learning is based on observable performance that clearly shows a change of the learner's behavior when completing tasks. Skinner is credited with what is known as "radical behaviorism," which removed the focus of learning from "the mind" to knowing what is learned due to behavioral observation. The VR environment relies specifically on observational behavior of the learner by either an instructor or software that is programmed to automatically detect and evaluate the learner's behavior. This fact brings the discussion of behaviorism full circle in that not only does the learner experience the task but also able to receive feedback through observation and feedback from the instructor, or what Skinner coined as the "programmed learning."

Skinner (1958) indicated that information presented to the student in any form was not enough to learn. His focus on the student led him to develop a "teaching machine" (p. 1), which was meant to encourage the student to become more of an active participant in their own learning. The concept of a teaching machine was based on the premise that students learn by developing the desired behavior instead of being told how to behave (Skinner, 1958). In this respect programmed learning simply used instructional design techniques where evidenced-based research was used to encourage the expected behavior change. For example, Skinner's (1958) teaching machine's content was programmed to begin with small steps and advance to more difficult steps. Today's self-paced learning which happens to involve technology is nothing more than modern day teaching machines, or programmed learning (Driscoll, 2005).

Harzem (2004) proclaimed that behaviorism does not exist exclusively in and of itself because it exists in all learning. The instructional design perspective of behaviorism is concentrated in the identification of learning/performance objectives and the environmental conditions in which learning occurs (Ertmer & Newby, 1993). Another perspective of behaviorism in instructional design involves the concept of reinforcement which indicates that the desired behavior increases when instruction is reinforced (Driscoll, 2005). The behaviorist philosophy indicates that the learner creates the desired behavior after being informed of the objective, in the appropriate environment, with reinforcement when necessary. VR allows the learner to practice the desired behavior until the task, or action, is perfected. Observing the change in behavior gives the teacher the ability to confirm that learning has occurred by the student's ability to successfully complete the task. However, there are aspects of learning that is not visually observable which contributes to a more cognitivist approach towards learning.

Cognitivism

Cognitivism is strongly tied to the study of internal mental structures involved with student learning (Bower & Hilgard, 1981). Learning from the cognitivist perspective is concerned with what the learner knows and how they came to know it (Jonassen, 1991). The cognitive theory more closely related to VR is situated cognition theory where there is more of a focus on the learning environment and activities (Driscoll, 2005). According to Wenger (1998) the premise surrounding situated cognition contains the following foundational principles:

- Humans are social.
- Knowledge is competence- and value- based.
- Knowledge is a matter of active engagement.
- Learning produces meaning.

At the center of situated cognition theory is the concept of legitimate peripheral participation (Lave & Wenger, 1991). For example, the layperson who is without the benefit of practical experience will have a different understanding than the more experienced tradesperson. In addition, by participating in the learning activity the layperson will become a practiced layperson as opposed to an informed layperson. Wenger (1998) referred to this as "negotiation of meaning" (p. 53), whereby the VR environment allows the layperson to learn through experience in essence becoming more aligned with the experienced tradesperson.

As the concept of situated cognition is relatively new, researchers continue to test and expand the knowledge base towards confirming validity of the theory. Grantham et al. (2013) conducted a study to test if situated cognition theory would describe the learner's cognitive process based on the environment of a learning activity. Zachary et al. (2013) applied situated cognition theory to explain the decision-making process of grocery shoppers. Gomez and Lee (2015) conducted a qualitative analysis to study the expanded level of knowledge attained using the social aspect of situated cognition theory.

Grantham et al. (2013) used the situated cognition theory to describe learning activity efficacy on cognition of the learner. The researchers used first-year engineering students at two different universities to complete a task to redesign a coffeemaker. In this instance the students represent the layperson and will have an opportunity to practice the engineering processes used by career engineers. Without the benefit of practicing the reengineering process these students would not have the opportunity to experience the working environment surrounding product redesign. The researchers found that situated cognition not only improved the product redesign, but also positively impacted learner creativity.

Zachary et al. (2013) conducted a study to understand how people make decisions to purchase certain types of groceries. Approaching the study from an ethnographic perspective the researchers conducted in-depth interviews and focus groups of low-income African American families with children. The researchers found that situated cognition theory provided insight towards understanding participant behavior. The results showed that structural qualities of the supermarket increased unhealthy purchases and decreased healthy purchases. It was the supermarket environment itself that served as the contributing factor towards decision-making, or food selection.

Gomex and Lee (2015) compared formal and informal learning environments to enhance sixth-eighth grade student learning. The researchers observed teacher-student interaction in a formal classroom environment and mentor-student interaction in an afterschool program or informal environment. The researchers found that the informal environment with mentor-student interaction created a situated learning phenomenon that improved student skills and expertise. In addition, afterschool program projects were made open to the public which served as a critical avenue towards receiving multi-sourced feedback that proved to further develop the student. The researchers argued that the situated cognition theory served as a model of opportunity for the students to informally practice what was previously learned in the formal environment.

As it relates to VR, the cognitivist approach involves presenting information that offers context to the learner (Ertmer & Newby, 2013). A large piece of VR is visual and, therefore, tied to the visual perception of the learner. There have been studies that closely tie cognitive and physical processes, meaning one affects the other (Wilson, 2002). Chao, Haxby, and Martin (1999) conducted a study that found when people were required to view and name a picture of a tool it activates premotor areas of their consciousness. This behavior was sparked simply by viewing the tool and, therefore, it stands to reason that the visual component within VR not only triggers the psychomotor reflex but also allows the learner to act on the visual representation.

Cognitivism is important to the learning process in that it addresses prior knowledge of the student, motivation of the student, and student reflection of the learning event (Anderson, 2008). To attain maximum learning instructional strategies should not only help the student understand the information, but also increase the rate of their comprehension. Instructional strategies, such as VR, that tap the learner's prior knowledge will help them form connections from long term memory to construct new meaning (Anderson, 2008).

Constructivism

The constructivist perspective implies that learning occurs when the learner creates their own reality based on their personal experiences (Ertmer & Newby, 2013). These experiences continue to build on one another with the learner forging a new reality with each new experience. Glasersfeld (1995) believed that as the teacher presents the problem the learner explores the information further to build their own knowledge which serves as the premise behind constructivism. Building knowledge includes actively constructing knowledge and skills and is considered learning (Branch & Kopcha, 2014). The quality of the learning experience has a direct effect on the learner's ability to construct the desired knowledge (Dewey, 1938). There must be some prior knowledge on which the learner can build (Schunk, 2012). Instructional design from the constructivist perspective is to assume that the learner will construct their own knowledge through the benefit of receiving a quality learning experience. VR plunges the learner into the industrial environment without the typical safety concerns often found in the real-world, or even the training environment. The constructivist instructional designer develops instruction that places the learning experience in the most appropriate context.

Constructivist principles are commonly integrated into simulation-based learning activities. The virtual environment serves as an opportunity to incorporate constructivist learning activities into the process of learning. Practical constructivism features include cognitive activity in a context that is built on prior knowledge then quickly applied through practical exercise with feedback and self-reflection (Baviskar, Hartle, & Whitney, 2009). The learner constructs their own knowledge while in the process of experiencing, or practicing, the learning activity.

A key constructivist was Lev Vygotsky who was a psychologist from Belarus that went mostly unnoticed until the 1960s (Driscoll, 2005). A primary Vygotsky viewpoint is surrounded by something known as the Zone of Proximal Development (ZPD) (Vygotsky, 1978). ZPD represents the point between the learner completing the task with assistance and the learner completing the task without assistance (Schunk, 2012). Vygotsky's definition is more intellectual in that he defined it as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p.86). According to Vygotsky (1978) the ZPD specifies the point at which actual learning occurs. To this point, Vygotsky determined that the ZPD only provides a window into what has developed but does not provide details regarding potential development (Driscoll, 2005). Vygotsky also considered the strong social aspect of ZPD in that the level and quality of instruction does have a solid relation to a higher level of learning regarding potential development (Vygotsky, 1978).

Vygotsky was considered more of a social constructivist in that he realized the role of the experienced person to guide the process of learning (Vygotsky, 1978). He believed that providing assistance and then systematically removing assistance, or scaffolding, allows learners to build or construct their own knowledge. Another aspect of scaffolding is cognitive apprenticeship where an expert mentor or coach instructs the learner to accomplish the task until they can do it without assistance (Collins, 1991). Instructions given in VR serves as the simulated expert mentor or coach who provides the necessary feedback based on the learner's actions. Cook et al. (2013) indicated that education does not make effective use of expert simulations, and Ramdass (2012) indicated that game-based tools, such as VR, must also include skill and knowledge of the tool instead of only addressing tool usage.

From the constructivist perspective, the role of instructional design is to provide realistic learning environments that will encourage critical thinking and problem solving which enables and enhances learning (Yoders, 2014). This is the instructional designer's challenge in that constructivism is more directed towards a less structured learning environment where the student is allowed to discover instead of individual instruction. As a result, constructivist instruction tends to be more conducive to an informal learning environment that is highly focused on the student's ability to learn through actual experience. For example, trade specific learning is usually taught through cognitive apprenticeship, or mentoring philosophy, within the actual trade-specific setting instead of a classroom environment. Not only does the learner learn from a seasoned tradesperson but they also become acclimated to the surrounding environment. Dewey (1938) reasoned that knowledge was not only representative of reality but is instead the process by which the individual is part of the reality through interaction. The more practical the learning environment the more likely information will be retained, and the learner will experience completing the task; a philosophy clearly associated with the concept of VR.

Experiential Learning Theory

Kolb (1984) indicated that experiential learning is based on the learner constructing knowledge by interpreting their learning experience. Kolb identified four stages of learning; concrete experience, reflective observation, abstract conceptualization, and active experimentation. Concrete experience involves the actual learning activities completed by the learner to acquire the skill (Kolb, 1984). Reflective observation involves the learner's reflection of the learning activity (Kolb, 1984). Abstract conceptualization involves the learner applying cognitive thought towards successfully accomplishing the actual learning activity (Kolb, 1984). Active experimentation involves the learner applying what was learned through practical experience (Kolb, 1984). Peterson, DeCato, and Kolb (2015) describe active experimentation as an individualized method whereas the learner is aware of their own experience, takes note of the experience, reflects on the experience, and then formulates a concept of how to successfully complete the task.

Dewey's (1938) principles of continuity and interaction indicate that learning experiences should be considered during the process of determining educational solutions. This process of determining educational solutions takes place during the instructional design process of developing educational solutions. The underlying premise of continuity and interaction is the relationship between the learning environment, the teacher, the learner, and the overall learning experience (Dewey, 1938). These are the components that instructional designers use to identify course design during the process of incorporating instructional strategies into learning activities (Dewey, 1938). The instructional designer identifies the learning environment and therefore the learner's experience; will it be the classroom, online, or laboratory environments?

The concept of experiential learning is different than current methods of learning in that the focus shifts from assessment to actual performance (Keenan, 2013). The philosophy of experiential learning is focused on improving performance which is a good strategy for the industrial setting due to the hands-on nature of skill-based learning. VR places the learner in the industrial location where they will physically experience the necessary level of awareness needed to remain safe instead of having to simply visualize the experience in the classroom or online environment.

Experiential learning is strongly tied to the learning environment which requires the instructional designer to communicate a detailed description for the purpose of instruction regardless of the methodology. The instructional designer must provide an instructional description that speaks to why the delivery method is the most appropriate delivery method; be it instructor-led, blended learning, or eLearning. The instructional designer must also be keenly aware of the target audience, for example, the learner is a tradesperson, engineer, apprentice, undergraduate student, or perhaps a graduate student. Understanding the target audience allows the instructional designer to frame the instruction into the applicable context. Lastly, the instructional designer is charged with explaining the anticipated learning experience by not only clearly stating the learning objectives but also predicting the expected learning outcomes.

The experiential environment must be realistic for learning to occur. VR provides an environment where learners have an opportunity to apply newly acquired skills and knowledge. However, VR adds an extra layer of consideration for the instructional designer. By considering the VR as a learning medium specific to the environment, the instructional designer must account for learning through the five senses; sight, taste, hearing, smell, and touch. The sense of sight is easily accomplished by completely immersing the learner in a 360-degree environment. For example, if the objective of the educational program is to successfully apply paint to a wall, then in order to tap the senses the virtual environment could include an actual system integrated paint brush using haptic devices for touch, perhaps the echo-like sounds of an empty room using surround sound headphones, a head mounted display that will allow the learner full immersion by blocking external sight interference, and perhaps even the smell of paint using some type of aroma technology. Incorporating these elements in VR will strongly enhance the experience which will in turn increase learning.

Activity Theory

With new technology there comes new theory towards the use of that emerging technology in learning. Activity theory serves as a good framework to understand the integration of new learning technology (Karakus, 2014). Much like constructivism, the principle of activity theory places responsibility of learning on the learner themselves. They must be actively engaged in the learning process (Van Lier, 2000). Unlike constructivism, or any other of the previously mentioned theories for that matter, Activity theory speaks to increased learner motivation and embracing a new technology. This focus would in turn, lesson the focus on the amount of time towards the student learning foundational knowledge. This theory is specific to human activity and then realized through goal-oriented actions within certain settings (Zhu & Mitchell, 2012). In addition, activity theory believes that learning cannot be separated from activity and the activity itself is mediated by learning tools (Said, et al., 2014). For example, research has found that learners have mixed motivations that are triggered and maintained through the use of various forms of technology (Jin & Zhu, 2010).

Activity theory could help researchers understand how people convert learning into action or activity (Barab, Barnett, Yamagata-Lynch, Squire, & Keating, 2002). VR serves as a tool for the activity system, in that it represents the tangible aspect of completing the activity and learner comprehension of how to accomplish the activity (Karakus, 2014). As this is a new theory there have not been many studies on the philosophy. Activity theory has been studied to: analyze the interaction of learner participation (Tocaimaza-Hatch, 2015), use task-based curriculum design (Campbell, MacPherson, & Sawkins, 2014), develop more insightful models of human behavior (Karanasios, et al., 2013), explore adult user activities and informal learning (Heo & Lee, 2013), and evaluate learning and development initiatives (Bourke, Mentis, & O'Neill, 2013).

Tocaimaza-Hatch's (2015) activity theory study viewed the orientation of students enrolled in a university course. The lens of the study indicated that activity theory is an application of sociocultural theory. The study analyzed student interaction and reflection during a collaborative activity while enrolled in a Spanish second language course. As ethnology, data collection included audio recordings, a questionnaire, and observation. The author concluded that using activity theory as the framework provided more insight to the learner's undisclosed needs, goals, and elements of the activity that either enhanced or inhibited performance. The results could have been very different if the activity that involved audio recordings were removed from the equation.

Campbell, MacPherson, and Sawkins (2014) conducted a case study that speaks directly to the use of activity theory during curriculum design process. The researchers considered activity theory to be more effective for curriculum design due to its organizing principle and focus on real-world learning experiences. The concept of activity theory has virtual or simulated activities on one end and real-world activities on the other end. Much like Tocaimaza-Hatch (2015), the researchers considered activity theory to be an application of sociocultural theory but indicated that it directed curriculum design due to connections made from the learning environment to the real-world. The researchers took it a step further by using Jonassen and Rohrer-Murphy's (1999) six-steps to activity theory:

- Clarify the purpose of the activity system.
- Analyze the context.
- Analyze the activity system.
- Analyze the activity structure.
- Analyze tools and mediators.
- Analyze activity system dynamics.

The study found that activity theory extends learner-centered practice which shifts the responsibility of learning from the instructor to the learner. This serves as a direct connection between activity theory and constructivism.

Karanasios et al. (2013) completed a case study of an individual's real-life experiences through *digital traces* using a foundation based on activity theory. Digital traces are user-generated content that users enter in the form of social media/Web 2.0 as blogs, discussion boards, comments, and personal videos (Karanasios, et al., 2013). The results of the study revealed that the use of technology allowed the researchers to understand complex human activity. Likewise, activity theory in VR-based training will aid in explaining human reactions to various activities when performed in a virtual environment.

Heo and Lee's (2013) used all six components of activity theory to describe the activity system: participants, tools, object(ive)s, outcome, community, rules, and division of labor. Their study explored activities and informal learning processes in blogs and social networking sites of adult users. The researchers indicated that activity theory was used as the framework for many technology-based learning projects. As a qualitative study with a case study approach, this study monitored and compared two educational websites. The participants were adult users of blogs and social networking sites and the tools were the actual blog and social networking sites. The activity was the voluntary use of the sites which served as an indication of end user intrinsic motivation, a critical component of activity theory. The outcomes were the users' engagement with the website activities and the assumptive knowledge obtained from completing the learning activity. The rules were represented by the webmaster of each respective site and the division of labor was represented by the various user roles established on each website. The findings indicated that activity theory could be used to expand understanding of complex educational implications.

