DEVELOPMENT AND QUASI-EXPERIMENTAL EVALUATION OF A SCREEN-BASED VIRTUAL REALITY TUTORIAL

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DEVELOPMENT AND QUASI-EXPERIMENTAL

EVALUATION OF A SCREEN-BASED VIRTUAL

REALITY TUTORIAL

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Title of Study: DEVELOPMENT AND QUASI-EXPERIMENTAL EVALUATION OF A SCREEN-BASED VIRTUAL REALITY TUTORIAL

Major Field: OCCUPATIONAL EDUCATION STUDIES

Abstract: The challenges users face when interacting with screen-based virtual reality (VR) are addressed in this study with theories from the literature to open a line of inquiry into pre-immersion training development as described by Ausburn and Ausburn (2010). Cognitive load (Sweller, 1988) and wayfinding (Lynch, 1960) are discussed as potential theories underlying the challenges new virtual reality users face, and a tutorial is designed employing the theories of advance organizers (Ausbel, 1960), discovery learning (Bruner, 1961), and chunking (Miller, 1956; Anderson, 1977) alongside Gagne's (1965) nine events of instruction to supplant (Ausburn & Ausburn, 2003; Solomon, 1970) those challenges. The researcher-developed tutorial is quasi-experimentally evaluated and qualitatively assessed by the study participants to inform the development of an introductory checklist for designing VR training tutorials. The researcher found that the experimental tutorial helped participants navigate within virtual reality environments, promoted the transfer of training with curricular materials, helped users develop a sense of presence in the virtual environment, and supported a reduction of the subjects' perceived cognitive load. However, expected gender differences were not evident in the data, and while users' perceived cognitive load was reduced by using the tutorial, there was no significant effect on their learning performance, suggesting that other factors may influence performance in virtual environments. Also, instructional design flaws of the screen-based tutorial were discussed, and the VR tutorial design checklist was outlined.

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CHAPTER I

INTRODUCTION

Introduction and Background

Virtual reality (VR) provides a convenient way to boldly go where one can't normally go, or where it is inconvenient or dangerous to go in the process of learning. This capability is important in career and technical education (CTE). Ausburn and Ausburn (2010) wrote, "Today, a new generation of virtual technologies can remove the walls of traditional classrooms and dramatically expand the ability of CTE educators to take their students 'on location'" (p.1). Specific examples of the application of virtual technologies from CTE and workforce training include:

- Nursing/surgical technology students who need access to the sterile operating room
- Health inspectors who need to experience the environs of numerous kitchens, pools, and food preparation areas
- Platform refinery welders who work underwater
- Criminologists who benefit from examining blood spatter and other evidence from uncontaminated crime scenes

VR allows potential users to interact with these and a multitude of other imaginable environments to begin effective practice in any content field from the convenient location of a computer (Ausburn & Ausburn, 2008a). In addition, VR also possesses potential as an equalizing agent in the educational services CTE institutions are able to provide. Unfortunately, CTE schools receive varied levels of funding generally based on local taxes (Biddle & Berliner, 2002), and it is accepted that the quality of available programs and resources vary widely from institution to institution (Butrymowicz, 2012). With the application of VR as a training tool, however, learners in all CTE programs can gain anytime, anywhere virtual access to the best possible training equipment and programs available.

According to Waller (2000), when combined with limitless access to potential training venues, "Computer-simulated environments hold promise for training people about real-world spaces" (p. 3), and Bollman and Friedrich (n.d.) indicated that virtual environments (VEs) demonstrate the capability for the transfer of training to real world work. In addition, other studies have shown evidence of the advantages of teaching, learning, and motivating with VEs (e.g., Ausburn & Ausburn, 2004; Ausburn, Ausburn, Dotterer, Washington, & Kroutter, 2013; Boehle, 2005; Pantelidis, 1993; Raubal & Egenhofer, 1998; Riva, 2003; Selwood, Mikropoulos & Whitelock, 2000; Sulbaran & Baker, 2000; Wittenberg, 1995). These studies have indicated that VEs and VR represent a valuable resource for CTE, and that in order to tap into the potential of the VEs presented in VR, users must learn to both *control the VR interface* and *understand that the VE is an immersive world* where one can interact and learn about a complex environment and transfer the learned skills for future application in real-world settings (Ausburn & Ausburn, 2010). Gaining these understandings requires careful training of VE users and practice to develop required skills and thought processes. Two models have developed as potential outlines for this process: Ausburn and Auburns' (2010) Introduction to Virtual Reality model (IVR), shown in Figure 1, and the Virtual Reality Global Immersion System for Learning, shown in Figure 2 titled virtual reality global immersion system (VRGIS), conceived by this researcher. Both models describe necessary steps to help new users assimilate control of the VR interface and the concept of a VE as a "real" learning environment. The Ausburn and Ausburn model focuses on the content of VR user training, while the proposed immersive model focuses on theory-based processes involved in the training.

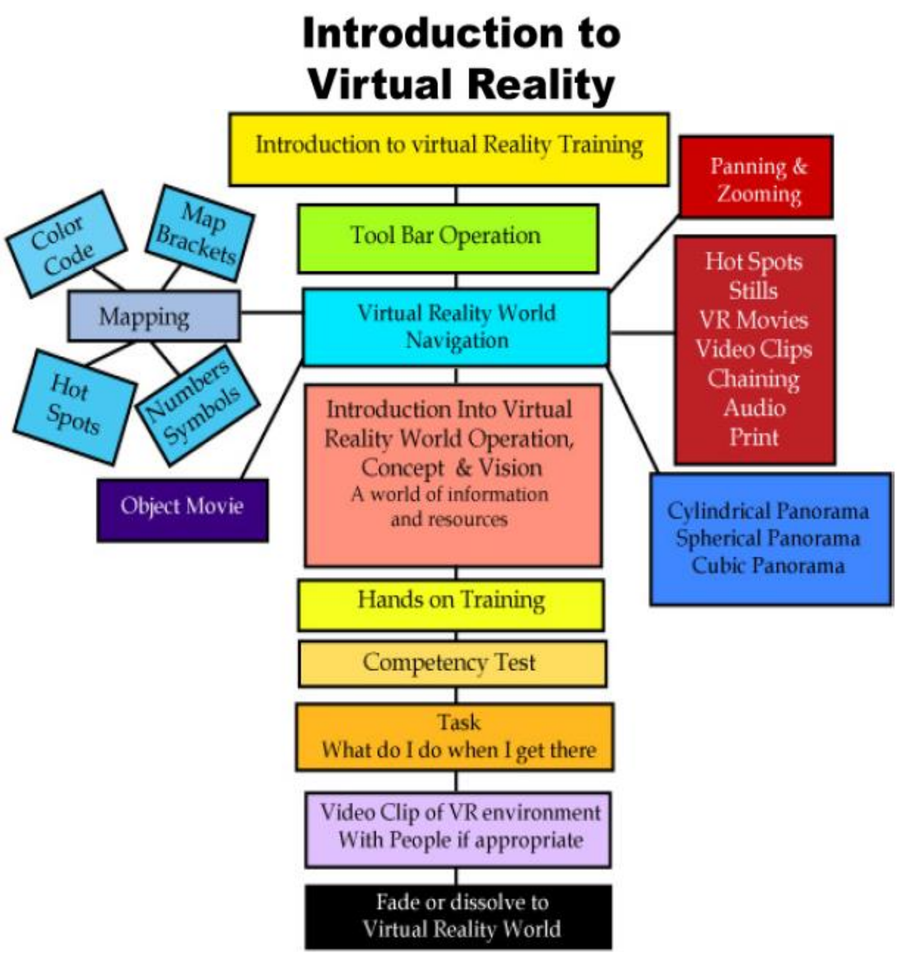

Figure 1: Introduction to Virtual Reality Training Model (IVR)
Source: Ausburn and Ausburn (2010)

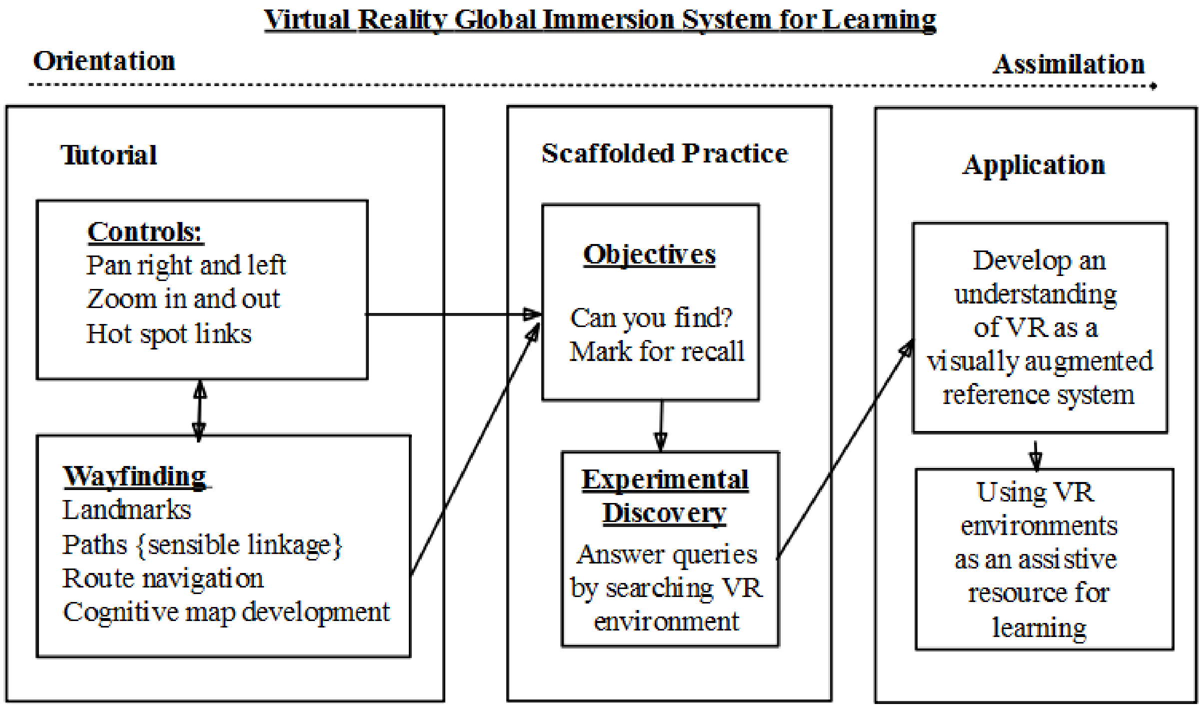

Figure 2: Theory Based VR Tutorial Design Developed by the Researcher
Virtual Reality Global Immersion System (VRGIS)

Several studies have demonstrated that users find understanding and controlling VR a considerable challenge (e.g., Ausburn & Ausburn, 2010; Ausburn & Ausburn, 2008b; Ausburn et al. 2010; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007; Ausburn et al., 2006; Boussard, Kermarrec, Buche, & Tisseau, 2008; Dotterer, Kroutter, Burkett, Braithwaite, & Jennings, 2008; Sanchez, Barreiro, & Maojo, 2000). In addition, gender-related issues complicate the matter further (Ausburn, 2012; Ausburn, Ausburn, & Kroutter, in press; Ausburn, Martens, Washington, Steele, & Washburn, 2009; Hunt & Waller, 1999; Lawton, 1994; Waller, Hunt, & Knapp, 1998). Ausburn and Ausburn (2010) summarized the challenges new users express with initial screen-based VR learning experiences as follows:

> …item analyses of post-test questions about user orientation and object location in our VEs has indicated that the "lost in space" phenomenon, failure to navigate effectively, and a lack of understanding of the learning purposes and goals of VE exploration are frequent occurrences despite our efforts to prepare learners through basic navigation training and explanation of what they should accomplish in their VE exploration. This quantitative evidence has been strongly reinforced by many

> qualitative comments from our research subjects and field research team members. (p. 9)

In view of the importance of training for users prior to VE immersion, this study (a) examined potential theoretical constructs at the core of the VR training challenges users face when interacting and learning with VR; (b) discussed a theoretically-informed design of a pre-immersion tutorial targeting the assimilation of VE learning in light of those constructs; and (c) experimentally evaluated the capability of the designed tutorial to improve users' experiences and understanding of VEs. Through this process, the researcher addressed improvement of the quality and expansion of the potential of VR in CTE training. The product of the study was a proposed checklist for future VR and multimedia designs that can help to diffuse the adoption of VR as an innovation from the decision stage to the implementation stage as described by Rogers (1962) in his diffusion of innovations theory.

Introduction to Screen-based Virtual Reality

Definition of Virtual Reality

Selwood, Mikropoulos, and Whitelock (2000) described VR as follows:

> Virtual Reality (VR) can be described as a multi-sensory highly interactive computer based environment, where the user becomes an active participant in a virtually real world. Freedom of navigation and interaction are essential for a computer environment to be characterized as a VR environment (virtual environment, VE) and in a sense the Virtual Reality system offers an extension of our normal experiences allowing as many degrees of freedom as possible to perform a given task.
>
> VR systems are generally classified according to the types of technology employed to implement the system and range from simulators and emulators, telepresence systems, CAVE systems, fully immersive systems, augmented systems and desktop VR systems. Depending on the level of the user's participation and interaction with the virtual environment, VR applications are also subdivided into passive, explorative or interactive environments. Unfortunately researchers and designers alike do not agree about the final generic term given to their systems and use a number of different terms for their working virtual reality systems. The most common include artificial reality, cyberspace, telepresence, and virtual reality. We believe that the term virtual reality is the most general and covers the whole field …. (p.233)

Ausburn and Ausburn (2004) simplified the description of VR with, "In all its manifestations, VR is basically a way of simulating or replicating an environment and giving the user a sense of 'being there', taking control, and personally interacting with that environment with his/her own body" (p. 34).

Creating Virtual Environments

Five basic components are needed to create a VR environment: a computer, source materials (i.e. image files, audio files, video files), VR software (to combine the source files into a usable VE), an input device for the user, and an output device to view the VE and the effects of interacting with the software (Wittenberg, 1995). As mentioned above, VR systems exist with varying levels of complexity, cost, and levels of perceived user presence (the feeling of really being in an environment) (Mikropoulos, 2006). For CTE educators, selecting the highest quality VR medium with sustainable costs, designs, and maintenance requirements is paramount to developing reusable training objects to prepare students for the world of work (Parrish, 2004). With these considerations in mind, screen-based VR may offer an acceptable medium.