Bourke, Mentis, and O'Neill (2013) analyzed a professional learning and development (PLD) program for educators using the cultural historical activity theory (CHAT). CHAT is premised on the philosophy that learning is social and mediated by artifacts, or technology (Bourke, Mentis, & O'Neill, 2013). Using a CHAT approach allowed the researchers to show points of program-specific tension between various different activity systems. The findings revealed that tension was concentrated at the community stage where teachers were required to practice the newly developed tool. The research indicated that learning, or understanding was not the student's challenge, but it was instead the action of applying what was learned that served as a challenge.

Virtual Reality

VR is the computer-generated simulation of a three-dimensional image or environment that interacts with a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (Miller R. , 2014). VR has a 48-year history beginning with Sutherland (1968) who created the first head-mounted display. While the actual cost of Sutherland’s head mounted display is unknown one can infer that it was very expensive. The work was supported in part by four different research entities: Advanced Research Projects Agency (ARPA) of the Department of Defense, Office of Naval Research, Bell Telephone Laboratories, and Harvard Computation Laboratory (Sutherland, 1968). Today’s Samsung Gear VR, VR head mounted displays can be purchased for $99 from popular mobile phone providers which give the user full immersion into a 360-degree virtual kingdom that is completely cut off from reality. In today’s technological society, it is no surprise that advances have reached the realm of VR. The use of this technology is finding a place in educational environments. Terms such as: virtual learning environments, virtual worlds, virtual tutee systems, augmented reality, and multi-user virtual environments are commonly used terms regarding educational environments.

Instructional Design

Instructional design is a systematic method used to: describe appropriate instruction, encourage learning, and apply educational descriptive and prescriptive theories (Smith & Ragan, 2005). Theory in general serves as the philosophical trigger used to design effective instruction. For example, anyone can design a lesson on how to tie a shoe, if they already know how to tie a shoe. However, the instructional value and amount of time it takes the student to learn is dependent on the instructional design of the lesson. What instructional strategies were used? What were the instructional materials or activities used to increase understanding? How do you know that the student has learned anything? Instructional design can answer these questions and more by using a systematic developmental process with evidence-based theories (Smith & Ragan, 2005).

Instructional personnel are educated on how to efficiently present information (Smith & Ragan, 2005), but what about instruction that does not have the benefit of an instructor? No matter what the medium of instruction, instructor, computer, video, or print, planning is critical (Smith & Ragan, 2005). Lessons are not planned without the benefit of initial instructional design to guide the actual instruction. The teacher, as an instructional professional, is often given a large inventory of professionally designed resources from which to select the most effective instructional strategy, material, and activities for their students (Smith & Ragan, 2005). Instructional design is strongly focused on developing learning tools for various settings from K-12 schools (Foshay, Villachica, & Stepich, 2014) to corporate and industrial learning environments. Instructional design becomes more critical when the adaptable medium, such as the teacher, is removed from the equation, as is the case with many technology-based learning solutions (Warren, Lee, & Najmi, 2014). It is for this reason that instructional designers must prescribe instruction that is based on proven research-based prescriptions.

Instructional design has several characteristics: learner centered, goal-oriented, meaningful performance, measurable outcomes, empirical, iterative, self-correcting, and team effort (Gustafson & Branch, 2007). The learner-centered characteristic implies that the instructional designer should be directly focused on the learner when designing the course (Gustafson & Branch, 2007). While that may be true, this characteristic focuses on the learner being made to feel the instruction is personalized or customized for them and speaks more to adaptive learning systems (Sims, 2009). The student must be motivated enough to learn and be an active participant in the process (Dewey, 1938). Without motivation, the learner will not initiate or continue the task of learning (Kim & Pekrun, 2014). Therefore, instructional design must stay in the forefront of instructional and learning theories in that educational endeavors must accommodate the changing landscape (Ashbaugh, 2013).

Instructional design must also be goal-oriented (Gustafson & Branch, 2007). Evaluation of learning is impossible without clearly defined objectives. The instructional designer identifies the learning objectives based on a complete analysis of the educational need. It is also important for the learner to be made aware of the objectives while learning (Gagne, 1977; Hunter, 1980). The instructional designer uses learning objectives to guide development of learning content (Loftus, Stavraky, & Urquhart, 2014). Learning objectives also serve as an indication of appropriate technology to accomplish the objective (Cook, et al., 2013).

Determining an instructional solution is based on upfront analysis that concludes instruction will in fact solve the problem or enhance the learning opportunity (Foshay, Villachica, & Stepich, 2014). However, “human performance technology (HPT), which is more focused on behavioral psychology to improve overall performance” is more in line with skills-based learning (Foshay, Villachica, & Stepich, 2014, p. 42). The ability to measure performance should equal the means by which success is determined (Foshay, Villachica, & Stepich, 2014). In particular, as it relates to skills-based instruction, the measurement really depends on the prescriptive information that guides the learner in skill acquisition (Tjiam, et al., 2012). It is at this point that the instructional designer must be sure the learning environment matches the setting where the skill is expected to be performed (Gustafson & Branch, 2007). The importance of this cannot be overemphasized in that learning must afford an opportunity to practice and apply newly learned skills in a realistic environment (Molenda & Pershing, 2008).

The instructional designer is required to make data-driven decisions throughout the entire instructional design process. This process is truly the source of “empirical, iterative and self-correcting” instructional design characteristics (Gustafson & Branch, 2007, pp. 10-16). The process begins by analyzing the data that indicated the knowledge or a performance gap being addressed and continues by analyzing the effectiveness of the said solution. Typically, the effectiveness of the solution is determined in the form of some type of assessment. The question regarding the validity and reliability of assessment data is at the heart of self-correction (Gustafson & Branch, 2007). Validity addresses if the assessment is measuring what was meant to be measured, while reliability means achieving the same results when repeating the same assessment (Murphy & Holme, 2014). The process of evaluation addresses the “self-correcting” characteristic as this data will identify the need for revisions (Gustafson & Branch, 2007).

Kirkpatrick's (1998) four levels of evaluation depend on data gathered through the use of research design as seen below.

- Level one: What was the learner's reaction or attitude to the learning experience?
- Level two: What did the learner learn?
- Level three: Did the learner's behavior change?
- Level four: What was the return on investment (Dick & Johnson, 2007)

Once the course has been evaluated the instructional design process is iterative in that analysis is re-visited to identify gaps in the existing educational solution.

Current Literature Review

This section includes a literature review of recent studies in instructional design and models, VR-based training, ETR, safety training, and VR-based safety training. While this review is not exhaustive, the studies detailed do provide foundational information which will enhance understanding of the individual topics.

Instructional Design and Models

The process of instructional design is based on a systematic model driven by complex educational contexts (Branch & Kopcha, 2014). Models serve to guide or organize investigations, such as the various instructional design models currently being used to encourage learning (Spector, 2014). The instructional designer's selection of a particular model is often based on one of three factors: employer, education, and timing. Oftentimes, organizations and institutions adopt a specific ISD model by which all employed instructional designers should follow when designing corporate training or academic courses (Obizoba, 2015). However, the practical application of these models is based on the educational and professional experiences of the instructional designer as well as the timeframe allowed for course development.

It is recommended that instructional designers use a taxonomy to select an appropriate model based on instructional context (Branch & Kopcha, 2014). Aside from being mandated to use a specific model established by organizational requirements, designers are more prone to use their most comfortable model. The most common used model in the business environment is based on five core components: analysis, design, development, implementation, and evaluation (ADDIE) (Branch & Kopcha, 2014; Chevalier, 2011; Lawson & Lockee, 2014). The fact that ADDIE contains foundational elements of all instructional design models implies that it could be considered more concept than model (Branch & Kopcha, 2014).

During the analysis phase of the ADDIE model, the instructional designer will learn as much as possible about the training topic (Smith & Ragan, 2005). The instructional designer will also determine the most appropriate means by which to train or teach the subject matter (Smith & Ragan, 2005). It is also at this point that the instructional designer will research best practices that identify appropriate technology as an effective instructional medium for the educational solution (Smith & Ragan, 2005).

During the design phase the instructional designer will plan the appropriate organizational and instructional strategies that will be used during instruction (Smith & Ragan, 2005). This point is also when the instructional designer investigates suitable instructional technology that will align with the appropriate instructional strategy to enhance overall learning. The design phase represents the canvas on which the instructional designer draws the conceptual aspect of how the student will learn the content, hence the “designer” label. To aid in design, emerging technology provides unique and creative ways for instructional designers to engage and motivate the learner (MacDonald & Ahern, 2015).

During the development phase the instructional designer develops the actual training by producing all required training material(s) and system(s) towards learning (Smith & Ragan, 2005). Development is also when the designer performs thorough research of best practices towards applying the appropriate lesson-specific technology. In addition, this is the stage where the instructional designer creates the actual learning objects/ activities of the course. Learning objects are micro-courses that can be combined with other micro-courses in order form a complete course (Horton, 2006).

Implementation involves deployment of the actual training program to learners (Smith & Ragan, 2005). As it relates to VR, it is during this stage that the designer would evaluate functionality of the educational technology components. Evaluation involves analyzing the effectiveness, or ineffectiveness, of training (Smith & Ragan, 2005). Evaluation requires the designer to research and implement evaluative models specifically geared towards technology use, or more specifically towards VR as a medium for learning. This process involves more than simply evaluating the training materials but also evaluating the use of the technology and the ability to enhance learning of the specific content.

As an emerging technology VR adds an additional layer of complexity to instructional design. While VR can be deployed on a standard personal computer, there is likely more to be gained from a fully immersive solution. Interaction within a three-dimensional environment requires specific instructional design that exploits technology to positively aid learning. Chen and Teh’s (2013) study determined that there are five principles for designing instruction using VR as a medium.

- Objectives: Identify the type of learning to take place in addition to the actual learning objective.
- Integrative goals: Integrate objectives with purposeful activity.
- Scenario/problem: Identify a learning activity scenario to include constructivist foundation, context, representation in the VR environment and VR manipulation requirements.
- Support Tools: Consider constructivist-based learning by including various cognitive tools.
- Instructional activities: Provide learning activity to support constructivist learning.

These principles should assist the instructional designer when designing VR-based training.

There are a variety of instructional design models to guide the instructional designer. The ASSURE model is based on: analyzing learners, stating objectives, selecting methods, media and materials, utilizing media and materials, requiring learner participation, and evaluation and revision (Smaldino, Lowther, & Russell, 2012). The

Dick and Carey Model is based on: identifying instructional goals, instructional analysis, entry behavior and learner characteristics, performance objectives, criterion-referenced test items, instructional strategy, instructional materials, and formative/summative evaluation (Dick, Carry, & Carry, 2015). Branch and Kopcha (2014) assume, despite the various ISD models currently in use today, that all models include five major activities: analysis, design, development, implementation, and evaluation. Table 1 provides a compare and contrast between these models.

Table 1

Instructional Design Models

ADDIE	**ASSURE**	**DICK AND CAREY**
Analysis	Analyze Learners	Instructional Goals Instructional Analysis Entry Behavior and Learner Characteristics
Design	State Objectives Select, modify, design methods, media, & materials	Performance Objectives Criterion-Referenced Test Items Instructional Strategy
Develop	Utilize methods, media and materials	Instructional materials
Implementation	Require learner participation	N/A
Evaluation	Evaluate and revise	Formative evaluation Summative evaluation

As evidenced in the table, all three models ADDIE, ASSURE, Dick and Carey, are based on the five major principles assumed by Branch and Kopcha (2014).

Research on Virtual Reality-Based Training

Based on a search of Walden University's online library, there are multiple recent VR studies involving the medical industry (Choi, He, Chiang, & Deng, 2015; Farra, Bric, Connolly, Kastenmeier, Goldblatt, & Gould, 2014; Gonsalves, Campbell, Jensen, & Straker, 2015; Miller, &Hodgson, 2015; Levin, Standen et al., 2015; Negu, & Matu, 2015; Sava, &David, 2015; Weiss & Keshner, 2015,). However, there are fewer recent VR studies involving computer-assisted instruction (Loukas, Rouseas, & Georgiou, 2013; Saleh et al., 2013; von Websky, et al., 2013), and even fewer VR studies involving training (Amjad et al., 2015; Sinitsky, Fernando, & Berlingieri, 2012), lesser still involving actual learning (Lin & Yu-Ju, 2015; Kober et al., 2013), and only one involving the use of VR technology in a construction environment (Jin & Nakayama, 2013). The medical industry's use of VR provides a means by which to allow experiential learning as practical training.

Standen et al. (2015) conducted a qualitative study to investigate the effectiveness of VR towards increasing patient adherence to home-based rehabilitation. The VR system translated a hand, finger, and thumb movement game. Participants of the study were 17 recovering stroke patients who were asked to use a VR system three times a day for no more than 20 minutes at a time. After an 8-week period, participants were interviewed to record barriers towards completing the VR game. The results revealed a lack of technology familiarity and other commitments as primary barriers to playing the game. However, the participants did report that the system was flexible, and they were highly motivated to use it as an intervention. The instructional design best practice from this study indicated that VR-based training should include specifics that acclimates users with the technology to improve familiarity.

Gonsalves et al. (2015) conducted a mixed-methods study to examine the motor patterns of children with developmental coordination disorder (DCD) by comparing them with typical development (TD) children when using an active VR game (AVG). This study involved 21 children with DCD and TD who were matched by age and sex. The AVG was a table tennis match between one DCD child and a same age/sex TD child. The AVG system was programmed to record the motions of both players and determine differences if any existed. The results revealed that children with DCD used slower hand path speed (backhand) but greater wrist extension (forehand) and elbow flexion (forehand) compared to children with TD. This study was able to identify the strength and weakness of a motor skill in children with DCD, which is an indication that VR safety training could identify areas of trainee weakness for further learner development. Therefore, in addition to including a technology familiarization lesson, a VR-based training course should focus not only identifying learner weakness but also provide directions to further develop learner skill.

Choi et al. (2015) conducted a quantitative study that involved the use of a VR simulation for the medical procedure of nasogastric tube insertion. This procedure involved inserting a plastic tube through the patient's nostril to the stomach in an effort to either feed the patient or drain unhealthy by-products (Choi, He, Chiang, & Deng, 2015). Current training for this procedure included practicing on rubber mannequins or human beings. The goal of VR in this study was to enhance the current training by using a more realistic application with less safety risk. The VR training system was programmed to determine and return performance data based on the user's actions. Nursing professionals evaluated the virtual realism of the training system through surveys, questionnaires, and structured interviews (Choi, He, Chiang, & Deng, 2015). Findings of this study indicated a positive evaluation of the VR system and that the computer-generated forces were realistic to actual nasogastric tube placement. This study indicated that VR-based safety training may not only increase student motivation but will serve in developing the necessary skill to complete certain tasks, much like the study conducted by Gonsalves et al. (2015).

Negu et al. (2015) performed a meta-analysis on 14 studies to investigate the relationship between classical paper-and-pencil/computerized testing measures and VR-based measures in order to determine the convergent validity of a neuropsychological assessment. Using a correlation coefficient *r* analysis, the results showed a positive significant medium correlation between VR measures and classical or computerized measures which demonstrated a moderate to good degree of association. The conclusion was that there is evidence in favor of the validity of VR-based measures, which adds validation to studies conducted by Gonsalves et al. (2015) and Choi et al. (2015). This study provides measures by which instructional designers could evaluate the effectiveness of VR-based training.

Amjad et al. (2015) conducted a quantitative study that assessed the predictive validity of a medical VR simulator for a residency program. Twelve urology residents attended weekly training sessions on the simulator and were required to complete three tasks over a three year and six-month period. Their performance was assessed on a monthly basis and compared with the previous month's performance using a correlative test. The results indicated that the VR simulator demonstrated poor predictive validity, but the researchers believed that the small number of participants may have skewed the results. However, this is a clear indication that VR may not always be the most effective training solution in all cases. This study contributes to the body of knowledge where instructional designers must consider the most appropriate technology to use during the instructional design process.

Farra, Miller, and Hodgson (2015) tested the Ace Star Model framework by implementing a VR simulation for healthcare professionals. The Ace Star Model is a model that is used to put evidence-based details into operational practice. This research was based on the five stages of converting knowledge to practice: knowledge discovery, evidence summary statement, practice guidelines, strategy to practice integration, and outcome evaluation. The findings indicated that the Ace Star Model is an adequate and valuable model to translate VR system teaching to improve practical disaster training to healthcare professionals. This model may serve as an instructional design best practice when designing VR-based training.