Screen-based VR

Screen-based VR combines the use of simple navigation controls with the presentation of high-resolution panoramic imagery on a computer to provide a low-cost, non-immersive VE for learning in any imaginable location (Ausburn & Ausburn, 2008a). Ausburn, Martens, Washington, Steele, and Washburn (2009) outlined the construction of VR environments as follows:

> Desktop VR "movies" are created by taking a series of digital still photographic images and then using special VR software to "stitch and blend" the images into a

> single panoramic scene that the user can "enter" and explore individually and interactively. The user employs a mouse to move and explore within an on-screen virtual environment as if actually moving within a place in the real world. Movements can include rotating the panorama image to simulate physical movements of the body and head, and zooming in and out to simulate movements toward and away from objects or parts of the scene. Embedded individual virtual objects can be "picked up," rotated, and examined as the user chooses, and clickable "hot spots" can also be used to navigate at will (Ausburn & Ausburn, 2008b; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007). What characterizes these desktop VR movies and distinguishes them from traditional video is that the user chooses where, when, and how to move, explore, and examine rather than being controlled by the prior production decisions of a videographer (Ausburn & Ausburn, 2004). (pp. 54-55)

The construction of such desktop VR "movies" allows instructional designers to develop learning/training programs and treatments with improved efficiency and productivity in preparing the future workforce (Ausburn & Ausburn, 2008b). Unfortunately, while the building blocks for effective VR training programs are readily available, the difficulties experienced by new VR users remain a challenge for instructional designers. This situation provided the impetus for the present study. The researcher addressed these issues through the development and empirical testing of an original theory-based virtual reality tutorial.

Outline and Organization of the Present Study

The stages of this study included the development and then the assessment of a theoretically-driven VR tutorial design. The design and development of the tutorial were completed by the researcher over a period of six years prior to undertaking the empirical testing phase of the study. This dissertation presents the development and testing of the researcher-developed VR tutorial in five chapters. First, Chapter I presents an introduction to the study through sections on instructional design considerations for the VR tutorial; a definition of terms; the statement of the problem; the purpose of the study; the research questions; a description of the theoretical and conceptual framework discussing the literature that offers a theoretical basis for addressing the difficulties new VR users face; the assumptions and limitations of the study; and the significance of the study.

Second, in Chapter II, a literature review is provided to further outline the theories involved in the study and introduce potential measures for the theoretical constructs applied in the design and assessment of a theory-driven VR tutorial training solution. In Chapter III, the methodology for the empirical assessment of the tutorial is presented. Finally, the results of the study and conclusions of the researcher are offered to inform future research in Chapters IV and V, respectively.

Instructional Design Considerations for the VR Tutorial

Instructional design theory played an important role in informing the researcher's development of the VR tutorial for this study. Martens (2012) provided a brief overview of the history of instructional design theory:

> Reiser (2001) outlined the history of instructional design starting from World War II, during which educators and psychologists worked with the military, both to develop training and to evaluate the skills of trainees to find the most suitable training for them. Work in both instructional design practice and research by this group of educators and psychologists continued after the war. Reiser noted that the major influences in instructional design that occurred in the decades of the 1950s and 1960s include B. F. Skinner's work on programmed instruction; Robert Mager and Benjamin Bloom's work on behavioral objectives; Robert Glaser's work on criterion-referenced testing; and Robert Gagné's work on domains of learning, events of instruction, and hierarchical task analysis. The 1970s saw the establishment and growth of the ISD (instructional system design) model, originally in the military, later expanding to business and industry, and continuing to rapidly grow through the 1980s. (p. 232)

The VR tutorial designed for this study generally followed Gagne's (1965) domains of learning based on the manner in which adult learners process information when presented with curriculum. According to Gagne, there exist nine events of instruction that address learning. Figure 3 illustrates Gagne's nine instructional events and the internal mental processes associated with each event.

Instructional Event	Internal Mental Process
1. Gain attention	Stimuli activates receptors
2. Inform learners of objectives	Creates level of expectation for learning
3. Stimulate recall of prior learning	Retrieval and activation of short-term memory
4. Present the content	Selective perception of content
5. Provide "learning guidance"	Semantic encoding for storage long-term memory
6. Elicit performance (practice)	Responds to questions to enhance encoding and verification
7. Provide feedback	Reinforcement and assessment of correct performance
8. Assess performance	Retrieval and reinforcement of content as final evaluation
9. Enhance retention and transfer to the job	Retrieval and generalization of learned skill to new situation

Figure 3: Gagne's Nine Events of Instruction

Source: Kruse (2006)

These overarching conditions for learning provided the basic structure for the design of the VR tutorial for this study. In order to meet each condition, additional theories further informed the instructional design of the tutorial as means to address elements of the nine conditions for learning. Specifically, the following learning theories and principles were applied to accomplish the nine conditions of learning: discovery learning (Bruner, 1966), advance organizers (Ausubel, 1960), and chunking (Miller, 1956). These theories were applied with the intention of supplanting or scaffolding the challenges users face when interacting with VR environments (Ausburn & Ausburn 2003; Salomon, 1970), and supporting users with the intended transfer of training/learning (Yamnil & McLean, 2001) about VEs and their application.

Definition of Terms

Conceptual Definitions

1. Advance Organizers: An instructional design theory that asserts "… the learning and retention of unfamiliar but meaningful verbal material can be facilitated by the advance introduction of relevant subsuming concepts (organizers)" (Ausubel, 1960, p. 267).
2. Chunking: "… a process of organizing or grouping the input into familiar units or chunks …" (Miller, 1956, p. 349).
3. Cognitive Load Theory: A learning and instructional design theory that asserts learning is made more difficult when working memory is overloaded and that one goal of instructional design is to minimize unnecessary working memory load. According to cognitive load theory, "…prime goals of instruction are the construction and the automation of schemas that are useful for solving the problems of interest. Although schemas are stored in long-term memory, in order to construct them, information must be processed in working memory. Relevant sections of the information must be extracted and manipulated in working memory before being stored in schematic form in long-term memory. The ease with which information may be processed in working memory is a prime concern of cognitive load theory" (Sweller, Merrienboer, & Paas, 1998, p. 258-259).

4. Screen-based Virtual Reality: "…desktop screen-based semi-immersive imagery under direct control of the learner" (Ausburn & Ausburn, 2004, p. 33), presented on a standard desktop or laptop computer.
5. Discovery Learning: "… an approach to instruction through which students interact with their environment-by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments" (Ormrod, 1995, p. 442).
6. Orientation/Wayfinding: "… our awareness of the space around us, including the location of important objects in the environment. Orientation in space is crucial for finding one's way (or wayfinding) from one location to another" (Hunt & Waller, 1999, p.4).
7. Supplantation Theory: An instructional design theory that advocates "…the explicit and overt performance or alteration of a learning task requirement that learners would otherwise have to perform covertly for themselves" (Ausburn & Ausburn, 2008b, p. 61).
8. Transfer of Training: The transference of knowledge or skill from a training environment to a different environment. According to this theory, "The final purpose of education or training is to apply what we have learned in different contexts and to recognize and extend that learning to completely new situations" (Bossard, Kermarrec, Buche, & Tisseau, 2008, p. 151).
9. Virtual Environments: "Virtual environments denote a real-time graphical simulation with which the user interacts via some form of analog control, within a spatial frame of reference and with user control of the viewpoint's motion and view direction" (Moshell & Hughes, 2002, p. 893).

10. Virtual Reality: "In all of its manifestations, VR is basically a way of simulating or replicating an environment and giving the user a sense of being there, taking control, and personally interacting with that environment with his/her own body" (Ausburn & Ausburn, 2004, p. 33).

Operational Definitions

1. Cognitive Load: The ease with which participants felt that they processed information during the evaluation of this study's VR tutorial was measured by items 23 - 25 of the study's orientation/wayfinding instrument, an adaptation of Hogg's (2007) cognitive load rating scale.
2. Orientation/Wayfinding: The capability of this study's participants to be able to orient and thus wayfind in a VR environment was measured by the scores from questions 6 – 22 of the orientation/wayfinding instrument adapted from Ausburn, et al., 2006.
3. Transfer of Training: Transfer of training refers to an individual's capability to effectively put into practice previously learned content. In this study, the transfer of training construct was measured through comparisons of the pre- and post- test of the surgical environment assessment and results from the orientation/wayfinding instrument.

Statement of the Problem

The problem for this study was that VR researchers and designers do not yet know how to consistently and effectively prepare new VR users to function in a screen-based VE. Both theory and empirical research have recognized that an unfamiliar VR interface can magnify the cognitive load (Sweller, 1988) challenges new users face while orienting and wayfinding (Lynch, 1960) in varied environments to the point of prohibiting meaningful learning and that interface familiarity is a critical element in performance in VEs (Hunt & Waller, 1999). Thus, informing potential learners about the interface prior to immersion in VEs represents a significant current challenge to the successful implementation of VR as an instructional tool. Until pre-immersion user training issues are resolved, VR is unlikely to reach its full potential.

Purpose of the Study

The purpose of this study was three-fold. The study was designed to: (a) develop a theory-based tutorial on using VR/VEs; (b) evaluate experimentally the effectiveness of the tutorial; and (c) based on the findings of the experiment, determine if a theoretically sound checklist could be developed for instructional designers to employ when creating pre-immersion training materials for VR. In light of the difficulties new VR users face learning to use the technology, the evaluation of the experimental tutorial measured the differences between users' perceived cognitive load and their orienting/wayfinding ability based on treatment group (i.e., use/non-use of tutorial prior to VE immersion) and gender. Gender was included as a second independent variable because of documented gender effects in VEs (Ausburn, 2012; Ausburn, Ausburn, & Kroutter, in press; Ausburn et al., 2009; Kroutter, 2010). The online VR tutorial was designed to allow potential users to acclimate to the controls and functions of VR as a learning environment, and supplant (Ausburn & Ausburn, 1978; Salomon, 1970), or scaffold, the challenges users face in order to advance the adoption of VR as a training tool. Through this evaluation process, several of the key components to effective implementation of VE learning mentioned by Ausburn and Ausburn (2010) were addressed, filling a gap in the current research, enhancing users' sense of a physical "presence", or feeling of "being there" (International Society for Presence Research, 2000) in the VE, and informing future research to enhance the designs and the value of implementing VR in CTE training.

Research Questions

This dissertation focused on the development and evaluation of a theoretically-based VR tutorial and resultant design checklist that can inform future tutorial designs and research. In this light, the research questions and, where appropriate, the inferential statistical hypotheses for the study were:

1. What instructional design theories inform screen-based VR tutorial and multimedia-based designs?
2. Do differences in mean performance exist between wayfinding/orienting capabilities of participants based on treatment group (i.e., use/non-use of VR tutorial)?

   H_{01}: No differences exist between mean wayfinding/orienting capabilities of participants based on treatment group.

   H_{A1}: Differences do exist between mean wayfinding/orienting capabilities of participants based on treatment group.
3. Do differences exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group (i.e., use/non-use of VR tutorial)?

   H_{02}: No differences exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group.

   H_{A2}: Differences do exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group.

4. Do differences exist between genders concerning mean wayfinding/orienting capabilities based on treatment group (i.e., use/non-use of VR tutorial)?

   H_{03}: No differences exist between genders concerning mean wayfinding/orienting capabilities based on treatment group

   H_{A3}: Differences do exist between genders concerning mean wayfinding/orienting capabilities based on treatment group

5. Do differences exist between genders concerning reported sense of cognitive load?

   $H_{04:}$ No differences exist between genders concerning reported sense of cognitive load

   H_{A4}: Differences do exist between genders concerning reported sense of cognitive load

6. Do differences in mean performance exist between transfer of learning/training for participants based on treatment group (i.e., use/non-use of VR tutorial)?

   H_{05}: No differences exist in mean performance between transfer of learning/training for participants based on treatment group

   H_{A5}: Differences do exist in mean performance between transfer of learning/training for participants based on treatment group

7. Can a checklist be developed from this study to guide design of effective screen-based VR training tutorials?

Theoretical and Conceptual Framework

As discussed previously, Figure 2 outlines the hypothesized outcomes for the theoretically-informed VR tutorial. Figure 4 takes the process one step further, outlining the theoretical and conceptual framework applied in this study. To expand upon the relationship between these theories, several topics are included. First, Figure 2 presents the theories of wayfinding (Lynch, 1960), orienting (Hunt & Waller, 1999; Padgett, 2002), and cognitive load (Sweller, 1998) as they represent a theoretical basis from the literature that may explain the difficulties that new virtual reality (VR) users encounter. Second, the instructional design theories concerning discovery learning (Bruner, 1961), advance organizers (Ausubel, 1960), and chunking (Anderson, 1977, 1996; Miller, 1956) used to inform the development of a VR tutorial (vrtutorial.com) are presented as tools to address the aforementioned difficulties and align the design of the tutorial with Gagne's nine events of instruction. Third, the tutorial is depicted as a tool to supplant (Ausburn & Ausburn, 1978; Salomon, 1970) users' abilities to achieve transfer of training/learning (Yamnil & McLean, 2001) in VEs. Finally, gender is pictured as an intervening variable that may additionally affect the participants' change in behavior, cognition, or performance intended from the application of the tutorial as a supplantation tool.

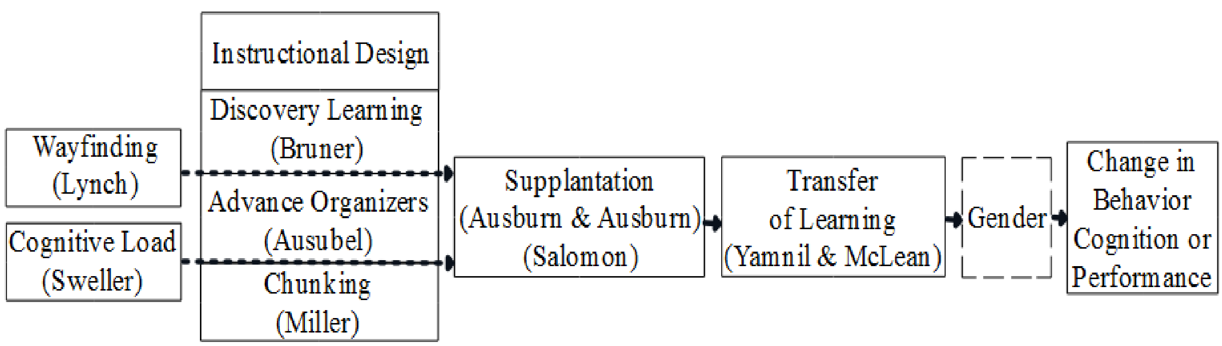

Figure 4: Theoretical/Conceptual Framework for the Study

Assumptions and Limitations of the Study

Assumptions

1. The instruments have construct validity and accurately measure the intended constructs based on the literature.

2. The sampling method provided nearly equivalent groups for comparison.

3. The participants possessed basic computer skills to access the tutorial and assessments.

4. The study's participants made good-faith effort to respond accurately to the instruments.

If these assumptions were not met by the study design, the outcomes from the data analyses would be negatively affected. A lack of construct validity, in-equivalent groups, the participants' inability to interact with the tutorial, and/or falsified responses would skew or potentially invalidate the results of the intended statistical and qualitative analyses.

Limitations

1. Use of a relatively small non-random sample makes generalizability of the study's findings and conclusions difficult and must be done with caution.
2. The relatively new instrumentation used in the study, carrying limited psychometry from use in previous research, raises questions about validity. These questions provide further cautions about the generalizability of the study's findings and conclusions.
3. Only the orientation aspect of wayfinding performance in a VE is evaluated in the study. Effects of the tutorial on other aspects of wayfinding performance must be addressed in further research.
4. Transfer of learning/training is measured as a change in performance on a single comparison of pre-test/post-test data. Future research must address the remaining aspects of transfer of learning/training.
5. Prior experience of VR users was not assessed in this study and may have affected performance outcomes in ways unknown to the researcher.
6. Participants may have lacked experience with technology due to economic or other factors, which may have affected performance outcomes in ways unknown to the researcher.

Significance of the Study

In response to calls in the research literature (Ausburn & Ausburn, 2012; Kroutter, 2013) for appropriate training of VR users prior to immersion in screen-based VEs, this study created and assessed experimentally a theoretically-based laptop VR tutorial design that addressed the difficulties new users experience when engaged with VR. The tutorial applied the instructional design theories of discovery learning, advance organizers, and chunking as tools to supplant both orienting/wayfinding and cognitive load in order to enhance the transfer of training resulting from user engagement with VR learning sessions. Through the experimental assessment process, several key components to effective implementation of VE learning were addressed (Ausburn & Ausburn, 2010), filling a gap in the current VR research, enhancing users' sense of a physical "presence", or feeling of "being there" in the VE, and informing future research to enhance the value of implementing VR in CTE training. As a final product, a checklist was developed and presented as a tool to guide CTE instructors and instructional designers in the creation of training tutorials that may help new VR/VE users learn effectively and efficiently from this emerging and exciting technology. Thus, this study addressed needs and interests of both researchers and practitioners in ways that can help advance the adoption of VR technology for technical, career, and workforce education.

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CHAPTER II

REVIEW OF LITERATURE

This goal of this study was to test empirically a researcher-developed pre-immersion tutorial for users of screen-based VEs and to then use the tutorial and the results of its test to develop a checklist to guide CTE instructors and other instructional designers as they work to extend the application of VEs and VR in educational settings. To discover which items should be included in the tutorial and on the checklist, several theories were reviewed interlaced with notes from the author describing:

- an outline of the challenges new VR users face with wayfinding, orientation, and cognitive load and potential measures for those constructs
- the role these constructs may play in influencing users' sense of presence in VEs
- the role and efficacy of supplantation theory (Ausburn & Ausburn, 1978; Salomon, 1970)
- chunking, advance organizers, and discovery learning theories
- the application of those theories to inform the instructional design of the VR tutorial and supplant the aforementioned challenges as a means to support the progressive transfer of training/learning (Yamnil & McLean, 2001) in VR and VEs for CTE educators and other instructional designers.

This review of literature addressed research question #1 for this study: *What instructional design theories inform screen-based VR tutorial and multimedia-based designs?* The findings from the literature provided guidance and theoretical foundation to the researcher for the design and development of the VR tutorial used as the experimental treatment in the empirical phase of the study.

Theories Outlining Current Challenges for VR

Three constructs stood out in the literature concerning the difficulties users may face in interacting with VR and VEs: wayfinding, orientation, and cognitive load. A description of these theories follows.

Wayfinding

The challenges of wayfinding and orienting as described below may help explain part of the "lost in space" phenomenon experienced and reported by VR users that may inhibit their sense of *presence* (or actually "being there") in VR. *Wayfinding* historically refers to techniques used by travelers to find routes to various physical destinations. Lynch (1960) formally defined wayfinding as the consistent use of definite sensory cues from the external environment to find one's way. Therefore wayfinding requires knowledge about one's current location, the intended destination, and the spatial relation between them (Chung, 2008). The difficulties that arise in the process of wayfinding include knowing where one is, where to go, and how to get from one place to another (Raubal & Egenhofer, 1998). Additionally, Jul (2001) added that wayfinding also includes directing the activities needed to find one's way successfully.

While wayfinding has been clearly defined for the physical world, Reiss (2001) helped move wayfinding theory into virtual environments as he described the process of using spatial and environmental data to navigate within built or constructed worlds. Darken and Sibert (1996) also conveyed that wayfinding in the physical world directly relates to virtual environments, however, they also stated that little support has been provided to inform effective wayfinding in virtual worlds, and Satalich (1995) added that designers are unsure of an efficient method to introduce learners to new environments and navigation within them. This situation provided part of the motivation for this researcher to develop the instructionally-designed VR tutorial to address these issues. Although the inherent difficulty of designing a program to study the development of learners' wayfinding skills through interactions with VEs may force some researchers to question the value of such a study, evidence supporting the value of research concerning the use of virtual environments, and thus wayfinding in those environments, is abundant. For example, Raubal and Egenhofer (1998) cited other researchers as follows:

> Goldin (1982) compared actual and simulated information as alternative sources of environmental information and concluded that under some conditions, for instance, when the goal is to convey perceptual details, a film or slide presentation may provide as much detail as a live tour through the environment, Allen (1978) suggested that a "presentation of slides separated by spatial intervals may closely parallel typical visual experience in large-scale environments" and used such procedure to assess the relationship between peoples' visual perception and spatial representation of an urban environment. (p. 902)

Furthermore, Satalich (1995) concluded that learners do not have to be in an actual environment to learn to wayfind, but cannot determine if active or passive involvement in an available environment is best suited for efficiency in that learning. As displayed by Satalich, comparing active and passive learner involvement in the introduction of VE navigation provides further support concerning the need and relevance for this kind of study. This researcher supports a need for studies of learner involvement and incorporated this construct into the present study. The instruments used to compare the active involvement included in this study's tutorial design are explained in Chapter III.

Jul (2001) asserted that wayfinding occurs alongside decision-making to aid in achieving any super-ordinate tasks which the user desires to accomplish. Timpf, Volta, Pollock, and Egenhofer, (1992) concurred with Jul as they referred to the reasoning process involved in successfully navigating in virtual environments. For learners to address super-ordinate tasks they must be able to wayfind in new environments. The question leads again to, "What do learners need to wayfind?" Boling (2001) offered the following questions learners ask about wayfinding in space: (1) Where am I? (2) Where can I go? (3) What can I do here? (4) How do I get back to where I was? and (5) How do I get out of here? While these questions appear simple, the burden of formulating answers is demonstrated by statements from Timpf, et al. (1992) in their discussion of the problem of simply navigating the Interstate Highway Network: "We applied diverse, previous research in such areas as spatial reasoning, default reasoning, formal methods, navigation and cognition to explore the problem"(p. 361). Evidently, the cognitive processes involved in wayfinding are highly complex and involve a vast array of skills, perceptions, and cognitive functions. When combined with the necessity of navigating an unfamiliar computer graphical user interface in order to answer wayfinding questions, the potential for increased cognitive load during wayfinding rises dramatically within VEs.

For the instructional designer then, applying theories and strategies to develop support systems augmenting users' construction of the necessary wayfinding schema concerning both the environment and the user interface for VR and VEs is an important goal. Darken and Sibert (1996) also commented on the need for innovative instructional design techniques to aid in the development of effective learning support systems for VR interfaces. The literature also provides sufficient support concerning the theory underlying the employment of varied designs to enhance learning (Keppel & Wickens, 2004).

As stated above, Timpf, et al. (1992) described the fundamental processes learners undertake in a new environment and the development of users' personal cognitive structures to aid in wayfinding. The literature suggests that learners attempt to reorganize their previous knowledge and skill sets to assimilate navigation and wayfinding alongside control systems manipulation in new environments by constructing various schema or strategies to provide a foundational structure to learn from (Anderson, 1977). Similar structuring (or scaffolding) is also necessary as learners attempt to navigate in virtual environments. Ausburn and Auburns' (2010) Introduction to Virtual Reality (IVR) training model (shown in Figure 1 in Chapter I) moves this concept toward fruition as a potential guide for aiding schema acquisition in virtual environments. Furthermore, the researcher's Virtual Reality Global Immersion System for learning (VRGIS; shown in Figure 2 in Chapter I) focuses on several elemental processes from the IVR. The VRGIS addresses the following elements of the IVR:

- Tool bar operation
- Virtual reality world navigation
    1. Panning and zooming
    2. Hotspots
    3. Stills

4. VR movies
5. Video clips
6. Audio
7. Cylindrical panorama

- Hands on training
- Task
- Competency test

The VRGIS outlines the steps taken to scaffold or supplant users' difficulties with acquiring schema concerning VR navigation from a user's orientation phase through the assimilation phase. In the first stage, the tutorial addresses orienting the user to the controls and wayfinding. The second stage provides the user with scaffolded practice which further supports searching and wayfinding in the VE and presents tasks to provide a means to assess users' competency with orienting and navigating in a cylindrical panorama, the cognitive load experienced, and the achievement of curricular goals. Through this process, the tutorial assists users' acclimation to VR as a visually augmented reference system that assists learning as depicted in the third and final stage of the VRGIS.

Although it is possible to gather data to assess wayfinding as a whole, due to the complex nature of the construct, *orientation*, the foundational element for wayfinding, was selected rather than wayfinding itself for measurement in this study based on similar applications in prior literature (Cubukcu, 2003; Ausburn, et al. 2006; Ausburn & Ausburn, 2008) to offer a preliminary assessment of the effectiveness of the VR tutorial as a orienting/wayfinding aid. A description of the literature concerning orientation follows.

Orientation

As discussed above, in order to wayfind, one must first know where one is. In fact, it is the element of *spatial orientation* that needs to be examined before an understanding of wayfinding is possible in both real and virtual environments (Chung, 2008; Darken & Sibert, 1996; Lynch, 1960). Chen and Stanney (1999) supported the need for orienting as they described a general theoretical model of wayfinding that can be used to guide the design of navigational aiding in virtual environments:

> Based on an evaluation of wayfinding studies in natural environments, this model divides the wayfinding process into three main sub processes: cognitive mapping, wayfinding plan development, and physical movement or navigation through an environment. While this general subdivision has been proposed before, the current model further delineates the wayfinding process, including the distinct influences of spatial information, spatial orientation, and spatial knowledge. (p. 671)

Kroutter (2010) also outlined orientation as a building block for wayfinding, citing several relevant sources from the literature:

> Orienting is the ability to acquire one's bearings in an environment. Blade and Paddgett (2002) defined orientation as a sense of up and down or north, south, east, and west. Orientation allows individuals to determine where they are, which direction they came from, and where they want to go. Hunt and Waller (1999) described orientation as "Our awareness of the space around us, including the location of important objects in the environment. Orientation in space is crucial for finding one's way from one location to another" (p. 4). Hunt and Waller explained that "A person is oriented when he knows his own location relative to other important objects in the environment, and can locate those objects relative to each other" (p.4). (p. 6)

Therefore, a user's sense of orientation in a VE was assessed in the present study to provide a preliminary indicator of surgical technology students' capability to wayfind in virtual environments. A detailed explanation of the assessment methods utilized in this study is presented in Chapter III.

Unfortunately, wayfinding and orientation are not the only obstacles new VR users face. As mentioned above, controlling the unfamiliar computer interface and interacting with curriculum information also confound users' ability to effectively interact with VR while learning. Sweller (1988) offered a possible explanation for this complicating effect: the cognitive load construct.

Cognitive Load

Cognitive load consists of the information involved in working memory where all conscious cognitive processing occurs (Weiss & Dotterer, 2012). Unfortunately, according to both foundational and current information processing theory, working memory can only handle a very limited number of novel interacting elements (Miller, 1956; Paas, Renkl, & Sweller, 2003), and the current manifestation of screen-based VR systems utilized in education requires users to simultaneously interact with the VR controls, wayfinding processes, and achievement of curricular goals. Unfortunately, processing large amounts of concurrent information increases the challenge of short term memory retention, leading to assimilation and storage problems in long term memory. Cognitive load theory provides guidelines for presenting information through instructional activities that optimize processing and enhance working memory to attain high learning performance in such complex systems (Sweller, Van Merrienboer, & Paas, 1998). This is achieved by helping individuals build on previous experiences to develop schema (Anderson, 1977) for assimilating each element of the VR interface, which in turn helps minimize cognitive load and aids learning and the adaptation of existing schema. Thus the concept of *chunking* of information can be hypothesized to assist learners adapt schema. This concept is addressed later in this literature review as an instructional design tool applied in the development of the VR tutorial for this study.

As stated, in a virtual reality environment, cognitive load elevates as learners must process both wayfinding in the VE and the functions of the on-screen controls in addition to the examination of the intended information or curriculum content. The cognitive load compounds as learners are distracted by the process of controlling the VR interface which is far removed from the super-ordinate task at hand (Jul, 2001). These irrelevant (to the content to be learned) VR tasks constrain the efficiency of acquiring skills or retaining information during a learning experience (Chandler & Sweller, 1991). The effect is similar to taking a test written in a foreign language and discovering that the words must be translated before the questions are understood and attempted.

Cognitive load theory possesses great potential for informing instructional design strategies (Sweller, 1999). For example, Cooper and Sweller (1987) related that studying previously-worked-out problems or examples facilitates learning as compared to a pure problem solving approach. Therefore, presenting the learner with examples of wayfinding strategies and control functions throughout a tutorial experience can be hypothesized to ease the amount of cognitive load encountered and scaffold the assimilation of the VR learning experience to existing schema, improving learning outcomes.

From the foundational theoretical constructs of wayfinding, orientation, and cognitive load defined above, this theoretical discussion next turns to the literature relating to particular established instructional design theories included in the design of a screen-based VR tutorial which this researcher developed and proposed could scaffold users through their initial experiences with VR environments. Discovery learning (Bruner, 1961), advance organizers (Ausubel, 1960), and chunking (Anderson, 1977, 1996; Miller, 1956) are offered in the following sections as effective instructional design strategies for this purpose.