Bric et al. (2014) conducted a study to develop robotic surgical skills by developing and validating a robotic training curriculum that used a VR simulator. The researchers hypothesized that newly trained surgeons achieved the same proficiency as experienced surgeons which indicated improved performance. Twenty-five medical students were recruited and required to complete specific laparoscopic surgical tasks which were scored before, during, and after being placed on the VR system. Once moved to the VR system the students were required to complete five specific tasks which were assessed at the conclusion of the training. The results revealed that all participants reached proficiency on all VR tasks which indicated that there was significant performance improvement on the robotic tasks. The methodology used in this study may speak to evaluative instructional design components when designing VR-based training. A best practice should include testing before, during, and after the training. Research regarding VR studies in the medical industry also includes studies specific to computer-assisted instruction.

Loukas, Rouseas, and Georgiou (2013) investigated the role of hand motion in the performance of a laparoscopic procedure using a VR simulator. The participants involved two groups: one group of experienced residents and another group composed of beginner residents. The hand motions during the procedure were evaluated using multivariate autoregressive (MAR) models. The results revealed that the experienced group outperformed the beginner group by performing more coordinated gestures. The researchers concluded that hand motion analysis is a suitable assessment approach to be used in VR simulators. The results of this study are in contrast to Bric et al. (2014) in that it showed that the use of VR technology on newly trained surgeons achieved the same proficiency as experienced surgeons.

Saleh et al. (2013) conducted a study to evaluate the performance of new ophthalmic trainees using a VR simulator. Eighteen participants completed and were scored on three attempts at five tasks specific to eye surgery using the VR simulator. The results revealed high significance between the first and second attempts but no significant difference between the second and third attempt. The study also indicated that performance varies significantly depending on the complexity of the task. The researchers recommend, as a result of this study, that VR simulators monitor performance instead of evaluating performance. This recommendation is in direct contrast to Gonsalves et al. (2015), Choi et al. (2015) and Negu et al. (2015).

Von Websky et al. (2013) conducted a study that tested self-controlled basic VR training against peer-group-derived benchmark basic VR training. The training involved developing laparoscopic skills from a randomized group of novice laparoscopic medical residents. The groups were split to include 34 residents as the self-controlled group and 34 residents as the peer-group-derived benchmark group. Peer-group-derived benchmark group training involves repeating the task until a pre-determined benchmark is reached. After basic training, both groups performed 60 VR laparoscopic procedures where their performance was analyzed. The results revealed that basic VR laparoscopic training is more effective with the peer-group-derived benchmark methodology than the self-controlled method. The results of this study indicate that peer-group-derived benchmarking could serve as a best practice when designing VR-based training.

Sinitsky, Fernando, and Berlingieri (2012) performed an evaluation of the usefulness of practicing psychomotor skills using a VR laparoscopic surgical simulator. The researchers provided insight on how an effective training curriculum might be developed to improve the use of training with the technology. Their findings suggest that time and motion assessment in VR does show construct validity and should include distributed practice over a massed practice with a certain level of supervision. This research indicates that VR-based training should include sequenced practice sessions which should be equally disbursed throughout the training.

Educational Technology Research

Educational technology studied in this research project is a hybrid designed project using EDR, also known as design-based research (DBR) (Barab & Squire, 2004), and DDR. Unlike more traditional philosophical and experimental methods there is current evidence of design-based research diversity specific to educational technology (Elen & Bishop, 2014). The official methodology of many studies is that of a qualitative Delphi technique which will be detailed in Chapter 3 of this dissertation. However, it would be remiss to ignore the heavy design-based impact. Bereiter (2002) said, “Design research is not defined by its methods but by the goals of those who pursue it” (p.321). As educational technology studies, EDR and DDR designs address two separate aspects of educational research. EDR is focused on the development of educational solutions, while DDR is specific to the field of instructional design (McKenney & Reeves, 2014). Based on descriptions from McKenny and Reeves (2004), a Venn diagram between EDR and DDR would resemble Figure 1.

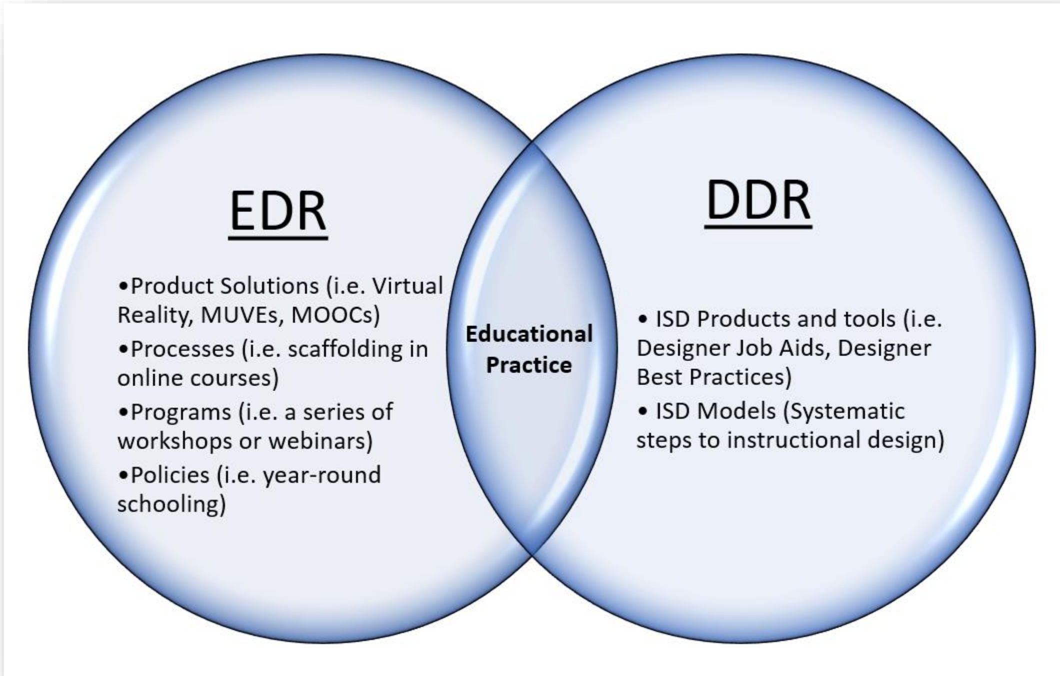

Figure 1. EDR/DDR Venn diagram.

VR as an educational solution will be studied from an EDR perspective, while studying the design aspect of developing VR-based safety training is specific to the DDR perspective.

Educational Design Research

EDR refers to the study of educational interventions, or the actual solution to an educational problem that yields new knowledge which informs the work of others (McKenney & Reeves, 2014). The goal of EDR is to improve education research specific to educational communications and technology (Barab & Squire, 2004; Burkhardt, 2009; Reeves, 2011; Schoenfeld, 2009; van den Akker et al., 2006). In the case of VR, an EDR approach would simply study the technology as an educational intervention to gain new knowledge (design best practices) that will inform the work of instructional designers.

There are several characteristics of EDR: pragmatic, grounded, interventionist, iterative, collaborative, adaptive and theory-oriented (McKenney & Reeves, 2014). Mckenney and Reeves (2012) indicated that EDR is pragmatic in that it is focused on practical problems and solutions and grounded by theory as a guide. They also indicated that EDR is interventionist because it seeks to change the learning outcome and iterative because it practices continuous improvement by testing and modifying the intervention for a better outcome. EDR is collaborative because it is research that takes place in the original setting where researchers and practitioners must work together (McKenney & Reeves, 2014). EDR is adaptive because of the changing landscape of the intervention as it is modified during iteration(s) (McKenney & Reeves, 2014). Lastly, EDR is theory-oriented as the actual intervention design and development is evidence-based (McKenney & Reeves, 2014).

The process of EDR consists of four phases: analysis, development, iteration, and reflection (Herrington, McKenney, Reeves, & Oliver, 2007). However, more recent variations of the process combine the phases as analysis/exploration, design/construction, and evaluation/reflections resulting in a three-phase process (McKenney & Reeves, 2014). All three of these phases would be re-iterated as the identified intervention is tested. The educational outcome of EDR is knowledge that guides educational practice. EDR should be used to: research the use of new teaching aids, use results to improve practice, build knowledge on intervention design, and develop human capital (Stemberger & Cencic, 2014).

EDR has provided multiple revelations as it relates to educational solutions, processes, programs, and policies. O'Rourke (2013) found that games-based learning, as an intervention, not only enhances learning but also teaching outcomes. Another component of EDR is the iterative approach towards verifying the effectiveness of the educational solution. For example, Chin and Tsuei (2014) used two iterations in testing digital game-based learning (DGBL) for children with chronic illnesses. The first iteration indicated that more learning content was needed in the DGBL and that student motivation should be increased. After modifying the DGBL using a multi-modal (beginner/advanced) design, the second iteration significantly increased student motivation and social interaction. The design research outcome from this study indicated that multi-modal DGBL increases motivation, enhances social interactivity and should be used when designing DGBL educational intervention.

EDR is not without its critics as there is a claim in the field that it stops short of recommending appropriate technology for certain learning experiences (Dede, 2004). Other concerns are related to the low focus on theory which speaks to the inability of EDR to further theory development (diSessa & Cobb, 2004). There is also a concern regarding the researcher/practitioner relationship commonly found in EDR which questions validity due to the possibility of inserting bias into the results (Barab & Squire, 2004). Despite the criticism, EDR is becoming more globally accepted (Anderson & Shattuck, 2012). A literature search using the Education and Information Technology

Library database returned 17,146 articles on *Design-Based Research* as a keyword search, and 22,703 articles with an *Education Design Research* keyword search. In addition, at least one of the previously cited critics have since determined EDR as an effective approach in studying instructor training program intervention (Dede, Ketelhut, Whitehouse, Breit, & McCloskey, 2009).

Design and Development Research

EDR and DDR designs speak to two separate aspects of educational research. EDR is focused on the development of educational solutions, while DDR is specific to the field of instructional design (McKenney & Reeves, 2014). DDR is specific solely to developing new knowledge and validating current practices in the field of instructional design (Richey & Klein, 2014). The definition of DDR is "the systematic study of design, development, and evaluation processes with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development" (Richey & Klein, 2007, p. 1).

The five core components, or phases, of the instructional design process are analysis, design, development, implementation, and evaluation. Characteristics of DDR projects range from the study of any or all of the five core components of the instructional design process, to the study of practicing project-specific instructional design for any or all of the five core components (Richey & Klein, 2014). The goal of DDR is to: produce knowledge, better understand the field of instructional design, and better predict learning outcomes (Richey & Klein, 2014). There are two types of DDR, research on instructional design products and tools, and research on instructional design models (Richey & Klein, 2014). Research on instructional design products and tools is specific to the design and development process and/or identifying useful tools to improve the process. Research on instructional design models is focused on developing or modifying existing models that guide the overall instructional design process. The following two sections provide study examples for each type of DDR.

Research on Products and Tools

Yuviler-Gavish et al. (2014) conducted a study to test the hypothesis that VR-based training efficiency could be improved by inserting partly observational learning techniques for procedural tasks. The researchers relied heavily on the enactive approach theory and the embodied cognition theory. The enactive approach theory addresses the physical actions required during training, while embodied cognition theory focuses on cognitive and physical processes directly influencing each other to enhance learning (Yviler-Gavish, Rodriguez, Gutierrez, Sanchez, & Casado, 2014). The study used a 75-step Lego assembly task to test their hypothesis. College undergraduate students experienced two VR-based training systems, one system that was fully active and the other system was partly observational.

The active VR-based training system involved the participant actively identifying the correct Lego brick and placing it in the correct Lego model. The partly observational VR-based training system required the participant to only identify the correct Lego brick and then observe the system placing it into the correct Lego model. The active system required two active steps while the partly observational system required one active step and one observational step, in essence making it a partly observational exercise. The results indicated that while both models resulted in similar performance time, final error and corrected error conditions, the partly observational model required less training time which made it more efficient. The results of this study indicate that designing VR can be beneficial with observational elements designed into the training (Yviler-Gavish, Rodriguez, Gutierrez, Sanchez, & Casado, 2014).

Research on Instructional Design Models

Chen and Toh's (2005) conducted a qualitative case study focused on a new constructivist instructional design model to develop a VR-based learning environment. The authors defined VR as either immersive (helmet or cave environment) or non-immersive (desktop PC or other monitor-based technology) environment. The instructional design model served as the plan the instructional designer used to develop instruction (Chen & Toh, 2005). The researchers selected what is known as the R2D2 model which focuses on: recursive, reflective (R2), design, and development (D2). The course developed in the VR learning environment was intended to simulate real world road scenarios to improve performance of novice car drivers (Chen & Toh, 2005). The participants were novice car drivers and the collected data and analysis were based on interviews of the driving license unit at the Penang Road Transport Department. The researchers concluded that designing a course that includes VR learning using this model proved to be useful in guiding the instructional design process for VR.

Chuah, Chen, and Teh (2011) conducted a quantitative study to identify a link between learner emotions and design of desktop VR-based training using Kansei engineering concepts. Kansei engineering is an evaluation methodology used to correlate emotion with design elements and has been used with product design, website design, and textile/fashion design (Chuah, Chen, & Teh, 2011). The methodology in the study was used to manipulate design elements that were systematically removed from the scenario. The course design elements in this study included: coaching or feedback messages, navigational aids, virtual agents or models, reduced 3D quality, hinting, audio narration, task instruction instead of storytelling, removed objectives, ignored multimedia designed principles (mixed font size, color, and formatting), and retaining all design elements resulting in ten design element scenarios of the same scenario. The participants were 90 randomly selected secondary school students. The students rated their feelings towards the developed courseware using a checklist containing 30 emotional words. Using Partial Least Squares analysis, the results of this study showed that using Kansei engineering concepts are effective in evaluating similar projects. The Kensai engineering concept could possibly serve as an evaluative tool for VR-based training. Research on evaluative methods for VR safety training in general was very scarce.

Research on Safety Training

The Australian National Occupational Health and Safety Strategy conducted a study that showed that its policy changes contributed to increased organizational safety training, as well as encouraged inclusion in university courses (Bahn & Barratt-Pugh, 2014a). Bahn and Barratt-Pugh (2014b) conducted an Australian study which found that there were less work-related injuries when construction-induction, or safety orientation, training was implemented. Another Australian study investigated the impact of supervisors on workplace safety (Bahn, 2013). Sunindijo (2015) conducted a study to identify barriers that limit safety improvement by small organizations, as well as to identify interventions to counteract the identified barriers. The following few paragraphs will detail these studies as well as present instructional design considerations that must be reflected when developing safety training.

As previously mentioned, Bahn and Barratt-Pugh (2014a) conducted a study to determine the impact of Australian governmental legislation on safety training design, delivery and outcomes. This study captured perceptions of occupational health and safety training field practitioners who were responsible for training. National organizations were required to incorporate regional specific safety concerns into regionally delivered safety training. To complicate matters more, all vocational training was required to be developed based on a national training regulator called the Australian Quality Training Framework (AQTF) and then delivered by registered training organizations (RTO) (Bahn & Barratt-Pugh, 2014a). RTOs were required to deliver workplace training regardless of the training environment or design: classroom, workshop, simulation (Bahn & Barratt-Pugh, 2014a), or even VR. Safety training was simply too expensive for organizations to implement and represented a failure in instructional design due to cumbersome legislation.

Bah and Barratt-Pugh's (2014a) study sought to locate evidence within governmental reports that training design, delivery, and evaluation patterns regarding the what and why changes were happening to Australian safety training. This study used participant interviews which encouraged reflection on safety training within the past decade in relation to Australian legislation. The study involved administrative personnel from four registered training organizations (RTO) and eleven other varied organizations ranging from regulatory to academic. Using text analysis from transcripts, the findings revealed a high level of safety training course design as a result of revised legislation which resulted in higher training costs (Bahn & Barratt-Pugh, 2014a). In addition, many participants felt that RTOs were more focused on increasing their revenue by designing courses that required longer delivery times which also contributed to high training costs. This study demonstrated the importance of designing safety training based on current and regional legislation. In addition, training should be designed for efficient delivery to decrease the overall cost of attendance.