Instructional Design Theories

Discovery Learning

Ormrod (1995) described *discovery learning* as, "…an approach to instruction through which students interact with their environment-by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments" (p. 442). To support learners and learning, Bruner (1966) stated that a theory of instruction should address four major aspects: (1) predisposition towards learning, (2) the ways in which a body of knowledge can be structured so that it can be most readily grasped by the learner, (3) the most effective sequences in which to present material, and (4) methods for structuring knowledge that result in simplifying, generating new propositions, and increasing the manipulation of information. In addition, Bruner reminded researchers that the task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding, and that any domain of knowledge can be represented in three ways or modes: by a set of actions (enactive representation); by a set of images or graphics that stand for the concept (iconic representation); and by a set of symbolic or logical statements (symbolic representation).

The VR tutorial developed for this study was designed with these principles in mind. First, the design presupposes the participants' desire to learn and utilizes the concepts of advance organizers (Ausubel, 1960) and chunking (Anderson, 1977, 1996), discussed below, to structure the experience supporting learning. Second, the most effective sequences of instruction were specified via the semi-linear nature of the web-based tutorial and the included audio/visual instructional segments leading the learner through the content and providing a built-in spiral review of the new information in order to increase the user's ability to grasp, transform, and transfer what is learned. These design features combine Bruner’s (1966) suggested sequencing from enactive (hands-on, concrete), to iconic (visual), to symbolic (descriptions in words or symbols) in a dynamic presentation. Finally, feedback is provided to the learner at critical junctures in the tutorial, following Bruner’s recommendations, providing the vital link for increased contextualized learning and improving the VR learning experience.

Advance Organizers

Ausubel (1960) introduced *advance organizers* as a cognitive instructional strategy promoting the learning and retention of new information. According to Mayer (2003), an advance organizer consists of information presented prior to learning used by the learner to organize and interpret incoming information. The ability of advance organizers to facilitate learning has been debated (Hartley & Davies, 1976; Mayer, 1979), however the same research indicated that the use of advance organizers correlates with improved understanding and recall for users. In effect, advance organizers supposedly clarify the task ahead by providing anchor points for contextualizing new material or experiences (Hartley & Davies, 1976). Effective advance organizers allow users to generate some or all of the logical relationships in the to-be-learned material and provide a means of relating unfamiliar material to existing knowledge and aiding schema acquisition (Mayer, 1979).

The advance organizers included in the VR tutorial designed for this study consist of automated videos combined with audio instructions that demonstrate the upcoming skills users will need as they advance through the elements of the tutorial. These videos provide foundational experiences that prepare the learners to perform the requested tasks that follow. In this manner, the advance organizers help to minimize the cognitive load incurred in learning about the VE by providing examples of expected actions prior to forcing the user to interface with the VR controls, making it easier to augment their existing schema.

Chunking

In his classic information processing theory and model, Miller (1956) proposed and advocated the importance of grouping or organizing information into small pieces or *chunks* to increase learners' capability to retain larger amounts of information and help augment schema. In support, Anderson (1996) proposed the ACT-R theory, stating:

> The Adaptive Character of Thought (ACT-R) complex cognition arises from an interaction of procedural and declarative knowledge. Procedural knowledge is represented in units called production rules, and declarative knowledge is represented in units called chunks. The individual units are created by simple encodings of objects in the environment (chunks) or simple encodings of transformations in the environment (production rules). A great many such knowledge units underlie human cognition.... (p.355)

In other words, to build an understanding of a complex experience, the human mind processes a compilation of chunked information a bit at a time via constructed procedures to move the entire process through the working memory to store the end result in long term memory as developed expertise in the experience (Eysenck, 2004). Anderson's (1996) ACT-R theory assumes that skill acquisition involves knowledge compilation; a shift from the use of declarative knowledge to the use of procedural knowledge as a result of prolonged practice, very similar to the concept of Anderson's schema acquisition discussed earlier.

The VR tutorial designed for this study utilizes chunking as a means to aid learners in developing expertise with the navigational controls and the assimilation of the VE as a learning tool by introducing small chunks of information in a semi-linear progression. The tutorial begins with the basic directional controls and environmental awareness, allows the user to practice those skills, assesses the users' expertise, and then moves on to include increasingly advanced locomotion and environmental awareness in the VE.

From the literature presented above, the instructional design theories were selected for the development of this study's VR tutorial. This selection process was guided by the concept of scaffolding or supplanting (Ausburn & Ausburn, 1978; Salomon, 1970) the challenges first-time VR users face in order to enhance the transfer of training/learning (Yamnil & McLean, 2001) encouraged by the interaction. The following sections outline the literature concerning the concepts of supplantation and transfer of training/learning and their roles in this study.

Supplantation

Salomon (1970) described *supplantation* as the process of altering or performing a task for a learner that the learner would normally be forced to do on his or her own. Ausburn and Ausburn (2003) adapted supplantation specifically as related to technology-based instructional treatments to mean, "…the use of an instructional treatment to either capitalize on learners' strengths or to help them overcome their weaknesses" (p. 3). In other words, supplantation theory intends that instructional treatments are designed to do something for learners that they could not normally do on their own to improve the process of learning.

In the context of this study, the VR tutorial design is intended to supplant new users' capability to simultaneously wayfind and learn to control the virtual interface to reduce the burdensome levels of cognitive load inherent in working with VR for the first time. It was hypothesized for this study that through such supplantation, learners would exhibit an increased capability to learn in constructed virtual environments and display increased levels of the transfer of learning/training (Yamnil & McLean, 2001) as discussed in the next section.

Transfer of Learning

Transfer of training/learning theory addresses measurement of effective applications of training objectives to the workplace (Yamnill & McLean, 2001). In short, when transfer occurs, education benefits translate into learning benefits measured in terms of a change in behavior, cognition, or performance. If a change cannot be measured, the training is ineffective. For learning to effect a change, three components are necessary: (1) One must be motivated to transfer or change, (2) There must be an appropriate design of the transfer, and (3) There must be an organizational climate that is conducive to creating transfer (Yamnil & McLean, 2001).

As mentioned previously, this study assumed that potential VR users are motivated to learn. The constructed VR tutorial was designed to provide for the remainder of the requirements described by Yamnil and McLean (2001) based on the appropriate research-based principles described in the sections above. The tutorial was designed to support an organized environment for facilitating the transfer of learning.

Based upon the definition of the transfer of training as a change in performance, this study examined the difference between pre-test and post-test scores on a curricular assessment as a limited means to quantify the transfer of training from a tutorial to a curricular content activity.

From an extensive literature review, the theories detailed above informed the VR training tutorial design for this study. It is now appropriate to move this literature review to a discussion of *measures* for the constructs of cognitive load and wayfinding.

Measures of Cognitive Load and Wayfinding

The literature presented several alternatives for measuring the theoretical constructs of cognitive load and wayfinding. In the paragraphs that follow, a description of the primary measure for cognitive load is provided, followed by a description of several means for measuring wayfinding.

For cognitive load, the primary measure described by Hogg (2007) consists of a subjective self-reported cognitive load rating scale, shown in Figure 5, developed by Paas (1992) and used for the first time in research by Paas and Van Merrienboer (1994). The scale consists of a 9-point Likert-type scale with 1 representing very, very low required mental effort and 9 representing very, very high required mental effort. The scale has demonstrated sensitivity to relatively small differences in cognitive load and stable validity and reliability based on research from Paas (1992), Paas and van Merrienboer (1993), Paas, van Merrienboer, and Adam (1994), and Marcus, Cooper, and Sweller (1996). Hogg (2007) also reported recommendations for using the question, including administering the scale immediately following the task, requiring no physical exertion in conjunction with the learning task, and delivering the scale via electronic means.

Please rate your mental effort required to complete this question:

1	2	3	4	5	6	7	8	9
very very low mental effort	very low mental effort	low mental effort	minimal mental effort	neither high nor low mental effort	some mental effort	high mental effort	very high mental effort	very very high mental effort
○	○	○	○	○	○	○	○	○

Figure 5: Cognitive Load Rating Scale (Hogg, 2007)

For the construct of wayfinding, several methods are reported in the literature for measurement. The five methods used in the research literature include: (1) self-report tests, (2) memory tests, (3) recognition tests, (4) spatial orientation tests, and (5) navigation tests. The following sections summarize the five methods of wayfinding assessment as described by Cubukcu (2003) with additional sources included to add depth to the review.

Self- Report Tests

Subjective questionnaires represent the majority of self-report tests. These questionnaires are often Likert-type scales that measure participants' self-assessment of wayfinding behavior, strategies, and perceived understanding of the setting for the task at hand. (e. g. Abu-Gahzzeh, 1996; Kozhevnikov & Hegarty, 2001; Lawton, 1994, 1996; Richardson, Montello, & Hegarty, 1999; Weisman, 1981). Other researchers have asked participants to rate their sense of direction and describe their wayfinding decisions (e. g. Kozlowski & Bryant, 1977; Lawton & Kallai, 2002; Murokashi & Kawai, 2000; Passini, 1984; Prestopnik & Roskos-Ewoldsen, 2000; Scholl 1988). Such self-report tests require little effort, time, and money, but have been criticized for inconsistency with participants' actual behaviors (Ericsson & Simon, 1984; Lam & Cheng, 2002).

Memory Tests

Memory tests ask participants to describe places or routes after an event or training session. For example, Ausburn, et al. (2006) employed the Operating Room Wayfinding Assessment Instrument (Appendix B) asking participants to answer multiple choice questions indicating the location of objects in an operating room in reference to their personal sense of location or possibly tele-presence (International Society for Presence Research, 2000) in order to assess their sense of orientation. In this approach to assessment of wayfinding, orientation is used as an indirect measure of wayfinding as suggested by Hunt and Waller (1999). Other examples described by Cubukcu (2003) include studies by Appleyard (1969), Carr and Schissler (1969), and Lynch and Rivkin (1976) in which participants described memorable places or routes they encountered during a task. Memory tests are also inexpensive and easy to administer, but are disadvantages in that they may rely on language ability as much as on wayfinding (Cubukcu, 2003).

Recognition Tests

In recognition tests, wayfinders are asked to identify images viewed during an activity. Participants are asked to order the images to describe routes taken or to identify images they actually experienced against images not included in the original activity. Cubukcu (2003) referenced the following examples:

> …Brunswik (1944) and Wagner et al. (1981) followed people and stopped them at varied intervals to ask what they were looking at. Magliano et al. (1995), Aginsky et al. (1997), Wilson (1999) and Murakoshi and Kawai (2000) showed participants pictures from the test environment and distracter pictures similar to

> the ones in the test environment but from different locations that the participant had never seen. They asked the participants to tell whether they had seen it in the environment or not. Heth et al. (1997) escorted children from an origin to a destination (original route) and then from the destination to the origin (return route), but the return route had loop branches attached to the original route. On the return route, they stopped children at some intervals and asked whether they were on or off the original path. Such tests measure if people recognize being somewhere when they are actually there. People may recognize being there but not know what they will see next. To test such knowledge, Magliano et al. (1995) showed pairs of pictures from the route and asked participants to decide which of the two pictures came first along the route. Abu-Obeid (1998) asked students to arrange a series of pictures to show a route. (p. 33)

Recognition tests also indirectly measure wayfinding and remain inexpensive and easy to facilitate. However, they do not provide information about how individuals perceive the spatial relationships between locations (Cubukcu, 2003).

Spatial Orientation Tests

Spatial orientation tests help indicate how people represent spatial environments. These tests generally ask participants to draw sketches from memory or estimate distances or direction to locations from memory. Cubukcu (2003) referenced studies utilizing sketching methods, including Aginsky, Harris, Rensink, and Beusmans (1997), Appleyard (1969), Carr and Schissler (1969), Kitchin (1997), Murakoshi and Kawai (2000), O'Neill (1991), Rossano and Reardon (1999), Rossano, West, Robertson, Wayne, and Chase (1999), Schmitz (1997), and Wilson (1999). Additional studies available in the literature include Wu, Zhang, Hu, and Zhang (2007), Hund and Minarik (2006), and Kroutter (2010). The ability of sketches to measure wayfinding is limited at best and does not provide an accurate representation of the navigation process. Therefore, other authors have employed estimates of distance or direction to aid in assessing wayfinding ability. These methods include verbal estimation, drawing straight lines, reproducing a route, comparing route choices, or pointing tests (e. g. Belingard & Peruch, 2000; Biel, 1982;

Jansen–Osman & Berendt, 2002; Rossano et al., 1999; Sherman, Croxton, & Giavanatto, 1979; Thorndyke, & Hayes-Roth, 1982).

Navigation Tests

Potentially the most time-consuming method for measuring wayfinding, navigation tests measure subjects' ability to take the shortest route, speed, turn summaries, and/or references to maps or directions. The tests include finding places, replicating a route, reversing routes, and describing routes or wayfinding processes to others. Cubukcu (2003) referred to articles using navigation tests including Abu-Ghazzeh (1996), Murakoshi and Kawai (2000), O'Neill (1991), Rovine and Weisman (1989), and Schmitz (1997). Additional authors using navigational approaches include Hund and Padgitt (2010), Moore and Benbasat (1991), and Waller, Hunt, and Knapp (1998).

Following Cubukcu (2003) on a journey through the wayfinding literature and visiting additional researchers along the way provided a wealth of potential measures for the wayfinding construct. This researcher observed that much of the literature neglected to outline the validity and reliability of the measures used. However, in the studies where the authors did comment on the psychometric properties of their measures, correlations such as the Cronbach's alpha (Cronbach, 1951) and test/retest methods were most often reported to address the internal consistency and time-stability reliability of the measures (e.g. Allen, Siegel, & Rosinski, 1978; Kozlowski, & Bryant, 1977; Wagner, Baird, & Barbarresi, 1981). Expert check, confirmatory factor analysis, repeated or multiple trials, and correlations with performances recommended as indicators were most frequently reported for validity (e.g. Kozhevnikov & Hegarty, 2001; Lawton, 1996; Prestopnik & Roskos-Ewoldsen, 2000).

Based on the theoretical foundations for this study and review of the literature reported here, adaptations of the subjective cognitive load rating scale (Hogg, 2007) and the Operating Room Wayfinding Assessment Instrument (Ausburn, et al. 2006) were selected by this researcher to be used in the present study to provide measures for the cognitive load and orientation/wayfinding constructs respectively. These items were selected with consideration for the time the sample would be available for assessment, the history of the instruments, and their intended measures. The methodology reported in Chapter III presents the instrumentation in detail.

CHAPTER III

METHODOLOGY

Research Design and Variables

This study used a pre-test/post-test control group quasi-experimental design. The study was considered quasi-experimental because the groups of participants were not randomly selected from the population (Fraenkel & Wallen, 2006). As is frequent in field-based experimental studies, random selection of subjects was not possible due to the necessity of working within the real-world parameters of the cooperating school site and instructors. Data collecting sessions were limited to one class period and the number of participants was limited to attendance during each session. This reality necessitated use of an alternative non-random sampling procedure, which created a quasi-experimental design. However, while random selection of subjects was not possible, random assignment to treatment groups was possible and was built into the research design to strengthen its integrity. Thus, the researcher controlled the variable for treatment group assignment, and provided the best controls possible for potential extraneous or confounding variables.

The independent variables in this study were presence or absence of the VR tutorial (i.e., experimental treatment) and the demographic variable of gender which was added because it received attention in the literature as an area of interest in VR research. The treatment group participated in the evaluation process while engaged with the VR tutorial, while the control group participated in the evaluation process without experiencing the VR tutorial. Measures of the effects of the VR tutorial on the learners' behavior, cognition, and performance were the dependent variables for this study.

Population and Sample

"A sample in a research study is the group on which information is obtained. The larger group to which one hopes to apply the results is called the population" (Fraenkel & Wallen, 2006, p. 92). The population for this study consisted of enrolled adult surgical technology students from CTE training facilities and three program instructors. The sample for this study consisted of adult surgical technology students enrolled in either evening classes during January of the 2013 spring semester (Monday-Thursday 3:30 P.M. – 10 P.M. for 12 months) or daytime classes during July of the 2013 summer semester (Monday-Friday 8 A.M. – 3 P.M. for 10 months) at Tulsa Technology Center, a top-tier central Oklahoma career and technology center. The pre-requisites for the surgical technology program used in the study included:

1) Age 18 or older
2) High School Diploma or G.E.D.
3) Basic computer literacy
4) Drug screen
5) Criminal background check
6) Verification of immunizations
7) CPR training

The tuition for the program at the time of the study was $3,498.75. Lab fees were $672, and additional costs were $280. Financial aid and career placement assistance were also available (Tulsa Technology Center, 2012). A convenience sample of the students attending classes at the time of each evaluation session provided the subjects for this study. The sample size for the groups were *n* = 13 for the evening classes, and *n* = 13 for the morning classes (*N* = 26 total). Participants were assigned ID numbers which were used for data-matching across the various data collection instruments used in the study. Table 1 presents the user identification numbers and demographic information collected from the participants. The technical skill ratings presented in Table 1 were self-assessed by the participants to indicate their personal perceptions of their familiarity with technology. The ratings are defined as:

- Novice: participants believed they were relatively unfamiliar with technology
- Moderate: participants believed they were relatively familiar with technology
- Power User: participants believed they were competent with technology

The VR experience ratings were defined as:

- Yes: participants had experienced VR in some form previously
- No: participants had not experienced any forms of VR previously

Table 1

User Identification Numbers and Demographic Data for the Sample

User ID	Sex	Age	Tech Skill	VR Experience	Treatment Group
200	F	22	Moderate	No	Tutorial
201	F	35	Novice	Yes	Non Tutorial
202	M	30	Novice	Yes	Tutorial
203	F	22	Moderate	No	Non Tutorial
204	F	21	Moderate	No	Tutorial
205	F	32	Novice	No	Non Tutorial

206	F	51	Novice	No	Tutorial
207	F	33	Moderate	No	Non Tutorial
208	F	33	Moderate	Yes	Tutorial
209	M	26	Moderate	Yes	Non Tutorial
210	M	27	Power User	Yes	Tutorial
211	F	31	Moderate	No	Non Tutorial
212	M	22	Moderate	No	Tutorial
501	F	40	Novice	Yes	Non Tutorial
502	F	28	Novice	Yes	Tutorial
503	F	24	Moderate	No	Non Tutorial
504	F	31	Moderate	No	Tutorial
505	M	34	Novice	No	Non Tutorial
507	M	43	Novice	No	Non Tutorial
508	F	23	Novice	No	Tutorial
509	F	23	Moderate	No	Non Tutorial
510	F	24	Moderate	Yes	Tutorial
511	F	22	Power User	Yes	Non Tutorial
512	F	51	Novice	No	Tutorial
513	F	36	Novice	No	Non Tutorial
515	F	20	Moderate	No	Non Tutorial

The VR Tutorial and Participant Testing Instruments: Procedures for Creating and Mounting Online

The theoretically-designed VR tutorial used in this study began as a *PowerPoint*® presentation integrating VR panoramas, audio, video, and still image components intended to address the issues described in Chapter I concerning the application of VR as a learning tool in CTE. The VR panoramas used in the tutorial treatment instrument for this study were obtained from the Oklahoma State University Occupational Education Studies Virtual Reality Team, of which the researcher was a member; the images, audio, and video elements incorporated in the tutorial were created by the researcher using the following software programs:

- *Activinspire* software available at http://www.prometheanplanet.com
- *Audacity* open source software available at http://audacity.sourceforge.net/

- *Camtasia Studio® 7* software available at http://www.techsmith.com/camtasia.html

The VR panoramas used in the assessment portion of this study were created by the researcher using the following hardware and software:

- Canon EOS Rebel T1i digital SLR camera with tripod
- *3DVista Stitcher 3.0* software available at http://www.3dvista.com
- *Tourweaver 7.0 Professional Edition* software available at http://www.easypano.com

In order to improve access to the VR tutorial, an online version was developed by the researcher from the initial PowerPoint presentation using the *Dreamweaver®* software included in Adobe's Creative Suite 3 software package to recombine the source files as an interactive online resource. In addition, the adapted participant evaluation testing instruments mentioned in Chapter II and discussed further in the next section below were created using the *Survey Monkey* online program available at the website http://www.surveymonkey.com, and all of the elements were woven into an online Internet presentation for the purpose of conducting this study. The html documents were then uploaded to the webhosting site http://www.ipage.com and the domain name *vrtutorial.com* was obtained by the researcher to provide access to the complete web site for the test subjects.

In order to ensure confidentiality and protect the participants' rights, an application to conduct the study was submitted to the Oklahoma State University Institutional Review Board (IRB) for approval. The obtained IRB approval is shown in Appendix A.

To protect the security, integrity, and anonymity of the data as required by the IRB, it was stored on the online site http://www.surveymonkey.com. The security measures this company takes with data stored on their site are outlined at on the company's website. These steps include (http://www.surveymonkey.com/mp/policy/security/):

User Security

- *SurveyMonkey* requires users to create a unique user name and password that must be entered each time a user logs on. *SurveyMonkey* issues a session "cookie" only to record encrypted authentication information for the duration of a specific session. The session cookie does not include either the username or password of the user.
- When a user accesses secured areas of the *SurveyMonkey* site, Secure Sockets Layer (SSL) technology protects user information using both server authentication and data encryption, ensuring that user data is safe, secure, and available only to authorized persons

Physical Security

- *SurveyMonkey* data center is located in a SOC 2, Type II audited facility
- Data center is staffed and surveilled 24/7
- Data center is secured by security guards, visitor logs, and entry requirements (pass cards/biometric recognition)
- Servers are kept in a locked cage
- Digital surveillance equipment monitors the data center
- Environmental controls are maintained for temperature, humidity and smoke/fire detection
- All customer data is stored on servers located in the United States

Network Security

- Firewall restricts access to all ports except 80 (http) and 443 (https)
- Intrusion detection systems and other systems detect and prevent interference or access from outside intruders
- QualysGuard network security audits are performed weekly
- McAfee SECURE scans are performed daily

Storage Security

- All data is stored on servers located in the United States
- Backups occur hourly internally, and daily to a centralized backup system offsite
- Backups are encrypted
- Data is stored on a RAID 10 array
- O/S is stored on a RAID 1 array

Organizational Security

- Access control to sensitive data in *SurveyMonkey* databases and systems are on a need-to-know basis
- *SurveyMonkey* maintains and monitors audit logs on their services and systems (they generate gigabytes of log files each day)
- *SurveyMonkey* maintains internal information security policies, including incident response plans, and regularly reviews and updates them

Software

- Code is in ASP.NET 2.0, running on SQL 2008, Ubuntu Linux, and Windows 2008
- *SurveyMonkey* engineers use best practices and industry-standard secure coding guidelines to ensure secure coding
- Latest patches are applied to all operating system and application files

Permission to use the facility and interact with the subjects was obtained from the Tulsa Technology Center surgical technology program director and the instructors in the surgical technology program (leadership personnel). Thus, they were aware of the subjects' participation because the subjects participated in the study during their regularly-scheduled class time. However, while the leadership personnel knew that certain students participated in the study, they did not know or have access to information about any specific data that could be associated with any specific individual students. Appendix B presents the Participant Information sheet as approved by the Oklahoma State University IRB that was placed on the introductory page of the research web site and provided in hard copy to the participants. On the same introductory page, linkage was provided to allow the students to opt in or out of the study as they desired. One link allowed the subject to select *Yes, I will participate (continue to the first activity)*, and the other allowed the subject to select *No, I will not participate (continue to a curricular review)*. The missing numbers in Table 1 (i.e., 213, 500, 506, and 514) were assigned to subjects who elected not to participate and went directly to a curricular review VE.

Instrumentation and Testing Procedure

The research questions for this study were:

1. What instructional design theories inform screen-based VR tutorial and multimedia-based designs?
2. Do differences in mean performance exist between wayfinding/orienting capabilities of participants based on treatment group (i.e., use/non-use of VR tutorial)?
3. Do differences exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group (i.e., use/non-use of VR tutorial)?
4. Do differences exist between genders concerning mean wayfinding/orienting capabilities based on treatment group (i.e., use/non-use of VR tutorial)?
5. Do differences exist between genders on reported sense of cognitive load?
6. Do differences in mean performance exist between transfer of learning/training for participants based on treatment group (i.e., use/non-use of VR tutorial)?
7. Can a checklist be developed from this study to guide design of effective screen-based VR training tutorials?

The instruments, methods of data analysis, and data sources concerning each research question for this study are summarized in Table 2.

Table 2

Assessment Structure

Research Question	Data Source	Analysis Method
1	Literature	Literature Review
2	Items 6 - 22 OR Wayfinding Instrument	*t*-test
3	Items 23 - 25 OR Wayfinding Instrument	*t*-test

4	Items 6 - 22 OR Wayfinding Instrument	*t*-test
5	Items 23 - 25 OR Wayfinding Instrument	*t*-test
6	Surgical Environment Assessments	*t*-test
7	Outcomes from the Study	Discussion

The first research question was addressed through literature review. The literature review presented in Chapter II outlined the theory-based design of the VR tutorial. The efficacy of this theory-driven tutorial design and its ability to generate an instructional design checklist for future VR tutorials are reflected in the results indicated by the data collected from the Surgical Environment Assessment (Appendix C) pre- and post-tests, the Operating Room Wayfinding Instrument (Appendix D), and qualitative responses gathered in the study from questions 27, 28, and 29 of the OR Wayfinding Instrument. These results are presented in Chapter IV.

For the constructs of cognitive load, wayfinding, and transfer of training, the remaining assessments were conducted as follows. First, as part of the quasi-experimental research design, the participants were divided between treatment and control groups. To randomize and divide the groups without intentional bias, colored slips of paper were handed out to the students along with participant information sheets as they entered the room at Tulsa Technology Center used for all participation in this study. Half of the slips were blue and coded with an even number to signify membership in the treatment group, and the other half of the slips were white and coded with an odd number to signify membership in the control group. The series of the number (2** for the evening spring semester participants and 5** for the morning spring semester participants) aided in identifying the session to which each member belonged, enabling possible future data comparisons beyond the scope of this study based upon the subject's session membership. The participants were seated in an alternating pattern based on treatment group. Both treatment and control groups of surgical technology students completed a pretest with an online version of the Surgical Environment Assessment (Appendix C) provided by the training facility.

Following the pretest, the treatment group engaged with the theoretically-designed tutorial to explore VEs while the control group explored the same VEs unaided by the tutorial. An outline of the tutorial is included in Appendix E. Two VEs were used for this part of the experiment. The first VE depicted an operating room used for training purposes. All of the standard OR equipment (i.e. scrub sinks, mayo stand, back table, etc.) and a mannequin patient were included. The second VE depicted a virtual crime scene with hot spots allowing users to interact with the VR and explore the nuances of linkage and wayfinding in VEs. In this crime scene, two mannequins were posed as victims in a mock apartment, and hot spots linked to images of the telephone, illicit drugs on the table, items with fingerprint evidence, and close up shots of a gun and one of the mannequins.

The subjects sat at computer stations in the same room. The room contained 24 Hewlett Packard desktop workstations running the Windows 7 operating system. Headphones were also provided. The participants were directed to the website (http://vrtutorial.com) to begin each session. The subjects in the test/experimental group followed the appropriate linkage to take their pretest and then open the tutorial program in order to interact with it, while the subjects in the control group followed the appropriate linkage to take their pretest and then were offered the same VEs utilized in the tutorial, minus the training structure, to explore at their leisure.

After the exploration or tutorial period, approximately 20 minutes, all subjects interacted for approximately an additional 20 minutes with the surgical environment curriculum/content VE constructed for this study which showed the current Tulsa Tech Surgical Technology training facility. The scrub room, the operating room (OR), the furniture, and instruments were included. Hot spots in the scrub room panorama were included that linked to videos covering hand washing techniques and proper surgical attire, and a navigational link connecting the scrub room to the OR. Hot spots in the OR linked to pop up images of each furniture item with a description of the functionality or relevant characteristics of each item in the surgical suite, and a navigational link allowing the participants to return to the scrub room.

Finally, the participants took a posttest of the online Surgical Environment Assessment (Appendix C) to collect data to assess the transfer of training/learning, and the Operating Room Wayfinding Assessment Instrument (Appendix D) to provide both quantitative comparisons and qualitative reflections describing the subjects' ability to orient in a virtual environment and their perceived sense of cognitive load from the VR experience as suggested by the theoretical/conceptual framework for this study.