Bahn and Barratt-Pugh (2014b) conducted a two-phased study to evaluate the impact of government training programs on commercial construction and regional housing and civil construction businesses (Bahn & Barratt-Pugh, 2014b). Bahn and Barratt-Pugh (2014b) argued in this study that evidence of a link between safety training and safety culture improvement was limited. Phase one of the study consisted of a 10-question questionnaire which was sent to 669 chief executive officers (CEOs) and supervisors in the construction industry (Bahn & Barratt-Pugh, 2014b). Phase two of the study included the same phase one questionnaire sent to 820 CEOs and supervisors in the housing and civil construction industry. After low questionnaire completion rates, on-site and telephone interviews were conducted to acquire the necessary information. Much like the researchers' previous study (2014a), data analysis was a side-by-side comparison of secondary data from government reports with the data received from the CEOs and supervisors.

The findings of Bahn & Barratt-Pugh's (2014b) study revealed a decrease in work-related injuries for the construction industry as well as in other industries. Findings indicated that safety training is not only necessary but critical to decreasing the number of work-related injuries. In addition, as a result of fewer work-related injuries, organizations were more productive which increased the revenue and attracted more workers to the industry (Bahn & Barratt-Pugh, 2014b). VR-based safety training will improve these statistics in that it places the user in a virtual representation of the construction environment. This study indicates the importance of evaluating the effectiveness of training in order to determine if positive change is the result.

Another Australian study investigated the impact of supervisors on workplace safety using a narrative format (Bahn, 2013). The focus of this study was to identify the need for additional safety training regarding supervisors. In addition, this study also researched supervisor impact on the safety culture developed within individual teams. The study used a grounded-theory approach for phase one and a case-study approach for phase two. Phase one included 28 managers in the civil construction industry while phase two included managers of an underground mining organization. Analysis involved a review of narratives received from the participants for themes and patterns. The findings revealed that the safety culture shared by employees on the worksite was greatly impacted by the safety concerns of the supervisor. This study also confirmed that there is a significant gap between training support and what is expected of supervisors. The results of this study indicate that instructional design for safety training should involve separate training considerations for the supervisor's role to support a culture of safety on the worksite.

Sunindijo (2015) conducted a study to identify barriers that limit safety improvement by small organizations, as well as to identify interventions that counteract the identified barriers. Small organizational barriers were identified as: client demands, negative perceptions towards safety, lack of safety knowledge and safety training, and poor safety culture (Sunindijo, 2015). Strategies to improve small organization safety performance were found to be proactive client safety roles, free safety training, and safety regulation enforcement (Sunindijo, 2015). This study used a questionnaire that was emailed to 967 construction companies. Gender was the only demographic information collected from the responding companies. Sixty-eight responses were received with 17% from women and 82% from men. A sample t-test was conducted on the responses received to rank them from the highest to the lowest. The top three barriers were: the subcontractor practice of awarding the lowest bid, clients who were more concerned with operational objectives than safety, and fierce industrial competition. Study respondents also indicated the top three intervention strategies as: safety should be a client project success factor, safety should also be considered criteria in tendering, and the government should subsidize safety training for small organizations. Sunindijo concluded that clients of small organizations, the Australian government, and large organizations must support efforts to improve safety within small organizations in order to improve overall safety within the construction industry. This study demonstrated that external factors must be considered when designing safety training.

Research on Virtual Reality-Based Safety Training

Safety training has a long history but emerging technology such as VR adds another level of immersion. In addition, the VR environment serves as an experiential learning opportunity without the associative risks that would be involved within the real environment. A review of literature did yield a small number of studies related to safety training and VR. Nakayama and Jin (2015) conducted research that indicated a 3D virtual safety training environment was effective safety training in a simulated environment but without the risk of a live environment. Another study tested safety training in a virtual construction site to determine feasibility and efficacy towards learning and recall (Sacks, Perlman, & Barak, 2013). Clevenger, Del Puerto, and Glick (2015) developed an interactive building information modeling (BIM) -enabled safety training to test in the classroom environment.

Nakayama and Jin (2015) conducted a pilot project to determine the efficacy of a 3D virtual environment safety training when compared to safety training conducted in a live environment. The participants used in this study were 89 university student volunteers. Students were randomly selected to attend one of three course delivery methods: lecture only, lecture plus physical laboratory environment, and lecture plus 3D virtual environment. After completing the respective course, students were assessed on the hazards and safety measures associated with operating a pedestal grinder by completing a test.

Testing results for Nakayama and Jin's (2015) study revealed that students learned more in the 3D virtual environment than the students did in the lecture only group, and just as much when compared to students in the lecture/physical lab environment. The primary difference between the 3D virtual environment and the physical lab environment was safety. There was no risk involved with learning in the 3D virtual environment, but the physical lab environment involved the same level of risk as using the pedestal grinder at the worksite. The study addressed the need for occupational safety and the challenges experienced by organizations when opting to use online safety training due to cost concerns. Nakayama and Jin made the case that adult learners learn better when involved with hands-on activities. The pilot study focused on the use of a virtual pedestal grinder safety training course.

Sack, Perlman, and Barak‘s (2013) study tested safety training in a virtual construction site to determine feasibility and effectivity towards learning and recall. The virtual construction site was presented on a 3D immersive VR power-wall. The researchers pointed out that the use of immersive virtual environments in the construction industry had not been rigorously tested, and also determined that the use of safety training scenarios to test the virtual environment would be more beneficial (Sacks, Perlman, & Barak, 2013).

The method used in Sack, Perlman, and Barak's (2013) study was an experimental design which compared conventional safety training with VR safety training. There were three groups of participants totaling 71. The experiment was a 5-step process: pre-test, safety training, post-test, experience questionnaire, and a recall test. Each group contained two subgroups with one group receiving traditional training and the other receiving training with the 3D power-wall virtual environment. An identical pre-and post-test was administered to participants, as well as the same test administered again one month later. After determining the difference between the before and after test score, the difference was evaluated using T-tests (Sacks, Perlman, & Barak, 2013). The researchers found that VR training was more effective in two out of three scenarios. In addition, VR training was more effective in maintaining attention and concentration as well as knowledge retention.

Clevenger, Del Puerto, and Glick (2015) developed an interactive building information modeling (BIM) -enabled safety training to test in the classroom. BIM provides a 3D visualization model that enhances the student's ability to conceptualize construction concepts (Clevenger, Del Puerto, & Glick, 2015). The purpose of this study was to test the efficacy of BIM-enabled training as it relates to safety procedure communication, hazard identification, and worksite conditions. The researchers focused the study on construction scaffolding safety because of the large number of fatalities associated with this equipment. The participants were 43 undergraduate students who were enrolled in the Construction Safety course at Colorado State University.

Clevenger, Del Puerto, and Glick's (2015) study used a mixed method approach with a four-step process. The first and last steps involved taking a pre-test with seven questions and post-test survey with 4 questions. The other two steps included two parts of the safety training module with the second part serving as a post-test assessment. Part one of the training used video animations, drag and drop simulation, and user guided placement. The collection of data followed a pre-test, intervention, post-test model and was used to measure the impact of the BIM-enabled module. Using pre- and post-test scores from the BIM-enabled group and a traditional teaching method group, the researchers performed comparative analysis. Findings indicated that the BIM-enabled method has the potential to be more effective than that of traditional teaching (Clevenger, Del Puerto, & Glick, 2015).

Despite the small number of VR-based safety training research, there have been a couple of recent studies that tested the actual components of VR. A review of literature yielded studies that are related to evaluating VR environments in order to determine the level of effectiveness. Hsu et al. (2016) constructed a "Vehicle VR Test System" (p. 1478) to evaluate a vehicle VR driving simulation. Serrano, Baños, and Botella (2016) tested the efficacy of a VR mood-induction procedure for inducing relaxation. Neguţ et al. (2016) conducted a meta-analysis to research VR assessment tools as compared to traditional neuropsychological assessment methods.

Hsu et al. (2016) conducted a study on vehicle driving simulation systems. Their primary objective was to develop a simulation for beginning drivers to practice their newly acquired driving skills. The simulation included environmental elements of driving such as incorporating various types of roads, time of day, types of weather, and the flow of traffic. While in the simulator, the driver's behavior was evaluated to determine the actual visual effects in order to reduce error rates. The simulation proved to be an effective means by which to reduce external factors when testing new drivers and by also allowing repeated practical experience.

Serrano, Baños, and Botella (2016) tested the efficacy of VR mood-induction procedures for inducing relaxation. The researchers tested 136 randomly selected participants who were assigned to an experimental condition for testing. The participants included 84 women and 52 men ranging in age 18-63. The first experimental condition was VR only (VR), the second condition added smell (VR+Smell), the third condition was VR and touch (VR+Touch), and the fourth condition was VR with touch and smell (VR+touch&smell). The researchers used a between-groups factorial study with pre- and post-tests. Using Analysis of Variance (ANOVA), the results did not indicate any significant difference based on the virtual strategies used in the study. However, Serrano et al. recommended that further research was needed to confirm results by using other VR environments.

Neguţ et al. (2016) conducted a meta-analysis to research VR assessment tools compared to traditional neuropsychological assessment methods. The researchers reviewed thirteen studies which assessed the cognitive process using VR and traditional assessment tools. Study selection criteria was based on assessing any VR cognitive process, using adequate data to compute and effective sample size, and was an English-based publication. The meta-analysis of the selected studies indicated that VR has a higher level of complexity and is more difficult which means that it requires additional cognitive resources. VR assessment has the potential to require more thinking which means more effective learning.

Safety training through VR does have a place in today's industrial environment, but there are multiple gaps in research. Continued study is needed of not only VR as a learning technology but also VR as a realistic means by which learners can demonstrate life-saving lessons learned. The previously mentioned studies serve as a good start, but more research is needed on VR as a learning technology and its benefits towards safety training.

Summary and Conclusion

The subsections of this literature review included the: literature search strategy, theoretical foundation, conceptual framework, literature review, and conclusion. Each section focused on the themes of instructional design, VR, and safety training. A review of literature indicates that VR-based training can simulate a real-world environment with risk-free scenario-based safety concerns (Backus et al., 2010).

The introduction section of this literature review indicated that instructional design is strongly focused on developing learning tools for various settings from K-12 schools (Foshay, Villachica, & Stepich, 2014) to corporate training environments. Instructional design becomes more critical when the adaptable medium, such as the teacher, is removed from the equation, as with technology-based learning (Warren, Lee, & Najmi, 2014). It is for this reason that instructional designers must prescribe instruction that is evidence-based.

The conceptual framework section addressed the theoretical and conceptual nature of instructional design. The theoretical framework addressed three primary groups of learning theory: behaviorism, cognitivism, and constructivism (Ertmer & Newby, 1993). Behaviorism as a learning theory is focused on observable behavior of the learner; cognitivism as a learning theory is focused on psychological conditions as it relates to learning (Januszewski & Molenda, 2008); constructivism as a learning theory is focused on the learner building their own knowledge (von Glasersfeld, 1995), and experiential learning which is a theoretical subset of constructivism where the learner constructs their own knowledge through actual experience. While cognitivism is an important learning theory, VR is mostly focused on behaviorism, constructivism, and experiential learning theories as they are more closely tied to the activities involved with VR in general.

The conceptual framework explained foundational details of VR and instructional design. VR is a computer-generated simulation of a three-dimensional image or environment that interacts within a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors. Instructional design is a systematic method used to describe appropriate instruction, encourage learning, and the practical application of educational descriptive and prescriptive theories (Smith & Ragan, 2005).

This literature review section focused on recent literature on the topics of VR, instructional design, EDR, DDR, safety training, and safety training using VR. Chapter 3 will not only provide details on the selected research design; the Delphi Method, but will also provide specific information on how best instructional design practices will be identified.

Chapter 3: Research Method

In this chapter I explain the specific research design for this study and the rationale for selecting a qualitative research design using a modified Delphi technique approach. I provide a brief description of qualitative research followed by an introduction to the Delphi technique and why it was slightly modified for this study. In addition to explaining my role as the researcher, I provide a detailed explanation regarding the definition of instructional design subject matter experts. This definition was critical towards identifying the logic used for selecting the participants of this study. Finally, I discuss issues regarding research trustworthiness to address concerns regarding this study's creditability, transferability, dependability, and confirmability.

The purpose of this qualitative study was to identify best practices that could be used by instructional designers when designing VR-based safety training in order to improve safety competence and practice in the industrial environment. In addition, I hoped that the results of this study would provide instructional designers with a better understanding of VR technology as a learning intervention.

Research Design and Rationale

This study included three central questions specific to instructional design elements when designing full immersion VR safety training.

RQ1: What design elements do expert instructional designers believe should be considered when designing full immersion VR safety training?

RQ2: What challenges do expert instructional designers believe will be experienced when designing full immersion VR as a medium for safety training?

RQ3: Which instructional design model do expert instructional designers believe would be most beneficial when designing full immersion VR safety training?

In addition to the research questions, I also answered the following subquestion based on participant responses.

SQ: Which learning and instructional design theories are reflected in best practices identified by expert instructional designers when designing full immersion VR-based safety training?

This research was a qualitative study using a modified Delphi method of inquiry with a panel of expert instructional designers. I considered a case study methodology as it documents programs and activities with the researcher immersed in the event (Creswell, 2014). I decided against case study in that it would have been difficult to rule out inadvertent bias from a validity perspective. I also considered a phenomenologicla approach, which involves the study of a phenomenon experienced by group of people, which for this study were instructinal designers (Creswell, 2014). I decided against phenomenology in that the results would be mostly narrative-based and would not provide instructional designers with clearly defined best practices.

I selected the modified Delphi method because of the limited amount of study regarding the practice of instructional design (Tracey & Boling, 2014). This study was a qualitative Delphi method of inquiry into the design elements used to develop VR-based safety training by a panel of expert instructional designers. Delphi studies are unique in that the participants are practicing experts in the field. According to Maxwell (2013), structured qualitative research is when the researcher decides on a specific method before research begins, and unstructured qualitative research is when the method is developed during research.

This study included three rounds of data collection where the panel of experts were asked their opinion regarding various instructional design considerations. The first round included an e-mailed questionnaire that asked open-ended questions based on the study's research questions. This initial round supplied information that I used in Rounds 2 and 3 for data analysis. The second and third rounds consisted of questionnaires administered to narrow best practices identified during the first and second rounds. For the second round of questioning I provided the panel a complete listing of the top five best practices identified from all panelists. At this point the panelists were asked to rank the top five practices from this listing based on importance and explain the reasoning for their selection. The ranking and explainations from Round 2 was compiled and sent to all panelists. In Round 3 I asked panelists to rank the top three from this listing and explain the reasoning behind their selection.

Qualitative Research

This study followed Maxwell's (2013) interactive approach to qualitative research design. This model has a flexible design structure that accommodates the interconnectedness needed in qualitative research (Maxwell, 2013). This model is based on five components: goals, conceptual framework, research questions, methods, and validity (Maxwell, 2013). Goals in this qualitative interactive approach provide a justification and rationale for the research (Maxwell, 2013). The conceptual framework provides foundational information which guides belief or theory towards understanding the phenomena or event being studied (Maxwell, 2013). Research questions specify exactly what would be studied, and the method identifies how the study is conducted (Maxwell, 2013). Lastly, validity speaks to threats and challenges of study results and conclusions, as well as how the researcher minimizes these threats and challenges during the course of conducting the study (Maxwell, 2013).

The following design map represents the qualitative research design of this study followed by a detailed explanation of the connections between each of the previously mentioned five interactive components (see Maxwell, 2013).