In addition to the data gathered from the participants, the instructors and technology center director (leadership personnel) experienced the tutorial, the constructed VE, and the assessment items using the same linkage as the treatment group of student participants. Following the leadership personnel's experience they were surveyed at a separate time from the other participants via email to discuss the potential implications of employing VR as a learning aid. To ensure their rights were protected, the leadership personnel signed a consent form for their surveys that stated:

> The purpose of this study is to test a theory-based tutorial on using Virtual Reality Environments and to determine if a theoretically sound checklist can be developed for instructional designers to employ when creating training materials. The study you are offered an opportunity to participate in will aid in the development of future virtual reality curricular materials. You will not be identified by name in the study. The data from this interview will be used for research purposes only, data will be reported only in aggregate, and your participation is appreciated. Please indicate your preference below:
>
> - Yes, I will participate
> - No, I will not participate

After providing consent, the leadership personnel received an email containing the following survey questions:

1) Talk about the tutorial and the experiment. Did the tutorial help you when you entered the training environment? If so, how?
2) What changes would make the tutorial more effective?
3) Would you recommend the tutorial?
4) Do you believe that virtual reality experiences would be beneficial to your program or similar career training programs? Why or why not?
5) How real did the virtual environment feel to you?
6) Do you have any questions or comments about the experience?

The responses to these questions are discussed in Chapter IV.

Working Hypotheses for the Study

Based on the study's theoretical framework and empirical support from research literature, it was hypothesized that users in the theoretically-designed VR tutorial treatment group would display higher scores on all of the assessments than the control group that experienced VR without the tutorial structure. Additionally, it was hypothesized that the posttests of wayfinding/orientation and cognitive load would demonstrate that members of the treatment group would report greater comfort in using VR and a positive view of VEs as a learning medium. To ensure equitable treatment for all participants and expand the data set for comparative study, the control group was also offered the opportunity to experience the tutorial following the study and retake the posttests of wayfinding/orienting and cognitive load. Note that the results collected from retakes will be held for future research and not reported in this study.

Data Analysis

Once collected via the *SurveyMonkey website,* the data was downloaded to a Hewlett Packard 6730s laptop and entered into *SPSS 16.0 Graduate Student Version* statistical software. The results of the comparative analyses are presented in Chapter IV. To protect the security and integrity of the study's data, the HP 6730s remained password protected and had the light speed suite software from Lightspeed Systems (http://www.lightspeedsystems.com/) installed that includes an antivirus for further data security. The computer has been and will remain accessible only by the researcher as long as it is retained for analysis and professional reporting.

The quantitative data gathered from the Operating Room Wayfinding Assessment Instrument (Appendix C) was compared via independent-sample *t*-tests to examine potential differences between treatment and control group performances and varying demographic variables, including gender, concerning orienting and wayfinding as suggested by Hunt and Waller (1999). Data from questions 23 – 25 provided *t*-test comparison points for the cognitive load construct, and the data from the surgical environment assessments provided group comparisons for the transfer of training achieved through the theoretically-designed VR learning application in terms of curriculum content.

The qualitative data gathered in the operating rooms learning exercise and from the instructor and director survey emails was read by the researcher and then coded into themes that emerged from the data during analysis. While this data was qualitative in nature due its open-ended nature, it was not collected through a qualitative procedure involving personal contact and probing questioning between researcher and subjects. This prevented the study from being a true mixed-study and instead qualified it as a quantitative study with mixed-techniques data analysis. The constant comparative method as described by Glaser (1965) was used to group the qualitative data into thematic groups and inform potential adaptations to the current tutorial design for future studies. Each item was typed verbatim into *Activinspire* software, enabling the researcher to physically re-arrange the comments into thematic groups in a digital format by using the camera tool and staging area provided by the software to construct graphic representations of the thematic groups that developed from the constant comparative method. The thematic groups that developed concerning each qualitative question are depicted in total in appendix F. The data included all subject provided responses from questions 27, 28, and 29 of the OR Wayfinding Instrument, responses from the school leadership personnel to the emailed questions described earlier, and additional responses from some of the participants who were asked by a member of the leadership personnel to submit responses en masse to the same email survey sent to the leadership personnel. The additional student responses to the email survey sent to the leadership personnel were not anticipated by the researcher at the outset of the study and were completely anonymous and without student identifiers of any kind. This data was therefore included in the appropriate analyses for this study as valuable additional qualitative data for informing future tutorial designs and potential future studies.

This open-ended data and its qualitative analysis was used to provide an in-depth examination of the participants' sense of presence within a VE, their recommendations for improving the VR tutorial and/or VE training experiences, and the potential implications of using VR as a learning aid. This data was also examined for additional theoretical underpinnings potentially relevant to the development of VR tutorial design and continuing research. Based on the findings presented in the next chapter, research question number seven was addressed. A discussion of the empirical support, or lack thereof, for the development of a checklist that offers specific guidelines for designing future VR tutorials that assist novice VR/VE users and help them use this medium as an effective learning tool is presented in Chapter IV.

CHAPTER IV

FINDINGS

Summary of Data Collected

As outlined in Chapter III, the majority of the data for this study was collected using online versions of the Surgical Environment Assessment (Appendix C) and OR Wayfinding Assessment (Appendix D) through surveymonkey.com. This data included both quantitative and qualitative data based on the nature of each item. Email responses were also collected from some of the participants and the leadership to provide further qualitative data for informing future tutorial designs and potential research studies (Appendix E). In addition to the user identification numbers and demographic information presented previously in Table 1(see Chapter III), Table 3 and Table 4 below illustrate the remaining data collected via the instruments used in the study. Table 3 outlines the wayfinding and transfer of training data analyzed, including:

- The subject ID
- The treatment group
- The pre-test score on the Surgical Environment Assessment, recorded as the number of correct responses

- The post-test score on the Surgical Environment Assessment, recorded as the number of correct responses
- The score from the OR Wayfinding Assessment for questions 6 -20, recorded as the number of correct responses
- The calculated difference (i.e. difference score) in performance for each subject from pre-test to post-test on the Surgical Environment Assessment

Table 3

Subject Treatment Group, Wayfinding, and Transfer of Training Data

ID	Treatment Group	Pre-test Score	Post-test Score	Wayfinding Score	Pre-Post Diff
200	Tutorial	68	92	93	24.0
201	Non-Tutorial	68	76	20	8.0
202	Tutorial	68	76	33	8.0
203	Non-Tutorial	64	88	53	24.0
204	Tutorial	68	96	33	28.0
205	Non-Tutorial	84	92	60	8.0
206	Tutorial	84	92	87	8.0
207	Non-Tutorial	68	68	73	0.0
208	Tutorial	68	72	40	4.0
209	Non-Tutorial	76	88	53	12.0
210	Tutorial	52	64	27	12.0
211	Non-Tutorial	80	72	27	-8.0
212	Tutorial	44	68	27	24.0
501	Non-Tutorial	76	84	20	8.0
502	Tutorial	68	60	67	-8.0
503	Non-Tutorial	96	92	40	-4.0
504	Tutorial	72	84	47	12.0
505	Non-Tutorial	80	68	33	-12.0
507	Non-Tutorial	56	64	60	8.0
508	Tutorial	44	28	40	-16.0
509	Non-Tutorial	60	84	93	24.0
510	Tutorial	64	84	33	20.0
511	Non-Tutorial	76	76	27	0.0
512	Tutorial	60	64	27	4.0
513	Non-Tutorial	68	76	40	8.0
515	Non-Tutorial	48	56	27	8.0

Table 4 includes the Cognitive Load data collected from the OR Wayfinding Instrument including:

- The subject ID
- The treatment group
- The self-reported level of confidence in the subjects' ability to understand the OR and answer the questions from the surveys. Originally reported with verbal statements, the confidence level data was codified according to the following five-point scale:
    1. I have no confidence in my understanding of the operating room and my answer accuracy
    2. I have a little confidence in my understanding of the operating room and my answer accuracy
    3. I have moderate confidence in my understanding of the operating room and my answer accuracy
    4. I have good confidence in my understanding of the operating room and my answer accuracy
    5. I have absolute certainty in my understanding of the operating room and my answer accuracy
- The self-reported mental effort required for learning about the operating room environment. Originally reported with verbal statements, the data was codified according to the following nine-point scale:
    1. Very very low mental effort
    2. Very low mental effort

3. Low mental effort
4. Minimal mental effort
5. Neither high nor low mental effort
6. Some mental effort
7. High mental effort
8. Very high mental effort
9. Very very high mental effort

- The self-reported mental effort required in answering the questions in the exercise. Originally reported with verbal statements, the data was codified according to the following nine-point scale:
    1. Very very low mental effort
    2. Very low mental effort
    3. Low mental effort
    4. Minimal mental effort
    5. Neither high nor low mental effort
    6. Some mental effort
    7. High mental effort
    8. Very high mental effort
    9. Very very high mental effort
- The self-reported mental effort required to navigate in the virtual environment. Originally reported with verbal statements, the data was codified according to the following nine-point scale:
    1. Very very low mental effort

2. Very low mental effort
3. Low mental effort
4. Minimal mental effort
5. Neither high nor low mental effort
6. Some mental effort
7. High mental effort
8. Very high mental effort
9. Very very high mental effort

- A total effort score calculated as the sum of the scores from the three prior mental effort ratings

Table 4

*Subject Treatment group and Cognitive Load Data**

Subject ID	Treatment Group	Conf Lvl	Effort OR	Effort Qs	Effort Nav	Effort Total
200	Tutorial	3	7	3	4	14
201	Non-Tutorial	1	3	9	9	21
202	Tutorial	3	5	3	5	13
203	Non-Tutorial	2	8	9	5	22
204	Tutorial	2	3	5	3	11
205	Non-Tutorial	3	3	7	3	13
206	Tutorial	3	3	8	8	19
207	Non-Tutorial	1	7	7	1	15
208	Tutorial	3	3	3	4	10
209	Non-Tutorial	4	3	4	2	9
210	Tutorial	5	9	3	9	21
211	Non-Tutorial	1	5	5	5	15
212	Tutorial	2	3	5	3	11
501	Non-Tutorial	1	8	8	8	24
502	Tutorial	3	8	3	1	12

503	Non-Tutorial	3	8	8	4	20
504	Tutorial	2	4	3	3	10
505	Non-Tutorial	1	5	5	5	15
507	Non-Tutorial	2	7	7	3	17
508	Tutorial	1	2	3	3	8
509	Non-Tutorial	4	3	7	4	14
510	Tutorial	3	3	2	2	7
511	Non-Tutorial	3	7	3	3	13
512	Tutorial	2	8	8	1	17
513	Non-Tutorial	4	9	8	7	24
515	Non-Tutorial	5	7	4	9	20

*NOTE: Cognitive load = perceived confidence level, 3 individual perceived effort levels, and an effort total score

These data sets were analyzed with *SPSS 16.0 Graduate Student Version* statistical software as indicated in Chapter III, Table 2. The sections that follow report the findings for each of the research questions based on the *t*-test analyses between treatment (tutorial) and control (non-tutorial) group and any additional analyses which were performed to better inform the outcomes for the study. Each question is presented in a separate section. Conclusions, discussion, and recommendations follow in Chapter V.

Research Question 1: What literature informs laptop VR tutorial and multimedia based instructional designs?

Challenges for VR

This research question was addressed through comprehensive integrated literature review. The findings are presented in detail in Chapter II and summarized here. As outlined in Chapter II, the theories of wayfinding, orientation, and cognitive load were selected from the literature as potential causes for the challenges users experience when engaged with VEs. Wayfinding theory was described as a possible impediment to a user's sense of presence when interacting with VR; orientation was included as a preliminary necessity for users' ability to wayfind; and increased cognitive load was presented as a potential result of the complexity involved when interacting with curriculum content, a new environment, and the VR user-interface simultaneously. These challenges inhibit the users' progress with the introduction to virtual reality as depicted by the Ausburn and Ausburn (2010) model in Figure 1(see Chapter I).

Meeting the Challenges

As shown in Chapter I, the researcher developed the VRGIS tutorial design (Figure 2) alongside Ausburn and Auburns' IVR training model (Figure 3) as an aid for outlining the necessary elements for developing a VR tutorial which could help users assimilate VEs as learning tools. To help realize the goals of the VRGIS and IVR, Gagne's nine conditions of learning were woven with the instructional design theories of discovery learning, advance organizers, chunking, and supplantation as key elements that could produce the desired users' transfer of training/learning about VEs as viable tools for CTE. It was the researcher's working hypothesis for this study that incorporating these instructional design theories would produce a VE tutorial that would meet the challenges inherent in wayfinding, orientation, and cognitive load issues in VEs identified in the research literature.

Research Question 2:
Do differences in mean performance exist between wayfinding/orienting capabilities of participants based on treatment group (i.e., use/non-use of VR tutorial)?

The level of significance for this analysis was set at $p \leq .05$. The wayfinding performance of the participants in the tutorial and non-tutorial groups was compared with an independent samples t-test with equal variances assumed based on a non-significant Levene's Test for Homogeneity of Variance between the treatment groups on the wayfinding scale scores. For this and all *t*-tests presented in this study, a Levene's Test for Homogeneity of Variance was conducted to determine if the variance of each group was approximately equal. This is an assumption of the *t*-test statistic and must be met *a priori* for the *t*-test analysis, otherwise, a type I error may occur. If a significant Levene's test occurs ($p \leq .05$), the *t*-test results with equal variances not assumed will be used to adjust for the standard error of the estimate and degrees of freedom (Gastwirth, Gel, & Miao, 2009). The results from the analysis are shown in Table 5.

Table 5

Wayfinding t-test Results Based on Treatment Group

Treatment Group	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Tutorial	12	46.1667	23.34264	24	.164	.871
Non-Tutorial	14	44.7143	21.62772			

A non-significant result ($p = .871$) suggests that the null hypothesis that no differences exist between mean wayfinding/orienting capabilities of participants based on treatment group should be retained.

Research Question 3:
Do differences exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group (i.e., use/non-use of VR tutorial)?

The level of significance for this analysis was set at $p \leq .05$. The perceived cognitive load of the participants in the tutorial and non-tutorial groups was compared with independent samples *t*-tests with equal variances assumed based on a non-significant Levene's Tests for Homogeneity of Variance between the treatment groups on the operating room effort, question effort, navigation effort, and composite effort scores. The results from the analysis are shown in Table 6. The tests for operating room effort and navigational effort returned non-significant results, however the question effort test returned a significant result (p = .005) and contributed to a slightly lower significance level for the composite effort test (p = .016). These results suggest that the null hypothesis should be rejected and the alternate hypothesis that differences do exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group should be accepted.

Table 6

Cognitive Load t-test Results

Operating Room Effort						
Treatment Group	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Tutorial	12	4.83	2.480	24	-1.193	.244
Non-Tutorial	14	5.93	2.200			
Question Effort						
Treatment Group	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Tutorial	12	4.08	2.021	24	-3.097	.005
Non-Tutorial	14	6.50	1.951			
Navigation Effort						
Treatment Group	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Tutorial	12	3.83	2.480	24	-1.036	.310
Non-Tutorial	14	4.86	2.538			
Composite Effort						
Treatment Group	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Tutorial	12	12.75	4.309	24	-2.586	.016

Non-Tutorial	14	17.29	4.581

Research Question 4:
Do differences exist between genders concerning mean wayfinding/orienting capabilities based on treatment group (i.e., use/non-use of VR tutorial)?