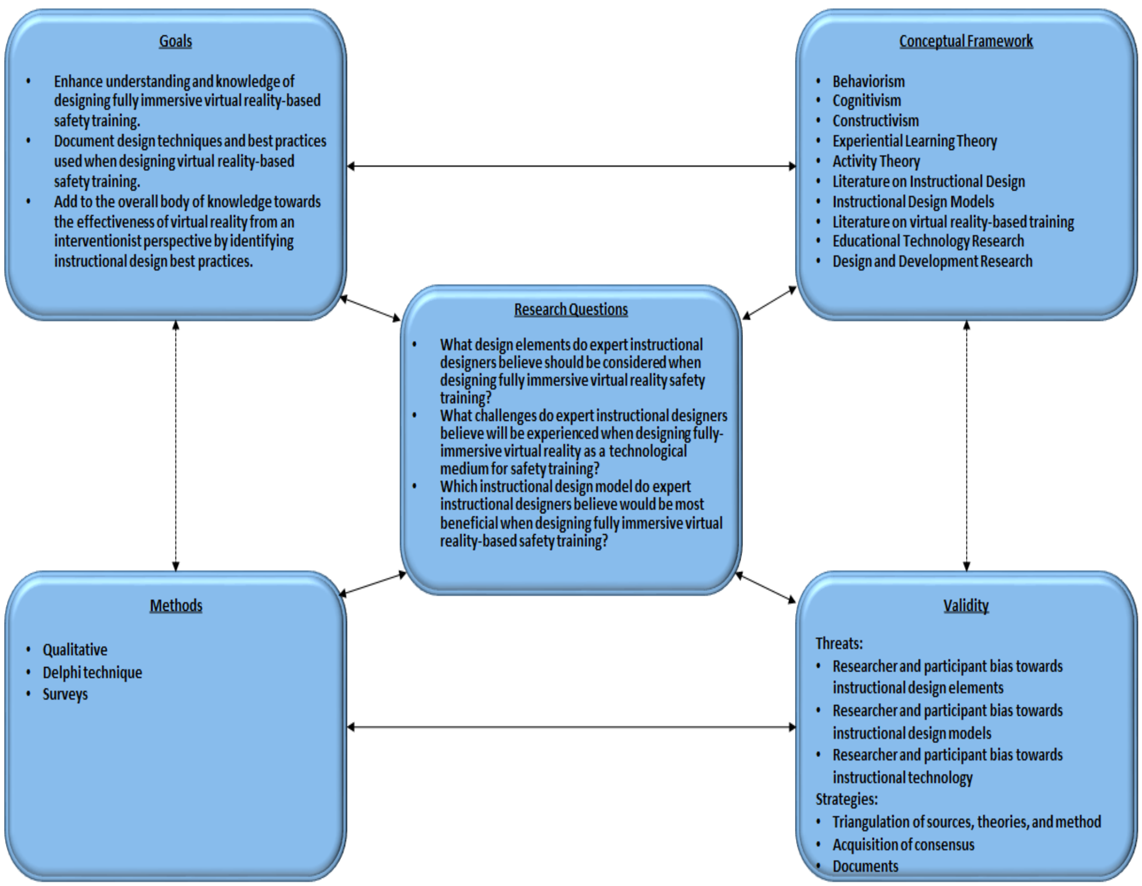

Figure 2. Research design map (Maxwell, 2013).

Research Design Map

The research questions of this study address three primary concerns for instructional designers: instructional design, safety training, and VR technology. The panel of experts determined the design elements that should be considered, identified the challenges experienced when designing such training, and predicted technology considerations by using the most appropriate instructional design model. Instructional design models typically include a certain level of evaluation which could provide insight on the technology as an intervention. Based on the research questions, the method for this study was qualitative using a modified Delphi technique primarily with surveys/questionnaires as the data collection instruments.

Goals in this qualitative interactive approach provided a justification and rationale for the research (see Maxwell, 2013). A goal of this qualitative interactive approach was specific to how the research would benefit the instructional designer. The goals for this study were to enhance understanding and knowledge of instructional designers, identify best practices, and evaluate the use of VR as an intervention. The conceptual framework provided foundational information that guided belief or theory towards understanding the phenomena or event being studied (see Maxwell, 2013). The conceptual framework for this study was guided by several theories and comprehensive study of research on the topic. Validity speaks to threats and challenges of study results and conclusions, as well as how I minimized these threats and challenges while conducting the study (see Maxwell, 2013). Validity concerns in this study are discussed further in the Issues of Trustworthiness section of this chapter.

Modified Delphi Technique

Delphi technique is typically used to gather and distribute expert opinions on a particular topic or problem, as well as encourage consensus towards a specific solution or solutions (Donohoe, Stellefson, & Tennant, 2012). The Delphi technique was used in this study to gather information from instructional designers to provide other instructional designers with best practices towards improving performance in the field. The Delphi technique in particular can be used in the field of educational technology (Nworie, 2011) because practitioners such as instructional designers grapple with making decisions regarding using the appropriate technology to enhance learning. In addition, the Delphi technique was beneficial in identifying and documenting contradicting opinions (Nworie, 2011). The contradicting opinions could serve as topics for future research, which could possibly target and identify required best practices for instructional designers.

I conducted this study was conducted using a modified approach to accommodate the flexibility that I needed (Murray & Hammons, 1995). The modified Delphi technique is primarily considered as such because it was not conducted in the traditional face-to-face or pen-and-paper approach for data collection (Donohoe, Stellefson, & Tennant, 2012). This study was considered modified based on two details. Firstly, the first round of questioning screened the level of expert experience. Another reason this study was a modified Delphi technique was due to the primary form of communication. I communicated with the experts through electronic means with questionnaires administered through e-mail and follow-up response clarifications using the continuous e-mail reply functionality.

Role of the Researcher

Qualitative research is based on an interpretive foundation with the researcher serving in part as the interpretive tool (Creswell, 2014; Patton, 2015). As researcher I played an integral role in this study as the overall project manager which included, study coordination, expert selection and coordination, data gathering and analysis, as well as facilitation towards achieving participant consensus.

I am currently a senior instructional designer with a large industrial organization. Her current responsibilities include the development of technology-based and instructor-led courses, specifically supporting the Information Technology, Engineering, and Technical Skills departments. With over 30 years of learning and development experience, my responsibilities include analysis, design, development, implementation, and evaluation of corporate and academic educational solutions. In addition, I have managed several large-scale educational initiatives for multiple government agencies and public/private organizations.

With over a 30-year span of experience, I have built several relationships with other professional instructional designers. The number of years I knew the participants in this study will vary from brief acquaintances to working colleagues. However, I did not have a position of authority over any of the study participants, which would decrease the concern of imposing my beliefs on a subordinate participant. Serving in the role of facilitator could have posed many ethical challenges that are addressed in the Issues of Trustworthiness section of this chapter.

Methodology

This methodology section includes an explanation regarding specifics on how the study was conducted, as well as a brief description of the qualitative approach used during the life of the study. This study used a modified Delphi Technique in order to take advantage of expert opinion, build consensus (Nworie, 2011), establish successful instructional design considerations, and ultimately formed a cohesive approach towards the use of VR-based technology in safety training. In addition, the Delphi Technique has been found to hold promise regarding the adoption of instructional and technological innovation (Nworie, 2011). This study benefited instructional designers when faced with decisions towards determining appropriate strategies to be used during the design and development phases of course development.

The Delphi technique is a methodology that instructional designers use every day as practitioners. The subject matter experts (SMEs) simply represent the panel of experts common to the Delphi technique. The analysis stage of the instructional design process involves gathering data from SMEs. Instructional designers compile data and present it to SMEs for verification and clarification. In the end, what appears in the training is based on SME consensus. Therefore, conducting a study using this technique should provide a certain level of comfort for the instructional designer. This study simply used the instructional designers as research-based SMEs. However, it was important to me that this study follows a more structured approach, as opposed to an unstructured approach.

The benefit of structured qualitative research includes the increased ability to compare sampling parameters and/or participants. In addition, structured methods help focus the data collection and analysis (Miles, Huberman, & Saldana, 2014). Structured methods are also good for inexperienced researchers who are studying well understood phenomena (Miles, Huberman, & Saldana, 2014). Unstructured qualitative research is more inductive in nature in that the phenomenon itself drives the data collection (Maxwell, 2013). As an inexperienced researcher this study will follow a structured qualitative methodology.

Participant Selection Logic

This study was a qualitative Delphi method of inquiry on the design elements of VR-based safety training by a panel of expert instructional designers. According to Maxwell (2013), selecting individuals who can answer the researcher's questions is the most important aspect of qualitative selection decisions. It is recommended that 10-18 expert panelists be used for a Delphi study (Okoli & Pawlowski, 2004). This study obtained 10 expert panelists to serve as part of the study. Creswell (2014) recommended a purposeful selection of qualitative participants be used in that it will aid the researcher in understanding the research questions. Patton (2015) defined purposeful sampling as selection by nature and substance that will enhance the question being studied. The purpose of this qualitative study was to identify best practices that could be used by instructional designers when designing VR-based safety training in order to improve safety competence and practice in the industrial environment. Therefore, purposeful selection of this Delphi study involved instructional design experts who have developed technology-based training.

Due to the limited number of VR instructional designers, a stratified purposeful sampling strategy was used. According to Patton (2015) this sampling strategy begins with one specific strategy and adds another strategy to focus the sample. In the case of this study the goal was to expand participation and began with a key informant strategy and included a snowball strategy by asking for additional contacts who could also serve as experts. The key informant strategy served the Delphi model in that experts in the field were selected as the initial sampling. The snowball sampling strategy also served the Delphi model in that existing experts may know other “unpublished” or “soon to be published” experts that will expand the overall sampling size as well as provide the most recent research in the field. Key informants never knew if their recommendations were contacted or used in the study, anonymity was maintained.

It was very important to me that study experts represented practicing instructional designers instead of published instructional designers to capture current challenges in the field. Participant selection criteria were based on the number of years of instructional design experience as well as the types of organizations the experience was gained. Participants had at least ten years of instructional design experience, completed more than ten instructional design projects as the practicing instructional designer, a degree/certificate in instructional design, education, or other business-related degree, industrial-based safety training experience, and incorporated various forms of technology into instructional design projects.

As this research specifically involved safety training, participants were selected from industrial organizations. Additional selection criteria also involved the types of courses designed by potential participants. All participants had designed courses that involved various forms of technology. As this training was specific to the emerging technology of VR, it was important that participating instructional designers bring prerequisite knowledge regarding challenges consistent with similar types of technology-based learning.

Instrumentation

Questionnaires are typically the instrument of choice when using the Delphi Technique methodology (Nworie, 2011). The first-round e-mail questionnaire were open-ended based on the study's research questions. E-mail protocol can be found in Appendix B. The second and third rounds involved questionnaires based on pattern and theme data received from the first and second rounds respectively. Table 2 represents the open-ended research questions and sub-questions.

Table 2

Open-ended Questions and Subquestions

Open-ended Research Question	Sub-questions to each research question
What design elements do you believe should be considered when designing full immersion virtual reality-based safety training?	
	What learning objective actions will be most appropriate when designing full immersion virtual reality-based safety training?
	What learning activities do you believe should be used when designing full immersion virtual reality safety training?
	What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training?
What practices do you use to overcome challenges experienced when designing full immersion virtual reality as a medium for safety training?	
	What practices do you use to familiarize yourself with newly emerged aspects virtual reality technology?
	What practices do you use to gauge the technical abilities of the student population?
	What practices do you use to evaluate the usage of virtual reality in your safety training?
Which instructional design model do you believe would be most beneficial when designing full immersion virtual reality-based safety training?	
	What considerations do you believe should be used to determine the most appropriate instructional design model when designing full immersion virtual reality safety training?
	What other instructional design models do you believe could be used when designing full immersion virtual reality safety training and why?
	Which instructional design model do you believe would be the second most beneficial when designing full immersion virtual reality-based safety training?

Procedures for Recruitment, Participation, and Data Collection

Instructional design professionals were invited, via email, to participate as experienced instructional designers. Panelists were selected from various conference presenter listings as well as published and unpublished instructional designers. Conference listings will include; International Society of Performance Improvement (ISPI) 2017 Conference, Association for Talent Development (ATD) 2017 International Conference, and Interservice/Industry Training, Simulation and Education Conference 2016. Presenter information was retrieved from public information contained on organizational conference information. If specific contact information was not present on the conference website, then it was attained from the secondary employer/organization website. All contact information was retrieved from public information.

In order to increase the number of participants, they were asked to provide recommendations for other participants as a process of snowball sampling (Patton, 2015). The more participants in the study the more opinions, but at the same time the more participants the harder it would have been to acquire consensus. It is recommended that 10-18 expert panelists be used for a Delphi study (Okoli & Pawlowski, 2004). After Institutional Review Board (IRB) approval (approval number 12-22-17-0176449), I e-mailed invitations to instructional designers (see Appendix A for sample invitation). Panelists were asked to reply to the email if they would like to participate, at which time I e-mailed a “consent to participate” document to provide specific details regarding the research process (see Appendix C for an example of the consent to participate email).

Round 1 of Data Collection

The first round of questioning was completed by e-mail. Demographic information included: name, email, current position and title, formal education, summary of instructional design experience, and delivery methods used for instructional design projects (York & Ertmer, 2011). Panelists were asked the three open-ended research questions from this study.

- What design elements do you believe should be considered when designing full immersion virtual reality safety training?
- What challenges do you believe will be experienced when designing full immersion virtual reality as a medium for safety training?
- Which instructional design model do you believe would be most beneficial when designing full immersion virtual reality safety training?

Panelists were asked to provide as much detail as possible to allow me an opportunity to note common themes. Using a blank page philosophy for the first round enabled panelists to freely express their opinions and allowed for more input (Nworie, 2011). If response was not received a reminder was sent once a week for two weeks to non-responsive panelists (see Appendix D).

Round 2 of Data Collection

During Round 2, panelists were presented with initial best practices identified from Round 1 participant responses (see Appendix E). This not only allowed them an opportunity to confirm the interpretation of their individual responses, but to also review response summaries from other panelists. Panelist identity remained anonymous and responses were not tied to individual panelists in any way. Panelists were asked to rank the top five best practices from the listing and provided their reasoning for each ranking. Round 2 data was in the form of panelist ranking and their associated textual responses. The textual data was entered into NVivo software where In Vivo coding was used to identify keywords and phrases across all participants (Miles et al., 2014).

The panelists were e-mailed a listing of all responses to each Round 1 question and asked to rank the top five best practices from the listing in order of importance. I also asked panelists to explain their reasoning for ordering the specific practices. Based on the average expert ranking, the five most important practices were ranked in an ascending order accordingly. Similar to Round 1, if a response was not received a reminder was sent once a week for 2 weeks to nonresponsive panelists.

Round 3 of Data Collection

During Round 3, panelists were presented with the resulting top five best practices identified from Round 2, as well as receive summarized responses from all the other panelists. Panelists were asked to rank the top three best practices from the listing and provide their reasoning for each ranking. Round 2 data was sent in the form of panelist ranking and summarized responses.

The panelists were emailed the ranking from the top five practices acquired during Round 2 and asked to rank the top three best practices from the listing in order of importance. Panelists were also asked to explain their reasoning for ordering the specific practices. Based on the average expert ranking, the three most important practices were ranked in an ascending order accordingly. Like rounds one and two, if response was not received a reminder will be sent once a week for two weeks to non-responsive panelists (see Appendix D).

Follow-up

Delphi is typically set up to allow each round to build on the previous round in order to expand the data set (Heimlich, Carlson, & Storksdieck, 2011). I tallied the top best practices based on panelist ranking, and prepare a discussion explaining the ranking.

Data Analysis Plan

I used NVivo as qualitative software that was geared specifically towards research discovery. This study was a qualitative Delphi technique in that it documented the perspectives of experts. The resulting data from this research were email questionnaire textual responses, as well as two rounds of questionnaire rankings. The data from the questionnaire responses was entered into the software for theme identification and analysis.

Round 1 data was in the form of textual responses received from expert panelists. Panelist responses were typewritten textual responses received via email. All responses were entered into NVivo software where In Vivo coding will be used to identify keywords and phrases across all participants (Miles, Huberman, & Saldana, 2014). Patterns were identified based on words and phrased used repeatedly by the panelists (Miles, Huberman, & Saldana, 2014).

A listing of best practices was identified from the patterns and then used during Round 2. I searched for any new patterns that were not identified during the previous round. A mean and standard deviation was used to determine a top five listing of best practices which was used for Round 3.

Round 3 textual data was entered into NVivo software where InVivo coding was used to identify keywords and phrases across all participants (Miles et al., 2014). A mean and standard deviation was used to determine a top three listing of best practices. It should be noted that absence of consensus is considered a possibility and valuable result to this study.

Issues of Trustworthiness

Credibility

The iterative nature of Delphi study makes it easy to triangulate the data, as there are three separate rounds of data collection. Consistent patterns and themes within the data was identified during at least three separate occasions. Therefore the selection process used for expert panelists was important to the credibility of a Delphi study. The first element in ensuring credibility was confirming the level of expertise achieved by the panelist. All experts had at least 10 years of instructional design experience, which I verified. As access to private information was typically limited, I had the ability to confirm expertise through panelist biographical information contained in conference materials or personal knowledge.

Credibility through the Delphi methodology was also addressed through the use of anonymity. Panelists were anonymous to each other but not anonymous to me. Panelists were able to reflect and consider the opinions of other panelists and judge accordingly. However, they were only aware of their specific answers provided from round to round. They were not aware of who the other panelists were, or which panelists provided which answers. This methodology reduced the risk of positive, or negative, influence between panelists (Donohoe, Stellefson, & Tennant, 2012). The Delphi Technique is in and of itself a peer review of panelists questionnaire responses based on the rating system used during rounds two and three.

Transferability

Transferability speaks directly to how well the study will resonate with other researchers and the ability to apply the methodology in another context (Miles, Huberman, & Saldana, 2014). As a qualitative study, the write-up and description of results addressed the transferability of the study. I provided a high level of detail regarding completions of the various rounds, as well as discussion surrounding panelist response. A “thick description” of the findings was used to afford the dissertation reader an opportunity to determine transferability (Miles, Huberman, & Saldana, 2014, p. 314). In addition, findings were shared with the panelists as a means by which to modify findings that may have been misinterpreted.

Transferability within a Delphi study could only be considered if conducted as a separate study. When researching the same questions, the findings from one study and one panel of experts could be compared with the findings from a separate study with a second panel of experts (Thangaratinam & Redman, 2005). To this end, I ensured that the study provided “thick description” of panel selection, data collection, and implementation in order to account for transferability in other studies (Miles, Huberman, & Saldana, 2014, p. 314).

Dependability

Dependability addresses the quality and integrity used in the study (Miles, Huberman, & Saldana, 2014). Delphi is good at resolving situations where there is no definitive evidence and we have no other choice but to rely on the knowledge and experience of experts (Thangaratinam & Redman, 2005). Therefore, this study depended on data received from expert panelists. My role as researcher in this study was facilitative and did not require data interpretation. Raw data was confirmed by the actual panelists to eliminate the possibility of data falsification. All panelist responses were entered into NVivo software where In Vivo coding was used to identify keywords and phrases (Miles et al., 2014). Patterns were identified based on words and phrases used repeatedly by the panelists (Miles et al., 2014).

Confirmability

Confirmability is specific to the neutrality of the study (Miles, Huberman, & Saldana, 2014). Trochim (2001) indicated that confirmability speaks to how much the data is confirmed by others. This study had the benefit of allowing the panelists an opportunity to confirm the responses provided during each round. The iterative nature of the Delphi technique allowed Round 1 response confirmation during Round 2, Round 2 responses confirmed during Round 3, and Round 3 responses were confirmed when panelists received first access to the actual dissertation. All findings were specifically linked to data received from expert panelists.

Ethical Procedures

As a Delphi Technique study, this research did include a panel of experts, or human participants. However, this study captured participant knowledge and included minimal risk. The risk in the study could be a misinterpretation of participant responses. This risk was minimized by allowing the panelist an opportunity to review the actual findings for accuracy. Participants were emailed an agreement to ensure that they understand procedures and expectations of the study (Appendix C).

As a dissertation, this study required IRB approval. The IRB ensured that research was consistent with ethical standards and follows federal regulations (Walden University, 2017). I submitted an IRB application and received approval before conducting the study. All revisions requested by the IRB were made in order to ensure that this study strictly followed all ethical standards.

Summary

This chapter explained the specific research design for this study and the rationale for selecting a qualitative research design using a modified Delphi technique approach. The modified Delphi technique that was used in this study was primarily considered as such because it was not conducted in the traditional face-to-face or pen-and-paper approach towards data collection (Donohoe, Stellefson, & Tennant, 2012). Instead communication and data collection were primarily through electronic (telephone and/or email) means. The Delphi technique was used in this study to provide instructional designers with a listing of possible best practices towards improving performance in the field.

This chapter also explained that there were three rounds of questionnaires where experts provided responses to the research questions and rate the level of importance for each. Participant selection criteria was based on the number of years of instructional design experience as well as the types of organizations the experience was gained. Participants had at least ten years of instructional design experience, completed more than ten instructional design projects as the practicing instructional designer, a degree/certificate in instructional design, education, or other business-related degree, industrial-based safety training experience and having incorporated various forms of technology into instructional design projects.

This chapter also provided details regarding the data analysis plan. Responses from the questionnaires will be entered into NVivo software for theme identification and analysis. While there were other qualitative software programs which served as useful tools for managing data, NVivo was the researcher's preferred selection for this research topic. The various file formats accepted by NVivo will offer more flexibility in data source options. In addition, the storage capability of source files will provide access to the entire project to any one of many electronic devices without the need to access specific hardware. Chapter 4 will provide details regarding results of data collection and analysis.

Chapter 4: Results

The purpose of this qualitative study was to identify best practices that could be used by instructional designers when designing VR-based safety training in order to improve safety competence and practice in the industrial environment. In addition, I hoped that the results of this study would provide instructional designers with a better understanding of how VR technology can be used as a learning intervention.

This study included three central questions specific to instructional design elements when designing full immersion VR safety training.

RQ1: What design elements do expert instructional designers believe should be considered when designing full immersion VR safety training?

RQ2: What challenges do expert instructional designers believe will be experienced when designing full immersion VR as a medium for safety training?

RQ3: Which instructional design model do expert instructional designers believe would be most beneficial when designing full immersion VR safety training?

In addition to the research questions, I also answered the following subquestion based on participant responses.

SQ: Which learning and instructional design theories are reflected in best practices identified by expert instructional designers when designing full immersion VR-based safety training?

In this chapter I provide introductory information regarding the purpose of this study and then proceeds to the research setting. I then discuss participant demographics, data collection, and data analysis to provide details surrounding the circumstances of each research component. Following data collection, I discuss research validity and reliability concerns in an Evidence of Trustworthiness section. I then present details regarding data analysis followed by addressing the process used to rank the best practices identified by the expert panel. The final section provides study results based on expert panelist questionnaire responses followed by the summary, which serves as a brief discussion of all Chapter 4 sections.

Setting

Participants were not impacted by any personal or organizational conditions that may have influenced their experiences. There were four expert panelists who were geographically disbursed across the United States. All participants were employed by large industrial organizations and developed multiple instructional design projects. Panelists were selected from various conference presenter listings as well as from published and unpublished instructional designers. In addition, I invited published authors of relevant instructional design articles.

Demographics

Participant selection criteria was based on the number of years of instructional design experience as well as the types of organizations where the experience was gained. Participants had (a) at least 10 years of instructional design experience; (b) completed more than 10 instructional design projects as the practicing instructional designer; (c) a degree/certificate in instructional design, education, or other business-related degree; (d) industrial-based safety training experience; and (e) incorporated various forms of technology into instructional design projects. There were three females and one male expert panelists.

Table 3

Participant Demographics

Participant number	Years of instructional design experience	Organization type(s)	Position title
1	20+	Military and industrial	Sr. instructional designer
2	30+	Military and industrial	Sr. instructional designer
3	10+	Military and industrial	Sr. instructional designer
4	20+	Military and industrial	Sr. instructional designer

Data Collection

After identifying participants, I began the data collection process. Participant recruitment was a lengthy process in that invitations were e-mailed in a staggered process based on when I was able to locate contact information. This process required researching and locating each of the potential participants and e-mailing the invitation when contact information was found. This process required an exorbitant amount of time and more research than originally expected. However, after several weeks there were no responses received. In order to be proactive and expand the reach of potential participants I requested, and was approved for, a change in procedure through the IRB. My request specifically asked to send the invitations to an additional 35 potential participants. The additional individuals included known colleagues, as well as newly identified conference presenters/attendees. The extra effort proved effective in that additional participants provided consent to participate and Round 1 could begin.

This research was a qualitative study for which I used a modified Delphi method of inquiry with a panel of expert instructional designers. It included three rounds of data collection wherein a panel of experts were asked their opinion regarding various instructional design considerations. The first round included an e-mailed questionnaire that asked open-ended questions based on the study's research questions. This initial round supplied information that was used in Rounds 2 and 2 for data analysis. The second and third rounds consisted of questionnaires administered to narrow best practices identified during the first and second rounds respectively. The second round of questioning provided the panel a complete listing of the Round 1 questionnaire responses identified from all panelists. At this point, the panelists were asked to rank the top five practices from this listing based on importance and were requested to explain the reasoning for their selection. The top five ranking and explanations from Round 2 were compiled and sent to all panelists. In Round 3 I asked panelists to rank the top three from this listing and explain the reasoning behind their selection.

Data collection from Round 1 spanned over 4 weeks to include 2 additional weeks of e-mail invitations. After a low response rate, I e-mailed more invitations to increase panel participation. I was encouraged in that several potential panelists responded to the invitation with questions regarding participation. A total of 62 potential participants were invited and four agreed to participate. Four panel experts seemed to be sufficient in that many studies have used at most four panelists, which did not compromise the value of the research (Linstone & Turoff, 2002). Others recommend at least two panelists/responses for each research question (Alder & Ziglio, 1996, as cited in Janio, 2007, p. 6). E-mail reminders were required for two participants during the first round.

Data collection from Round 2 spanned over 6 weeks to include 2 additional weeks of e-mail invitations. All panelists responded to the Round 2 questionnaire by ranking the top five responses from all panelists. Data collection from Round 3 spanned over 2 weeks with panelists ranking the top three best practices from the determined top five best practices from Round 2.

Data Analysis

This study was a qualitative Delphi technique in that it began with a request for inputs from the participants on what should be included in the Delphi ranking process. NVivo was the qualitative software used to identify themes and patterns. The resulting data from this research were e-mail questionnaire textual responses, as well as two rounds of questionnaire rankings. I entered the data from the questionnaire responses into the software for theme identification and analysis.

Round 1 of Data Collection

Round 1 data was in the form of textual responses received from expert panelists. Panelist responses were typewritten textual responses received via e-mail. I entered all responses into NVivo software where In Vivo coding was used to identify keywords and phrases across all participants (Miles et al., 2014). Patterns were identified based on words and phrases used repeatedly by the panelists (Miles et al., 2014). Appendix A represents the actual questionnaire sent to panelists.

I identified seven themes based on responses from panelists: instructional design model, learning activities, technology, learning objective alignment, professional development, instructional design team, and 3D model quality. I coded two prominent themes from the panelist responses: instructional design model, which received the twenty references, and learning activities, which also received twenty references. The learning object alignment theme was the third most prominent reference with nine references. A few panelist quotes regarding instructional design models are detailed in Table 4.

Table 4

Round 1 Quotes

Quotes
The Knowledge / Skill Builder model would be an appropriate choice as it would easily be a good framework for the incorporation of VR and other modern learning techniques and strategies. This model is characterized by the following steps: • Gain attention • Set Direction / establish 'what's in it for me' • Present intro content • Practice and assess • Call to Action/connect to OJT application
Since a main aspect of VR in safety training is performing a task in an environment that simulates the real world, appropriate instructional design models should focus on relevance to job (true-to-life scenarios), real world performance, and measurable outcomes.
I would do a thorough task analysis to understand the tasks and how they are performed. I would derive a selection criterion for selecting VR tasks.

The lowest number of references received was "3D model quality". As quality of the "3D model" is based on the technology the theme would fall under technology.

When using the autocode feature in the NVivo software application, seven themes were identified as well; learning, training, objectives, activities, instructional design, development, and analysis. NVivo's autocoding identified the two most prominent patterns to be learning activities, which received six references and learning objectives, which received two references. However, I did not rely solely on autocode but reviewed the information in search of commonality between the responses. An NVivo word count query was also performed and showed the highest count as the word "learning" with twenty-seven instances and second highest with objectives with fourteen instances. The key terms to pull from the word count listing would; objectives, model, activities, environment, equipment, analysis, design, and technology. These words all fit into the themes and patterns identified by me and by NVivo autocoding.

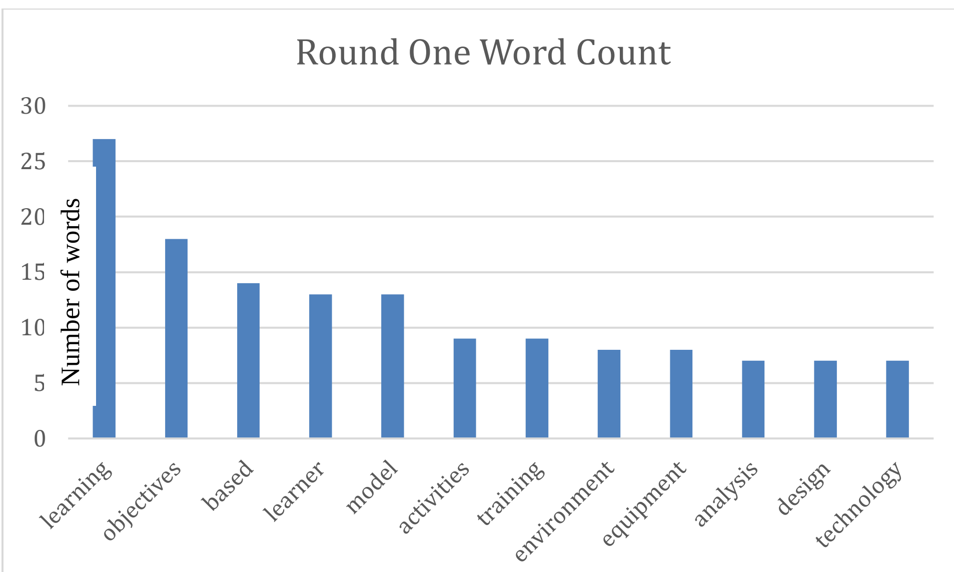

Figure 3. Round 1 word count.

Round 2 of Data Collection

Round 2 data was in the form of panelist identified ranking after having had an opportunity to review all responses received from the Round 1 questionnaire. Panelists were asked to rank the top five best practices based on responses received from all panelists. Appendix E reflects the Round 2 questionnaire emailed to expert panelists.

Round 2 ranking data was entered into NVivo software where In Vivo coding was used to identify keywords and phrases across all participants (Miles, Huberman, & Saldana, 2014). A mean and standard deviation was used to determine the top five listing of best practices for Round 3.

Due to the similarities between panelist responses, 75% of the panelists categorized the responses and numbered them based on the category they felt most important. A mean and standard deviation was used to determine the top five listing of best practices. Central tendency (mean) is typically used in Delphi studies, as well as the level of dispersion (standard deviation) to show collective judgement (Hasson, Keeney, & McKenna, 2000). Using the 84^{th} percentile of mean and standard deviation percentages, panelist responses returned the following top five best practices in order of highest to lowest rank:

1. I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills.
2. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations

should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

3. I believe VR is best used for drill and practice and proficiency building, not initial learning.
4. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.
5. Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive.

There was a three-way tie between best practices three through five. Appendix G represents the mean, standard deviation and percentile ranking of all Round 2 responses. The above five responses represent the determined top five best practices and were sent to panelists to select the top three best practices. When asked to provide reasoning for order selections, panelists returned the following responses:

- “I ordered the practices based on the significance of the practice in terms of designing effective VR employing current technology and associated costs.”
- “I ordered the practices based on the likelihood of their application resulting in a modern learning experience. There are only four responses per question, so I ranked top 4, with 1 being the first best practice.”
- “1. ADDIE (Analysis, Design, Development, Implementation, Evaluation)

2. Hard coding

3. Task analysis

4. Cognitive, psychomotor, and affective domain

5. Learning objective alignment”

Round 3 of Data Collection

Round 3 data was in the form of panelist identified ranking after having had an opportunity to review the top five best practices identified from the Round 2 questionnaire. Panelists were asked to rank the top three best practices based on the top five best practices determined from Round 2. The best practice mean and standard deviation percentages from Round 2 were not included on the questionnaire in order to eliminate the potential for bias. Appendix F reflects the Round 2 questionnaire emailed to expert panelists.

A mean and standard deviation was used to determine the top three listing of best practices. Central tendency (mean) is typically used in Delphi studies, as well as the level of dispersion (standard deviation) to show collective judgement (Hasson, Keeney, & McKenna, 2000). Using the 84th percentile of mean and standard deviation percentages, panelist responses returned the following top three best practices in order of highest to lowest rank:

1. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.

2. Develop and employ a competency-based assessment program with pre- and posttesting. However, the focus should be assessing psychomotor skills.
3. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

It is important to note that the fourth and fifth best practices tied for fourth with an 84th percentile mean and standard deviation of 1.71%. Appendix H represents the mean, standard deviation and percentile ranking of all Round 3 responses.

Evidence of Trustworthiness

Credibility

The iterative nature of Delphi study makes it easy to triangulate the data, as there are three separate rounds of data collection. Consistent patterns and themes within the data was identified during at least three separate occasions. Therefore the selection process used for expert panelists was important to the credibility of a Delphi study. The first element in ensuring credibility was confirming the level of expertise achieved by the panelist. All experts had at least 10 years of instructional design experience, which I verified. As access to private information was typically limited, I had the ability to confirm expertise through panelist biographical information contained in conference materials.