The level of significance for this analysis was set at $p \leq .05$. The orienting/wayfinding performance of the participants was first compared as a preliminary test with an independent samples *t*-test with equal variances assumed based on a non-significant Levene's Tests for Homogeneity of Variance between genders on the wayfinding scale scores. The results from the analysis are shown in Table 7.

Table 7

Orienting/Wayfinding t-test Results Based on Gender

Gender	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Male	6	38.8333	14.11973	24	-.827	.416
Female	20	47.3500	23.79357			

In addition to the *t*-test, A two-way analysis of variance (ANOVA) was performed to combine the treatment group and gender factors to determine any interaction effects that may exist. Once again, a non-significant Levene's Test for Homogeneity of Variance allowed the assumption of equal variances. The results of the ANOVA are presented in Table 8.

Table 8

Two-Way ANOVA: Orienting/Wayfinding, Treatment Group by Gender

Factor	*df*	*SS*	*MS*	Sig. (2 tailed)
Treatment Group	1	206.361	206.361	.521
Gender	1	297.386	297.386	.442

Treatment Group*Gender	1	790.107	790.107	.215

The non-significant results for the gender *t*-test (p = .416) and the two-way ANOVA interaction of gender by treatment group (p =.215) suggest retention of the null hypothesis that no differences exist between genders concerning mean wayfinding/orienting capabilities based on treatment group.

Research Question 5:
Do differences exist concerning reported sense of cognitive load based on gender?

The level of significance for this analysis was set at $p \leq .05$. The percieved cognitive load of the participants was assessed with an independent samples *t*-test with equal variances assumed based on non-significant Levene's Tests for Homogeneity of Variance between genders on the operating room effort, navigation effort, and composite effort scores. A significant Levene's Test for Homogeneity of Variance for the question effort scale required that equal variances could not be assumed for that individual test; pooled variance estimates were therefore used instead for this test. The results from the analysis are included in Table 9. The tests for operating room effort (p = .918), question effort (p = .187), navigational effort (.901), and composite effort (p = .637) returned non-significant results.

Table 9

Cognitive Load t-test Results Based on Gender

Operating Room Effort

Gender	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Male	6	5.33	2.338	24	1.367	.918
Female	20	5.45	2.417			

Question Effort

Gender	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Male	6	4.50	1.517	13.723	-1.390	.187
Female	20	5.65	2.445			

Navigation Effort

Gender	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Male	6	4.50	2.510	24	.126	.901
Female	20	4.35	2.581			

Composite Effort

Gender	*N*	*M*	*SD*	*df*	*t*	Sig. (2 tailed)
Male	6	14.33	4.320	24	-.478	.637
Female	20	15.45	5.186			

These results suggest that the null hypothesis be retained that differences do not exist between the cognitive load profiles of participants while engaged with VR environments based on gender.

Research Question 6:
Do differences in mean performance exist between the transfer of learning/training for participants based on treatment group (i.e., use/non-use of VR tutorial)?

The level of significance for this analysis was set at $p \leq .05$. The transfer of learning/training for the participants was assessed with independent samples t-tests for the pretest scores and posttest scores between treatment groups and a paired samples *t-test* to demonstrate the change between the subjects' scores from the pre-test to the post-test regardless of the treatment group each subject belonged to. Table 10 illustrates the results of these analyses.

Table 10

Transfer of Learning/Training Independent and Paired t-test Results Pretest/Posttest

Pretest Independent *t*

Group	*N*	*M*	*SD*	*df*	*t*	Sig(2-tailed)
Tutorial	12	63.333	11.672	24	-1.709	.100
Non-Tutorial	14	71.429	12.340			

Posttest Independent *t*

Group	*N*	*M*	*SD*	*df*	*t*	Sig(2-tailed)
Tutorial	12	73.333	18.787	24	-0.690	.497
Non-Tutorial	14	77.429	11.050			

Pretest – Posttest Paired Samples *t*

Group	*N*	*M*	*SD*	*df*	*t*	Sig(2-tailed)
Pretest – Posttest	26	-7.846	11.675	25	-3.427	.002
Pretest	26	67.692	12.492			
Posttest	26	75.539	14.938			

The non-significant results from the independent *t*-tests suggest that no difference exists between treatment groups on the pretest and the posttest for transfer of learning/training. The significant results of the paired samples analysis ($p = .002$) suggests that definite changes took place between the subjects' pre-test and post-test scores on the surgical environment assessment overall, regardless of treatment group. This indicates that post-test performance improvement occurred independent of tutorial treatment.

To determine if the tutorial influenced the apparent differences in performance between the pre-test and post-test scores, an independent samples *t*-test was performed between treatment groups based upon the calculated difference in performance scores for each subject as reported in Table 3. The level of significance for this analysis was set at $p = .05$, and a non-significant Levene's Test for Homogeneity of Variance allowed equal variances to be assumed. The results of that analysis are presented in Table 11.

Table 11

Pre-test to Post-test Difference Independent t-test Results Based on Treatment Group

Group	*N*	*M*	*SD*	*df*	*t*	Sig(2-tailed)
Tutorial	12	10	13.15640	24	.867	.432
Non-Tutorial	14	6	10.37749			

The results of this analysis were non-significant, and suggest that, although differences exist between pre-test and post-test subject performance overall, this effect could not be attributed to the tutorial treatment. Thus, the null hypothesis that differences do not exist in mean performance on transfer of learning/training for participants between treatment groups should be retained.

Research Question 7: Can a checklist be developed from this study to guide design of effective laptop VR training tutorials?

The results from the quantitative measures when combined with qualitative responses from a subset of the sample and the leadership at Tulsa Technology Center did provide the opportunity to develop a potential checklist to guide the design of effective laptop VR training tutorials. A discussion of the implications suggested by the entirety of the collected data is included in the sections that follow. First a summary of the results from the quantitative data are provided. Next, a review of the qualitative comments offered by the participants in the study targeting the effectiveness and potential changes for the tutorial is included. Finally, a potential checklist to guide the design of effective laptop VR training tutorials is presented.

Quantitative Summary

The results of the quantitative analyses described above suggest that:

- No differences exist between mean orienting/wayfinding capabilities of participants based on treatment group.
- Differences do exist between the cognitive load profiles of participants while engaged with VR environments based on treatment group, in favor of the tutorial treatment.
- No differences exist between genders concerning mean orienting/wayfinding capabilities based on treatment group. There is no interaction between gender and treatment.
- Differences do not exist between the cognitive load profiles of participants while engaged with VR environments based on gender.
- Differences do exist in mean performance between transfer of learning/training for participants between the pre-test and the post-test score sets; however that difference was not due to treatment group.

Qualitative Data Review

The qualitative data collected in the study via survey illustrated several themes concerning the development of effective VR training tutorials. Each question and the apparent themes that emerged through constant comparison of the data are described in detail in the sections that follow. The entire set of open ended responses is also reported verbatim in Appendix F. First, the responses collected from the leadership personnel and participants were read and analyzed for apparent themes according to each question and reported in the numbered qualitative question sections that follow. Second, the responses were analyzed as a cumulative data set to inform future research, tutorial designs, and the development of a VR checklist as discussed in the summary of the qualitative responses section and Chapter V. Since every participant did not answer every question, the limited nature of the responses, both in number of subjects that elected to respond and in length of the individual responses, made for a rather simplistic set of developed themes both by question and as a total data set; however, all responses were coded as accurately as possible and treated as valuable data for interpreting the results of the study. A summary of the qualitative results is included in the last section, and conclusions based upon the data, a discussion of all of the results from Chapter IV, and recommendations for further research are presented in Chapter V.

Qualitative Question 1: Talk about the tutorial and the experiment. Did the tutorial help you when you entered the training environment? If so, how?

The responses to this question developed three themes; positive feedback, negative feedback, and mixed feedback. The five positive responses suggested that the tutorial did help the participants as they entered the VR training environment. The respondents indicated that the tutorial explained how to navigate, how to use the various features of the VR interface, and appropriately introduced the OR environment. The negative responses indicated that one participant felt confused due to unfamiliarity with the curriculum content. Two other subjects indicated that the tutorial did not help them at all, and two additional subjects who responded were in the non-tutorial group, thus they could not offer an informed opinion concerning the tutorial. The final comment which comprised the mixed feedback theme for question one indicated that the tutorial helped to some degree since the subject was already experienced in the OR.

Qualitative Question 2:
What changes would make the tutorial more effective?

Responses to question two suggested themes of no changes to the tutorial and potential changes to consider and make the tutorial more effective. Four respondents indicated that no changes were necessary. The other three participants commented that they would prefer to know more about the OR before they were asked to interact with the VR, or that they were not sure what changes they would make, but that they had difficulty with navigating in the environment.

Qualitative Question 3:
Would you recommend the tutorial?

Positive and negative themes were used to group the data. Three participants indicated that they would not recommend the tutorial. Eight other subjects stated that they would recommend the tutorial. These supportive statements also included the following suggestions transcribed directly from the participants' responses:

- Introducing the tutorial later in their coursework would help
- The tutorial was helpful with navigation
- The tutorial facilitated the student and made the program user friendly
- More basic info would be helpful

Qualitative Question 4:
Do you believe that virtual reality experiences would be beneficial to your program or similar career training programs? Why or why not?

A non-beneficial theme and a beneficial theme were apparent in the responses. Three subjects indicated that the tutorial was not helpful. Eight participants allowed that VR experiences would be beneficial. A summary of additional comments included with the beneficial responses suggested that the virtual reality experience in this study:

- Helped with exploring the OR without having to go into a physical environment
- Was relevant to the subject or career
- Would have been better if the non-tutorial subjects had interacted with the tutorial
- Would be helpful for individuals with a photographic memory or to remember what was seen or for preparing to enter an actual OR environment
- Was more interactive than just video

Qualitative Question 5:
How real did the virtual environment feel to you?

Responses to this question separated into a real theme and a not real theme. Four respondents indicated that the virtual environment felt real or somewhat real. One participant stated that on a scale of 1 to 10 it was probably about an 8, and another indicated that the virtual environment was as realistic into the surgical culture as could be expected. The seven subjects who related that the virtual environment did not feel real in paraphrase commented that: the virtual environment reminded them of a video game; they would prefer to experience the real environment; or they did not feel that the environment felt real at all.

Qualitative Question 6:
Do you have any questions or comments about the experience?

Two of the participants from the leadership made comments, while seven other subjects had no questions or comments. The leadership comments were:

- "I am very thankful that Mr. Burkett has selected the surgical technology program as the subject of his experiment. There are not any virtual reality experiences available to students. This would be a very worthwhile tool to make available to students before they actually go to their surgery rotation."
- "Overall very useful for students to learn/refresh what they are studying. It will be helpful to most I think since students seem to be more visually oriented now."

Qualitative Question 7:
Talk about the tutorial and the experiment. Did the tutorial help you when preparing for the assessment? If so, how?

The responses to this question developed three themes, positive feedback, negative feedback, and mixed feedback. The eight positive responses indicated that in addition to as an overall helpful resource for preparing for the assessment, the tutorial:

- Helped with finding the answers and using the hot spots
- Helped with visualization by zooming in
- Taught the users to navigate around the virtual room
- Gave an overview of the OR
- Provided clear instructions
- And offered one user a point of view without having entered the room

The three negative responses indicated that the tutorial did not help the participants prepare for the assessment and offered that the tutorial, had no sound for one user, and should have let users know that they needed to pay attention to details in the scene. The two thematically mixed responses described both pros; “The vr is very good”; “…It was helpful…”; and cons; “It would be more useful if we knew what questions were asked at the end…”; "I am not comfortable with navigating the virtual environment…the technology was something I had to overcome.”

Qualitative Question 8:
What changes would make the tutorial more effective? Would you recommend the tutorial?

A recommended theme and a not recommended or referenced theme developed from the responses to this question. Eight participants allowed that they would recommend the tutorial and offered the following suggestions:

- Offer the tutorial after the users had been in the actual OR and were more familiar with the equipment
- An older user felt pressured to keep up with younger classmates and that they needed to adapt to the new situation
- Add the ability to tour the VR from additional angles
- Make the images clearer when zooming in
- Let the users know what to look for before the assessment

The five subjects who did not recommend or even reference the tutorial offered the following comments:

- Let the viewer know to pay close attention to details before the questions
- Make the videos larger or capable of being displayed full-screen
- Enhance the sound
- Could be more interactive

Qualitative Question 9:
Please make any additional comments.

The participants either made pertinent comments or comments that were not pertinent to the goals of the study. The non- pertinent comments included:

- "I have no other additional comments :-)"
- "Good luck!!! This was fun"
- "Great experiment"
- "None"

The comments that pertained to the study included:

- "actually had I known that there were going to be questions pertaining to how much I remembered seeing, I probably wouldn't have went through it quite so fast"
- "I like it but it should be broken down into sections of the OR after having an overview look"
- "too busy with equipment, need less to orient the user for the first time use"
- "Although tutorials may be nice for the advances in today's society, I would much rather be learning hands on and actually in the environment."
- I think it would also help to be able to mess around with the tools and things in the labs

Summary of the Qualitative Responses

The qualitative responses provided insight into potential changes for future tutorials and several indicators of the participants' perception of the effectiveness of the tutorial overall. The themes which developed throughout the constant comparative method used to analyze the qualitative responses consisted of three encompassing general commentary categories: supportive of the tutorial and VR, opposed to the tutorial and VR, undecided as to the value of the tutorial and the VR as reported in Table 12. Each category and the recommendations for potential changes to the tutorial are discussed in the sections that follow.