Credibility through the Delphi methodology was also addressed through the use of anonymity. Panelists were anonymous to each other but not anonymous to me. Panelists were able to reflect and consider the opinions of other panelists and judge accordingly. However, they were only aware of their specific answers provided from round to round. They were not aware of who the other panelists were, or which panelists provided which answers. This methodology reduced the risk of positive, or negative, influence between panelists (Donohoe, Stellefson, & Tennant, 2012). The Delphi Technique is in and of itself a peer review of panelists questionnaire responses based on the rating system used during rounds two and three.

Transferability

There were no adjustments made to transferability strategies identified in Chapter 3. Transferability speaks directly to how well the study will resonate with other researchers and the ability to apply the results in another context (Miles, Huberman, & Saldana, 2014). As a qualitative study, the write-up and description of results addressed the transferability of the study. I provided a high level of detail regarding completions of the various rounds, as well as discussion surrounding panelist response. In addition, findings were shared with the panelists as a means by which to modify findings that may have been misinterpreted.

When researching the same questions, the findings from one study and one panel of experts could be compared with the findings from a separate study with a second panel of experts (Thangaratinam & Redman, 2005). To this end, I ensured that the study provided “thick description” of panel selection, data collection, and implementation in order to account for transferability in other studies (Miles, Huberman, & Saldana, 2014, p. 314).

Dependability

There were no adjustments made to dependability strategies identified in Chapter 3. Dependability addresses the quality and integrity used in the study (Miles, Huberman, & Saldana, 2014). Delphi is good at resolving situations where there is no definitive evidence and we have no other choice but to rely on the knowledge and experience of experts (Thangaratinam & Redman, 2005). Therefore, this study depended on data received from expert panelists. My role as the researcher in this study was facilitative and did not require data interpretation. Raw data was confirmed by the actual panelists to eliminate the possibility of data falsification. All panelist responses were entered into NVivo software where In Vivo coding was used to identify keywords and phrases (Miles, Huberman, & Saldana, 2014). Patterns were identified based on words and phrases used repeatedly by the panelists (Miles, Huberman, & Saldana, 2014).

Confirmability

There were no adjustments made to confirmability strategies identified in Chapter 3. Confirmability is specific to the neutrality of the study (Miles, Huberman, & Saldana, 2014). Trochim (2001) indicated that confirmability speaks to how much the data is confirmed by others. This study had the benefit of allowing the panelists an opportunity to confirm the responses provided during each round. The iterative nature of the Delphi technique allowed Round 1 response confirmation during Round t2wo, Round 2 responses confirmed during Round 3, and Round 3 responses were confirmed when panelists received first access to the actual dissertation. All findings were specifically linked to the data received from expert panelists.

Ethical Procedures

As a Delphi Technique study, this research did include a panel of experts, or human participants. However, this study captured participant knowledge and included minimal risk. The risk in the study could be a misinterpretation of participant responses. This risk was minimized by allowing the panelist an opportunity to review the actual findings for accuracy. Participants were emailed an agreement to ensure that they understand procedures and expectations of the study (Appendix C).

As a dissertation, this study required IRB approval. The IRB ensured that research was consistent with ethical standards and follows federal regulations (Walden University, 2017). I submitted an IRB application and received approval before conducting the study. All revisions requested by the IRB were made in order to ensure that this study strictly followed all ethical standards.

Study Results

As stated above, this study focused on the following three central questions:

RQ1: What design elements do expert instructional designers believe should be considered when designing full immersion VR-based safety training?

RQ2: What practices do expert instructional designers use to overcome challenges experienced when designing full immersion VR as a medium for safety training?

RQ3: Which instructional design model do expert instructional designers believe would be most beneficial when designing full immersion VR-based safety training?

I also answered the following subquestion based on participant responses.

SQ: Which learning and instructional design theories are reflected in best practices identified by expert instructional designers when designing full immersion VR-based safety training?

Research Question 1

Results from the following Round 2 expert panelist response received the highest level of consensus regarding this research question: "As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions." In addition, this same response was identified by panelists as the third highest ranked best practice. This response speaks to how well the user feels immersed in the virtual is based on the acceptability of the environment.

Head-mounted displays provide a 360-degree view into the virtual environment, which tricks the brain into believing that the user is in the real world. Therefore, immersion and interactivity to move around in the virtual environment gives the user a real sense of presence (Passing, David, & Eshel-Kedmi, 2016). The environment must be realistic enough to fully persuade the user that their virtual experience is in the actual environment (Cakiroglu & Gokoglu, 2019). Convincing the user that they are in the real environment will leave more of an impression when unsafe conditions occur as a direct result of their actions. The controlled nature of the virtual environment is what makes it ideal for safety training.

The following two responses tied for the next highest level of consensus regarding this research question.

- "I believe VR is best used for drill and practice and proficiency building, not initial learning."
- "High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks."

These two responses speak to the level of activity experienced in the virtual environment. It implies that the ability to conduct practical application within the virtual environment will enhance learning. The first of these two, *"I believe VR is best used for drill and practice and proficiency building, not initial learning."*, tied as the fourth highest ranked best practice by expert panelists (1.71%).

Research Question 2

The following Round 2 expert panelist response received the highest level of consensus regarding this research question: "I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills." When considering a competency-based approach it is important to reflect on the limitations of VR technology. The 3I characteristics of VR stated by Burdea and Coiffet (2003); immersion, interaction and imagination, cost constraints on tracking real-time human movement is a barrier towards successfully assessing psychomotor skills. A comprehensive evaluation plan must be incorporated into the developmental aspects of designing the VR system itself as well as designing the instructional components of the system.

The following Round 2 expert panelist response received the next highest level of consensus regarding this research question: “VR is still an evolving technology and you will most likely learn as you go. What has been done in the past may not necessarily work in your particular situation.” The debate regarding VR as an emerging technology is just beginning. Most people have at least heard of the term and experienced it through video games, 3D movies, or something as simple as a smartphone application (Ludlow, 2015). Perhaps what could be said is that what is truly emerging from VR is an emerging environment of mixed reality (MR). Mixed reality not only includes VR but also includes augmented reality (AR). AR is a virtual object which overlaid on real-world objects (Quora, 2018).

Research Question 3

The following Round 2 expert panelist response received the highest level of consensus regarding this research question. “Model should contain the five ISD phases, analysis, design, development, implement, evaluate. The model should provide for a media analysis of learning objectives.”

The following Round 2 expert panelist response received the next highest level of consensus regarding this research question. “VR is still an evolving technology and you will most likely learn as you go. What has been done in the past may not necessarily work in your particular situation.” The technological components inherent with VR are not the only emergent reflections as it relates to the instructional design process. There is some research specific to the realism of the virtual environment and learner interaction (Dalgarno & Lee, 2010). However, with emerging technology there are new emergent considerations, such as identity construction (Fowler, 2015). If the VR environment has any element(s) of user representation, such as a hand or other body part, the question of identity must be addressed (Fowler, 2015) during the instructional design process. How is the instructional design developer to accommodate the various physical characteristics users that may experience the VR-based training?

Research Subquestion

Expert panelists identified the following top three best practices to use when designing VR-based safety training:

1. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.
2. Develop and employ a competency-based assessment program with pre- and posttesting. However, the focus should be assessing psychomotor skills.
3. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

Best practices identified by expert panelists speaks to completing “psychomotor tasks”, critical thinking through problem solving and assessment, and building competency using scenario-based challenges within the simulated environment. These elements speak directly to the three primary theories of this study: behaviorism, cognitivism, and constructivism.

Summary

As stated in Chapter 1, the purpose of this qualitative study was to identify best practices that could have been used by instructional designers when designing VR-based safety training in order to improve safety competence and practice in the industrial environment. As instructional designers develop safety training for a variety of industrial environments, identification of high-level best practices should serve as guidance when developing such training.

This chapter explained the data collection which included three rounds of data collection where a panel of experts were asked their opinion regarding various instructional design considerations. The first round included an emailed questionnaire which asked open-ended questions based on the study's research questions. This initial round supplied information that was used in rounds two and three for data analysis. The second and third rounds consisted of questionnaires administered to narrow best practices identified during the first and second rounds respectively. The second round of questioning provided the panel a complete listing of the Round 1 questionnaire responses identified from all panelists. At this point the panelists were asked to rank the top five practices from this listing based on importance and were requested to explain the reasoning for their selection. The top five ranking and explanations from Round 2 were compiled and sent to all panelists. Round 3 asked panelists to rank the top three from this listing and explain the reasoning behind their selection.

Data analysis used NVivo as the qualitative software which was geared specifically towards research discovery. The resulting data from this research were email questionnaire textual responses, as well as two rounds of questionnaire rankings. The data from Round 1 questionnaire responses was entered into the software for theme identification and analysis. I coded two prominent themes from the panelist responses; "Instructional design model" which received the twenty references, and "learning activities" which also received twenty references. The learning object alignment theme received the third most prominent reference with a distant nine references.

Round 2 ranking mean and standard deviation were calculated. Using the 84th percentile of mean and standard deviation percentages, panelist responses returned the following top five best practices in order of highest to lowest rank:

1. I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills.
2. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.
3. I believe VR is best used for drill and practice and proficiency building, not initial learning.
4. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.

5. Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive.

Round 3 ranking mean and standard deviation were calculated. Using the 84th percentile of mean and standard deviation percentages, panelist responses returned the following top three best practices to use when designing VR-based safety training in order of highest to lowest rank:

1. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.
2. Develop and employ a competency-based assessment program with pre- and posttesting. However, the focus should be assessing psychomotor skills.
3. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this qualitative study was to identify best practices that could be used by instructional designers when designing VR-based safety training in order to improve safety competence and practice in the industrial environment. I also sought to answer the question regarding which instructional design theories are best practices as identified by expert instructional designers when designing full immersion VR-based safety training.

This study included four expert panelists who were experienced instructional designers geographically dispersed across the United States with more than 10 years of experience. The panelists participated in three rounds of questionnaires with the first round including an e-mailed questionnaire which asked open-ended questions based on the study's research questions. The second round of questioning provided the panel a complete listing of the Round 1 questionnaire responses identified from all panelists, and the panelists were asked to rank the top five practices from this listing based on importance. A top five ranking from Round 2 was sent to all panelists as Round 3 and panelists were asked to rank the top three from this listing.

I used NVivo as the qualitative software geared specifically towards research discovery based on identification of themes and patterns. The resulting data from this research were e-mail questionnaire textual responses, as well as two rounds of questionnaire rankings from expert panelists. After three rounds of questionnaire responses, results revealed that best practices should include scenario-based instructional strategies that use psychomotor skills with competency-based assessment(s). This chapter provides an interpretation of findings followed by limitations of study, recommendations, implications, and conclusion sections.

Interpretation of Findings

The goal of this study was to explore instructional designer considerations used when designing VR-based industrial safety training. Expert panelists identified the following top three best practices to use when designing VR-based safety training:

1. High level cognitive scenario based troubleshooting and problem solving. Difficult and critical psychomotor tasks.
2. Develop and employ a competency-based assessment program with pre- and posttesting. However, the focus should be assessing psychomotor skills.
3. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

The panelists agreed that best practices speak to completing psychomotor tasks, critical thinking through problem solving and assessment, and building competency using scenario-based challenges within the simulated environment. These elements speak directly to the three primary theories of this study: behaviorism, cognitivism, and constructivism.

As stated in Chapter 2, the most common used model in the business environment is based on the five core components of ADDIE: analysis, design, development, implementation, and evaluation (Branch & Kopcha, 2014; Chevalier, 2011; Lawson & Lockee, 2014). The fact that ADDIE contains foundational elements of all instructional design models implies that it could be considered more concept than model (Branch & Kopcha, 2014). Branch and Kopcha (2014) assumed that despite the various ISD models currently in use today, all models include these five major activities: analysis, design, development, implementation, and evaluation. Mastrian et al. (2011) considered these five major activities as the underpinning for every instructional design process. The panelists agreed; the following Round 2 response received the highest level of consensus: "[Instructional Design] Model should contain the five ISD phases, analysis, design, development, implement, evaluate. The model should provide for a media analysis of learning objectives."

Limitations of the Study

As noted in Chapter 1, limitations in using the Delphi technique include the lengthy amount of time involved with conducting multiple rounds of questionnaires and the level of experience associated with expert panelists. While the multiround nature of this methodology could have resulted in attrition, it did not prove to be the case in this study. In order to increase the number of participants, panelists were asked to provide recommendations for other participants as a process of snowball sampling. However, despite the use of snowball sampling this study was limited by the number of participants included in the study. It was recommended that 10-18 expert panelists be used for a Delphi study (Okoli & Pawlowski, 2004) but this study consisted of four expert panelists, which limited the amount of data used to identify potential best practices.

The second limitation involved the danger of preconceived opinions through participant selection criteria, which was based on the number of years of instructional design experience as well as the types of organizations where the experience was gained. This study included participants who had (a) at least 10 years of instructional design experience; (b) completed more than 10 instructional design projects as the practicing instructional designer; (c) a degree/certificate in instructional design, education, or other business-related degree; (d) industrial-based safety training experience; and (e) incorporated various forms of technology into instructional design projects. As this research specifically involved safety training, participants were also selected from industrial organizations. Additional selection criteria also involved the types of courses designed by potential participants. All participants designed courses that involved various forms of technology. As this study was specific to the emerging technology of VR, it also included participating instructional designers with prerequisite knowledge regarding challenges consistent with similar types of technology-based learning. Expert instructional designers with less VR experience from the technological perspective may have eliminated preconceived opinions.

Recommendations

Based on the findings from this study, there are three recommendations to be used when designing VR-based safety training. The first recommendation is to closely tie instructional strategies with scenario-based cognitive situations and incorporate learner psychomotor tasks. This practice will require the learner to consider the most appropriate action when placed in certain situations. In doing this, the learner's action/reaction will demonstrate that the learning outcome has been attained.

The second recommendation involves the type of assessment used to measure learner success. The assessment should answer questions regarding (a) competence towards completing the task, (b) number of attempts completed before mastery was attained, (c) competence before receiving the VR-based safety training, and (d) competence after receiving the VR-based safety training. The answers to these questions could be attained automatically within the VR-based assessment tool and should be based on the psychomotor actions of the learner.

The final recommendation involves the type of scenarios presented to the learner. The learner should be placed in unsafe conditions in order to learn the right and wrong actions that should be taken. If all of the scenarios presented to the learner is a safe scenario, the learner will never learn from making unwise decisions. One of the primary benefits of using a virtual environment is to safely learn from the consequences of making bad decisions in an unsafe environment.

Because VR is a technology primarily based on activity theory, it should be used to encourage a specific behavior as the learning outcome. Scenario-based learning outcomes should be clearly identified when learners are required to apply situational critical thinking. VR immerses the learner in a virtual environment that not only provides a realistic experience but also provides a means by which to assess learner actions when required to quickly gauge situational awareness to react in an unsafe environment.

Implications

Positive social change can be achieved through this study by providing an understanding of critical design elements that should be considered by instructional designers when designing VR-based safety training. Ultimately, this information can be used as a guide in designing VR based safety training, which may improve learner knowledge by allowing them to experience seemingly unsafe environments without actually risking their safety and potentially their lives, thereby decreasing the number of safety-related accidents in the industrial environment. While much fewer accidents happen in office environments, VR-based safety training could be equally beneficial in that setting. Most advanced manufacturing/industrial organizations have both an industrial environment as well as an office environment and would incur minimal expense to duplicate an office virtual environment.

Conclusions

As an interdisciplinary field, instructional design draws theory from psychology, science, sociology, and education (Smith & Ragan, 2005). The primary research design of this study represented a DDR perspective. DDR is the systematic study of design, development, and evaluation of instructional and noninstructional products and tools (Richey & Klein, 2007). The goal of this study was to explore instructional designer considerations used when designing VR-based industrial safety training. As an emerging technology VR adds an additional layer of complexity to instructional design. Immersive VR provides a naturalistic environment for workers to physically experience the work environment without the associated risk.

The Delphi technique used in this study was considered modified because it was not conducted in the traditional face-to-face or pen-and-paper approach in regard to data collection (Donohoe, Stellefson, & Tennant, 2012). Instead, communication and data collection were primarily conducted through electronic (telephone and/or e-mail) means. I used the Delphi technique in this study to provide instructional designers with a listing of possible best practices towards improving performance in the field.

NVivo was used as qualitative software that was geared specifically towards research discovery. The resulting data from this research were e-mail questionnaire textual responses as along with two rounds of questionnaire rankings. Based on the findings from this study, I concur with the expert panelists and recommend the following best practices should be used when designing VR-based safety training:

1. High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.
2. Develop and employ a competency-based assessment program with pre- and posttesting. However, the focus should be assessing psychomotor skills.
3. As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.

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Appendix A: Round 1 E-mail Questionnaire Protocol

The following table reflects the email questionnaire protocol that will be used during first round:

Length: 30 minutes	
General Information	
Panelist Name:	
Date/Time email sent:	
Date/Time email response received:	
Questionnaire	
Question	**Response**
What design elements do you believe should be considered when designing full immersion virtual reality-based safety training?	
• What learning objective actions will be most appropriate when designing full immersion virtual reality-based safety training? Please explain your reasoning.	
• What learning activities do you believe should be used when designing full immersion virtual reality safety training? Please explain your reasoning.	
• What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training? Please explain your reasoning.	
What practices do you use to overcome challenges experienced when designing full immersion virtual reality as a medium for safety training?	
• What practices do you use to familiarize yourself with newly	

emerged aspects of virtual reality technology? Please explain your reasoning.	
• What practices do you use to gauge the technical abilities of the student population? Please explain your reasoning.	
• What practices do you use to evaluate the usage of virtual reality in your safety training? Please explain your reasoning.	
Which instructional design model do you believe would be most beneficial when designing full immersion virtual reality-based safety training?	
• What considerations do you believe should be used to determine the most appropriate instructional design model when designing full immersion virtual reality safety training? Please explain your reasoning.	
• What other instructional design models do you believe could be used when designing full immersion virtual reality safety training? Please explain your reasoning.	
• Which instructional design model do you believe would be the second most beneficial when designing full immersion virtual reality-based safety training? Please explain your reasoning.	

Appendix B: Round 2 E-mail Questionnaire Protocol

Please review all responses received to each question and rank the top five best practices from the listing in order of importance. A rank of one represents the first best practice and five represents the fifth best practice.

Length: 30 minutes

General Information

Panelist Name:
Date/Time email sent:
Date/Time email response received:

Questionnaire		
Question	**Responses**	**Rank**
What design elements do you believe should be considered when designing full immersion virtual reality-based safety training?	I believe VR is best used for drill and practice and proficiency building, not initial learning.	
	That there is a clear alignment between VR safety training activities, learning objectives, and assessment.	
	Design should be heavily activity based.	
	Strong analysis of the target audience and defining the desired learning outcomes.	
• What learning objective actions will be most appropriate when designing full immersion virtual reality-based safety training? Please explain your reasoning.	Since the benefit of VR is learner ability to experience an alternate physical reality that may inaccessibly or dangerous, or use equipment that is unavailable or expensive, objectives should require learner to successfully perform a task, operate equipment, or react to situation in the environment.	
	Cognitive, psychomotor, and affective domain.	
	Learning objectives should be demonstrative in nature. VR is primarily focused on activity of some sort.	
	Learning objectives should be based on the desired change in behavior.	
• What learning activities do you believe should be used when designing	Activities should align with objectives, to include in working in and using equipment in virtual (training) environments. For safety training, environments could be hazardous, enclosed physical spaces, etc.	

full immersion virtual reality safety training? Please explain your reasoning.	High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.	
	Skill-based and measurable activities are needed to provide accurate feedback to trainees.	
	Learning activities should really lend itself from the perspective of the learner's presence. VR that displays a third-party perspective or view is confusing and does not enhance learning.	
• What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training? Please explain your reasoning.	To ensure quality of finished training deliverable, a concern would definitely be accuracy of representation. This is directly impacted by quality of modeling related to game space and project assets.	
	Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive	
	The instructional designer should consider the limitations of the technology such as the inability to determine techniques used by the trainees.	
	As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.	
What practices do you use to overcome challenges experienced when designing full immersion virtual reality as a medium for safety training?	Practices require not skipping steps in Analysis and Design phases. This includes owning the responsibility to design courses mindfully, thoroughly analyze/understand learner population, and determine an appropriate evaluation plan before course development.	
	VR is still an evolving technology and you will most likely learn as you go. What has been done in the past may not necessarily work in your particular situation.	
	Multidisciplinary team.	
	Strong subject-matter expert support.	

• What practices do you use to familiarize yourself with newly emerged aspects of virtual reality technology? Please explain your reasoning.	With rapid changes in technology, reviewing blog content and resources available on HW and SW sites is a good way to keep pace and determine what is feasible for a project.	
	Attend VR trade shows, subscribe to VR magazines, join VF groups, do research on VR, discuss VR with engineering. Do small scale trial and error	
	Research literature	
	Conference attendance to stay at the forefront of the technology.	
• What practices do you use to gauge the technical abilities of the student population? Please explain your reasoning.	I've gauged technical abilities by having learner complete prerequisites / pretest or introduce the course with refresher activity.	
	I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills	
	Human observation	
	Hard coding into the software as much as possible, such as timing and touch points.	
• What practices do you use to evaluate the usage of virtual reality in your safety training? Please explain your reasoning?	I would do a thorough task analysis to understand the tasks and how they are performed. I would derive a selection criterion for selecting VR tasks.	
	Evaluating course effectiveness of VR safety training is consistent with evaluating non-VR training development efforts; business objectives must be established by stakeholders. Some organizations may require ROI projections to justify development costs	
	Human observation	
	Gagne's Level three evaluation due to the direct on-the-job observation	
Which instructional design model do you believe would be most beneficial when designing full immersion virtual reality-based safety training?	The models I prefer emphasize learner practice / performance of skills and abilities, and usually employ some variation of the 'show me, try me' strategy.	
	Air Force Instructional Design Models.	
	ADDIE	
	ADDIE	
	Since a main aspect of VR in safety training is performing a task in an environment that	

• What considerations do you believe should be used to determine the most appropriate instructional design model when designing full immersion virtual reality safety training? Please explain your reasoning.	simulates the real world, appropriate instructional design models should focus on relevance to job (true-to-life scenarios), real world performance, and measurable outcomes.	
	Model should contain the five ISD phases, analysis, design, development, implement, evaluate. The model should provide for a media analysis of learning objectives.	
	Systematic and iterative because the technology is always changing.	
	Models that make most use of constructivist theory to account for the learning controlling their path towards learning.	
• What other instructional design models do you believe could be used when designing full immersion virtual reality safety training? Please explain your reasoning?	The Knowledge / Skill Builder model would be an appropriate choice as it would easily be a good framework for the incorporation of VR and other modern learning techniques and strategies. This model is characterized by the following steps: • Gain attention • Set Direction / establish 'what's in it for me' • Present intro content • Practice and assess • Call to Action/connect to OJT application	
	US Navy ISD model	
	ADDIE, as project team members are more educated and accustomed to this instructional design model.	
	ADDIE as a personal favorite.	
• Which instructional design model do you believe would be the second most beneficial when designing full immersion virtual reality-based safety training? Please explain your reasoning?	The Content Mastery model would be an interesting choice as it is characterized by: • Collaborative, problem-based learning • Mastery via cumulative activities that are relevant and meaningful • Variety of learner interactions that allow for team-based VR learning experiences.	
	US Navy ISD model	
	Successive Approximation Model (SAM) in that it speaks the agile system of software development.	
	None	

Please explain your reasoning for ordering the specific practices.	

Appendix C: Round 3 E-mail Questionnaire Protocol

Please review all responses received and rank the top three best practices from the listing in order of importance. A rank of one represents the top best practice and three represents the lowest best practice.

Length: 30 minutes	
General Information	
Panelist Name: Date/Time email sent: Date/Time email response received:	
Questionnaire	
Responses	**Rank**
I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills.	
As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.	
I believe VR is best used for drill and practice and proficiency building, not initial learning.	
High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.	
Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive.	

Appendix D: Round 2 Response Rankings

Please review all responses received and rank the top five best practices from the listing in order of importance. A rank of one represents the top best practice and five represents the lowest best practice.

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
What design elements do you believe should be considered when designing full immersion virtual reality-based safety training?	I believe VR is best used for drill and practice and proficiency building, not initial learning.	0	5	4	1	2.5	2.38	4.88
	That there is a clear alignment between VR safety training activities, learning objectives, and assessment.	0	4	2	0	1.5	1.9	3.4
	Design should be heavily activity based.	0	1	3	1	1.25	1.25	2.75
	Strong analysis of the target audience and defining the desired learning outcomes.	0	0	0	0	0	0	0
What learning objective actions will be most appropriate when designing full immersion virtual reality-based safety training? Please explain your reasoning?	Since the benefit of VR is learner ability to experience an alternate physical reality that may inaccessibly or dangerous, or use equipment that is unavailable or expensive, objectives should require learner to successfully perform a task, operate equipment, or react to situation in the environment.	0	5	1	1	1.75	2.2	3.95
	Cognitive, psychomotor, and affective domain.	0	4	4	1	2.25	2.06	4.31
	Learning objectives should be demonstrative in nature. VR is primarily focused on activity of some sort.	0	3	2	1	1.5	1.29	2.79
	Learning objectives should be based on the desired change in behavior.	3	3	1	1	2	1.1	3.1

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
What learning activities do you believe should be used when designing full immersion virtual reality safety training? Please explain your reasoning?	Activities should align with objectives, to include in working in and using equipment in virtual (training) environments. For safety training, environments could be hazardous, enclosed physical spaces, etc.	0	4	2	0	1.5	1.9	3.4
	High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.	0	5	4	1	2.5	2.38	4.88
	Skill-based and measurable activities are needed to provide accurate feedback to trainees.	0	3	1	1	1.25	1.25	2.5
	Learning activities should really lend itself from the perspective of the learner's presence. VR that displays a third-party perspective or view is confusing and does not enhance learning.	0	5	3	0	2	2.44	4.44
What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training? Please explain your reasoning?	To ensure quality of finished training deliverable, a concern would definitely be accuracy of representation. This is directly impacted by quality of modeling related to game space and project assets.	0	4	2	4	2.5	1.91	4.41
	Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive	0	5	1	4	2.5	2.38	4.88
	The instructional designer should consider the limitations of the technology such as the inability to determine techniques used by the trainees.	0	3	3	0	1.5	1.73	3.23

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
	As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.	2	5	4	0	2.75	2.2	4.95
What practices do you use to overcome challenges experienced when designing full immersion virtual reality as a medium for safety training?	Practices require not skipping steps in Analysis and Design phases. This includes owning the responsibility to design courses mindfully, thoroughly analyze/understand learner population, and determine an appropriate evaluation plan before course development.	0	5	3	0	2	2.44	4.44
	VR is still an evolving technology and you will most likely learn as you go. What has been done in the past may not necessarily work in your particular situation.	0	4	4	3	2.75	1.89	4.64
	Multidisciplinary team.	5	2	1	0	2	2.16	4.16
	Strong subject-matter expert support.	0	4	0	0	1	2	3
What practices do you use to familiarize yourself with newly emerged aspects of virtual reality technology? Please explain your reasoning?	With rapid changes in technology, reviewing blog content and resources available on HW and SW sites is a good way to keep pace and determine what is feasible for a project.	0	3	2	3	2	1.4	3.4
	Attend VR trade shows, subscribe to VR magazines, join VF groups, do research on VR, discuss VR with engineering. Do small scale trial and error	4	4	1	0	2.25	2.06	4.31
	Research literature	0	0	3	3	1.5	1.5	3

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
	Conference attendance to stay at the forefront of the technology.	0	3	4	3	2.5	1.73	4.23
What practices do you use to gauge the technical abilities of the student population? Please explain your reasoning?	I've gauged technical abilities by having learner complete prerequisites / pretest or introduce the course with refresher activity.	0	0	2	5	1.75	2.36	4.11
	I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills	0	5	1	5	2.75	2,62	5.37
	Human observation	0	2	4	0	1.5	1.91	3.41
	Hard coding into the software as much as possible, such as timing and touch points.	0	0	3	0	0.75	1.5	2.25
What practices do you use to evaluate the usage of virtual reality in your safety training? Please explain your reasoning?	I would do a thorough task analysis to understand the tasks and how they are performed. I would derive a selection criterion for selecting VR tasks.	0	5	2	2	2.25	2.06	4.31
	Evaluating course effectiveness of VR safety training is consistent with evaluating non-VR training development efforts; business objectives must be established by stakeholders. Some organizations may require ROI projections to justify development costs.	0	5	2	2	2.25	2,06	4.31
	Human observation	0	2	3	2	1.75	1.25	3
	Gagne's Level three evaluation due to the direct on-the-job observation	0	4	4	2	2.5	1.91	4.41

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
Which instructional design model do you believe would be most beneficial when designing full immersion virtual reality-based safety training?	The models I prefer emphasize learner practice / performance of skills and abilities, and usually employ some variation of the 'show me, try me' strategy.	0	3	1	0	1	1.41	2.41
	Air Force Instructional Design Models.	0	4	2	0	1.5	1.91	3.41
	ADDIE	0	4	3	0	1.5	2.06	3.56
	ADDIE	0	4	4	0	2	2.3	4.3
What considerations do you believe should be used to determine the most appropriate instructional design model when designing full immersion virtual reality safety training? Please explain your reasoning?	Since a main aspect of VR in safety training is performing a task in an environment that simulates the real world, appropriate instructional design models should focus on relevance to job (true-to-life scenarios), real world performance, and measurable outcomes.	1	5	2	4	3	1.8	4.8
	Model should contain the five ISD phases, analysis, design, development, implement, evaluate. The model should provide for a media analysis of learning objectives.	0	5	4	0	2.25	2.62	4.87
	Systematic and iterative because the technology is always changing.	0	3	1	0	1	1.41	2.41
	Models that make most use of constructivist theory to account for the learning controlling their path towards learning.	0	5	3	0	2	2.44	4.44

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
What other instructional design models do you believe could be used when designing full immersion virtual reality safety training? Please explain your reasoning?	The Knowledge / Skill Builder model would be an appropriate choice as it would easily be a good framework for the incorporation of VR and other modern learning techniques and strategies. This model is characterized by the following steps: - Gain attention - Set Direction / establish 'what's in it for me' -'Present intro content - Practice and assess - Call to Action/connect to On-the-Job application	0	3	1	0	1	1.41	2.41
	US Navy ISD model	0	4	2	0	1.5	1.91	3.41
	ADDIE, as project team members are more educated and accustomed to this instructional design model.	0	4	3	0	1.75	2.06	3.81
	ADDIE as a personal favorite.	0	4	4	0	2	2.3	4.3
Which instructional design model do you believe would be the second most beneficial when designing full immersion virtual reality-based safety training? Please explain your reasoning?	The Content Mastery model would be an interesting choice as it is characterized by: - Collaborative, problem based learning - Mastery via cumulative activities that are relevant and meaningful - Variety of learner interactions that allow for team-based VR learning experiences.	0	3	2	0	1.25	1.5	1.75
	US Navy ISD model	0	4	4	0	2	2	4
	Successive Approximation Model (SAM) in that it speaks the agile system of software development.	0	3	1	0	1	1.41	2.41
	None	0	0	3	0	0.75	1.5	2.25
	None							

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
Please explain your reasoning for ordering the specific practices.	I ordered the practices based on the significance of the practice in terms of designing effective VR employing current technology and associated costs.							
	I ordered the practices based on the likelihood of their application resulting in a modern learning experience. There are only four responses per question, so I ranked top 4, with 1 being the first best practice.							
	1. ADDIE 2. Hard coding 3. Task analysis 4. Cognitive, psychomotor, and affective domain 5. Learning objective alignment							

Appendix E: Round 3 Response Rankings

Please review all responses received and rank the top three best practices from the listing in order of importance. A rank of one represents the top best practice and three represents the lowest best practice.

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
What practices do you use to gauge the technical abilities of the student population? Please explain your reasoning?	I would develop and employ a competency-based assessment program, I employ pre-and post-testing. However, the focus should be assessing psychomotor skills.	1	3	2		1.5	1.29	2.79
What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training? Please explain your reasoning?	As the primary purpose of using a VR simulated environment is to provide a safer learning environment, technology considerations should make it a point to reflect decisions or scenarios that would result in unsafe conditions.			3	2	1.25	1.5	2.75
What design elements do you believe should be considered when designing full immersion virtual reality-based safety training?	I believe VR is best used for drill and practice and proficiency building, not initial learning.	2	1			.75	.96	1.71
What learning activities do you believe should be used when designing full immersion virtual reality safety	High level cognitive scenario based, troubleshooting and problem solving. Difficult and critical psychomotor tasks.	3		1	3	1.75	1.5	3.25

		Panelist Rank						
Question	Response	1	2	3	4	Mean	Standard Deviation	84th Percentile
training? Please explain your reasoning?								
What technology considerations do you believe should be integrated into the learning activities when designing full immersion virtual reality safety training? Please explain your reasoning?	Fidelity requirements, how close to real world should VR be. The higher the fidelity requirement the more expensive.		2		1	.75	.96	1.71