Table 12

*Qualitative Responses (99 responses from 26 participants and 3 leadership personnel)**

Question	Total Responses	Supportive	Opposed	Undecided	Non-Categorical
Question 1	11	5	3	1	2
Question 2	7	4	3		
Question 3	11	8	3		
Question 4	11	8	3		
Question 5	11	4	7		
Question 6	9	2			7
Question 7	13	8	3	2	
Question 8	13	8	1		4
Question 9	10		5		5

*NOTE: Non-categorical responses consist of responses that did not provide any of the participants' perceptions of the tutorial (i.e. Question: Do you have any questions or comments about the experience? Answer: No)

Positive Response Summary

The supportive group of comments contained forty-seven instances that:

- Recommended the tutorial
- Stated the tutorial was beneficial
- Stated the tutorial did help with participation in the study
- Stated the tutorial should not be changed
- Stated that the environment felt real or somewhat real

- Stated that the tutorial was a helpful resource

The participants provided additional positive feedback about the tutorial as a facilitation tool for learning. A summary of those comments about the tutorial included:

- User friendly
- A relevant experience
- Prepared the user to enter the OR
- Helped with navigation via hot spots and zooming
- More interactive than video
- Provided clear instructions
- Helped review curriculum and find the answers to the questions

Negative Response Summary

The oppositional group of comments contained twenty-eight instances that:

- Did not recommend the tutorial
- Stated the tutorial was not helpful or beneficial
- Stated that the tutorial needed to be more interactive

Additional negative feedback from the participants addressed their perceived shortcomings or limitations of the tutorial. Those comments concerning the tutorial included:

- Not realistic or like a video game
- No sound
- The users did not know exactly what to expect in the assessments or what to look for prior to the assessments
- Hard to navigate

- Need to know more about the OR before this experience
- Not interactive enough
- Not as good as the real environment or hands-on experiences
- Too busy for an introduction to VR

Mixed Response Summary

The three responses from the undecided category related that the tutorial was "good" or "helped to some degree", but that it was perceived as hard to navigate within and that the technology had to be "overcome". Another participant stated that the tutorial helped since the subject had previous OR experience. In addition, one subject echoed the responses from the oppositional group stating that knowing what questions would be asked during the assessment phase would be helpful.

Recommendations for Changes to the Tutorial

The participants recommended several potential changes for the tutorial. These suggestions included:

- Make the videos larger or capable of being viewed full screen
- Allow the user to interact with the furniture and equipment in the lab
- Add additional points of view or angles to view each panorama from
- Make the images clearer when zooming
- Introduce the VR experience later in the program of study after the participants have gained familiarity with the OR and the furniture.

CHAPTER V

Conclusions, Discussion, and Recommendations

Summary of the Study

As educators and trainers explore the best practices for teaching and learning in the digital age, 21st century tools such as laptop virtual reality and the development of virtual environments offer users the ability to work in any imaginable field and in any potential environment. The efficacy and acceptance of these training tools is apparent in the literature addressed in Chapters I and II, however little research has targeted introductory training concerning the challenges new users face when interacting with VR, namely, the user interface, navigation, and an understanding of VR as a learning aid for curricular goals. This study began building a bridge across that training chasm by developing a checklist for designing theoretically informed virtual reality tutorials which supplant the challenges new users face when interacting with VR.

The initial tutorial design used in this study was developed based upon the principles embedded in the IVR (Fig. 1), the VRGIS (Fig. 2), and Gagne's nine events of instruction (Fig. 3). These principles were applied alongside the instructional design theories of advance organizers (Ausubel, 1960), chunking (Anderson, 1977, 1996), and discovery learning (Bruner, 1961) in effort to supplant (Salomon, 1970; Ausburn & Ausburn, 2003) new users' difficulties with orientation (Hunt & Waller, 1999) and the inherent cognitive load (Sweller, 1998) experienced with using VR. The design was tested quasi-experimentally between a treatment group of surgical technology students from Tulsa Technology Center which experienced the tutorial and a control group that did not experience the tutorial in online VR sessions. The quantitative data revealed that:

- No differences existed in mean performance between wayfinding/orienting capabilities of participants based on treatment group. Therefore, the tutorial did not affect the wayfinding/orienting capabilities of participants.
- Differences did exist between cognitive load profiles of participants engaged with VR based upon treatment group, in favor of the experimental tutorial group. Therefore, the tutorial lowered the cognitive load profile of the participants.
- No differences existed between genders concerning wayfinding/orienting capabilities based on treatment group. Therefore, the tutorial did not interact with gender to affect wayfinding/orienting.
- No differences existed between genders concerning reported sense of cognitive load. Therefore, differences in reported cognitive load among participants were not related to gender, but to some variable(s).
- Transfer of training occurred for all subjects from the pre-test to the post-test however, no differences in performance existed between the transfer of learning/training profiles for participants based upon treatment group. Therefore, pretest/posttest transfer and improvement could not be attributed to the tutorial.

In Chapter III, it was hypothesized that participants in the tutorial treatment group would display higher scores on all of the assessments used in the study than users in the group that experienced VR without the tutorial structure. The researcher also hypothesized that the posttests of wayfinding/orientation and cognitive load would demonstrate that members of the treatment group would report greater comfort in using Laptop VR and a positive view of VEs as a learning medium. The results of the quantitative analysis did not support these hypotheses overall. Statistically, however, the assessments did indicate that the tutorial reduced the cognitive load profile of VR users in the study.

To gain additional information regarding the participants' level of comfort with using VE's the qualitative data gathered in the study was subjected to constant comparative analysis to develop broad themes to inform decisions concerning the efficacy of the tutorial, future tutorial designs, and the development of a checklist for designing virtual environments. The three overarching themes that developed included: favorable responses to the tutorial experience, negative responses to the tutorial experience, and mixed responses toward the tutorial experience. Therefore, participants' responses to the VR tutorial were mixed, presenting both praise and suggestions for improvement. Given the exploratory nature of the tutorial and the lack of guidelines from previous research, this mixed reaction was expected and considered both appropriate and helpful for identifying further research and experimentation with pre-immersion training for laptop VR experiences.

The researcher interpreted the results of the quantitative and qualitative analyses as indicators of the potential for future VR tutorial designs to reduce cognitive load for new

VE users and the need for additional research concerning pre-immersion VR training. The theories, constructs, and measures used to design and evaluate the tutorial represented only the first set of variables applied to address the issues inherent in using VR as a training tool. While the results did not fully support the hypotheses presented, future research will benefit from the evidence gathered, and alternate strategies will be better informed based on the development of a VR checklist. Therefore, in the sections that follow, the conclusions drawn from the researchers' interpretation of the data and recommendations for future research are discussed.

Conclusions and Discussion

Several conclusions were drawn from the data collected and analyzed in this study. These included:

1. The tutorial designed for the study helped the majority of participants assimilate the necessary skills to navigate within VR environments.

The majority of the qualitative responses collected in this study recommended the tutorial as a learning tool. Specifically, according to the qualitative responses, the tutorial: a) helped users navigate through the virtual environment and explained the functionality of the program's features, including hot spots and zooming, b) assisted users with visualizing the OR set up, and gave them a basic knowledge of the environment, and c) made the program user friendly and helped users with clear instructions. These reflections on the VR experience demonstrated that the tutorial designed for the study did address the intended elements of the IVR (Fig. 1) and the orientation phase of the VRGIS (Fig. 2) as described.

A few of the qualitative responses did not recommend the application of the tutorial and/or made comments about feeling uncomfortable with navigating the virtual environment, overcoming the technology, or feeling pressured to keep up with younger students. Based on the frequency and limited nature of the qualitative responses, further study of training tutorials and their application as a catalyst for the adoption of VR as a learning tool in CTE is warranted, and the issues apparent from the negative responses should be addressed and assessed in future tutorial designs. The researcher's intended future studies will be outlined in part in the recommendations section of this chapter.

2. The VR tutorial is a tool that further promotes the transfer of training with curricular materials and the application of VR as a learning tool for CTE.

The quantitative results for research question 3 demonstrated that 19 of the 26 participants (79%) improved their understanding of the embedded curriculum in the virtual environment regardless of presence or absence of the VR tutorial. This assertion is supported by the pre-test to post-test difference score presented in Table 3. This result supports the claims of prior literature that learning indeed occurs in virtual environments (e.g., Ausburn & Ausburn, 2004; Ausburn, Ausburn, Dotterer, Washington, & Kroutter, 2013; Boehle, 2005; Pantelidis, 1993; Raubal & Egenhofer, 1998; Riva, 2003; Selwood, Mikropoulos & Whitelock, 2000; Sulbaran & Baker, 2000; Wittenberg, 1995). Furthermore, qualitative responses from the administration at Tulsa Tech reported that the VR environment is a worthwhile tool for preparing students for surgery rotations and useful for review purposes. Additional comments that provided evidence of improved transfer of training/learning resulting from the VR experience included many of the comments from the researcher's first conclusion discussed above. Not only did curricular content learning occur regardless of treatment group, but the tutorial allowed many of the users to develop and adapt schema which aided the self-reported transfer of training concerning controlling the VR interface and navigating in the VE. This evidence further supports the continued development of VR tutorials and the inclusion of VR and VEs as learning tools for CTE. While the pre-immersion VR tutorial developed for this study could not be clearly and directly tied to higher levels of wayfinding/navigating in the laptop VE, it did appear to lower the cognitive load profile of users in the VE. Further refinement of the tutorial may strengthen its connection and contribution to improved performance in a curricular VE by capitalizing on its cognitive load reduction capabilities.

3. The theories selected from the literature review support a reduction of perceived cognitive load on the part of new VR users when challenged to answer curricular questions.

The quantitative results from research question 3 indicated that experiencing the tutorial improved the participants' perception of the cognitive load experienced when answering curricular questions on the post-test of the Surgical Environment Assessment (Appendix C). This finding illustrates the potential of tutorials to help improve users' perception concerning the assimilation of VR and VE as a learning tool for CTE as described in the VRGIS (Fig. 2). While the data did not support statistically significant differences concerning the users' perception of the cognitive load involved in navigating the VR or learning about the OR, the effect upon the perceived cognitive load implies that alternate tutorial designs may possess the potential to influence cognitive load in these and other areas.

4. Users can develop a limited sense of presence when experiencing laptop VR.

From the qualitative responses, it appears that the tutorial and the VR experience helped users to develop a sense of presence or actually "being there" (Ausburn & Ausburn, 2004) in the OR environment. For example, when talking about the tutorial and the experiment, a summary of participants' statements included:

1. The tutorial gave me an idea of what might be in there and helped with exploring the OR without actually having to go into one.
2. It gives a person an impression of what to expect in the OR and shows some of the things found there.
3. It gave me a point of view without being in the room.
4. It helps to explore the OR so it is somewhat familiar.

When asked about how real they felt the VE felt, the participants stated:

1. I felt the virtual environment was as realistic into the surgical culture as could be expected.
2. On a scale of 1-10 it was probably about an 8.
3. It was somewhat real or real.
4. 3D helped a lot but it would have been better to step foot in.
5. Similar to a good/old video game; nothing can replace the real thing.
6. I would rather be learning hands on and actually in the environment.

These responses illustrate that presence pertaining to laptop VR is based on individual perception much like the construct of cognitive load, and can be measured only on an individual basis similar to Likert-type scales or Paas and van Merrienboer's Cognitive Load Scale (1994). This may be due to the fact that with laptop VR, the size of the VE is limited by the size of the computer screen on which it is displayed. This suggests that instructional designers should not expect laptop VEs to ever achieve subject ratings of perfectly real or of VR experiences with fully perceived presence. Regardless, since some sense of presence can be achieved by VR users, this reinforces the application of VR as a learning tool for use in CTE, particularly for hazardous or remote environments where having at least a partial idea of one's surroundings could help alleviate the cognitive load involved in learning to work there effectively.

5. Instructional design flaws impede learners' outcomes when working with VR.

Several of the negative comments collected and the researcher's reflections on conducting the study shed light on instructional design flaws that should be considered for future tutorial studies. These flaws included timing of VR experiences, informing participants of expected tasks, accessibility issues, and hardware-knowledge issues that may arise given online deployment of VR interactions. Discussions of these flaws follow.

The first potential instructional design flaw to consider dealt with the timing of the VR experience. For the purpose of this study, the participants were assessed prior to entering the physical OR for the first time and before learning about the various types of equipment used there. This decision was made consciously by the researcher and was intended to provide naïve (i.e., inexperienced) participant reactions to both new curriculum and a new VE to obtain reference points for comparing the variables in the study. When participants were asked about potential changes or reactions to the VR, their responses included:

1. It was a little confusing because it asks about stuff we had not even mentioned or learned about before.
2. I would do the tutorial after the class know the OR equipment.
3. Have a basic understanding of the OR first.
4. …not during the second week; later would be better.
5. … after some basic info.
6. … Id also recommend it be used after a class had been to the room and had a better idea of the items in the video. This class has not learned any of them so when asked at the end where certain things are I don't believe it will be as accurate.

The comments above address the timing of employing VR applications in the learning process. Given that the "assessments" used in the study used that title, the participants may have reacted as though the results of their efforts would be considered as a summative evaluation rather than a formative one, which may explain some of their concerns, however the participants raised valid points concerning accuracy and using the VR experience at different times in their learning cycle. In fact, it is considered a best-practice among educators to continually recycle learning activities to promote learning and increase understanding (Jones, 2007). Thus, VR should perhaps be used in the beginning and throughout the learning process in order to introduce and reinforce concepts across individuals' learning cycles to improve their retention and accuracy with the material and improve their existing cognitive schema. In addition to illuminating timing concerns, these comments depict the confounded nature of the current tutorial's design. The curriculum content elements were embedded into the VR design and separating the navigational and cognitive load elements for independent assessment was impossible. Another implication of the comments of the participants in this study regarding when they felt the VR might be most effective is that VR may be more appropriate as a practice and review tool than as an actual substitute for physically visiting a site. On the other hand, VR environments with minimal design flaws may be fully capable of replacing physical visits to a site. This is an important issue for VR as a learning tool and merits further research.

The second instructional design flaw dealt with not informing the users of the nature of the activities that would be included at the end of the VR experience. Advanced organizers were used in the design of the tutorial to instruct the users on the processes involved, however the participants were never informed of the exact nature of the tasks involved in the final assessments before they experienced them. This was an unfortunate oversight apparent in the learners' reflections, for example:

1. It would probably be more useful if we knew what questions where asked at the end or had an idea.
2. The vr is very good but if your not told what you need to look for its hard to be accurate at the end.
3. When taking the tutorial I didn't know I really needed to pay attention to details so I didn't find the tutorial too useful.
4. Know what to be looking for.
5. Let the viewer know to pay close attention to details you may see while watching the tutorial before the questions.

6. Actually, had I known that there were going to be questions pertaining to how much I remembered seeing, I probably wouldn't have went through it quite so fast.

This flaw can be addressed easily in future designs with an additional advanced organizer, and it further indicates the need for additional studies to reveal other opportunities to improve upon tutorial designs, and increase the researcher's experience with potential designs.

The third instructional design flaw deals with partitioning the content into smaller chunks. Responses outlining this flaw included:

1. I like it, but it should be broken down into sections of the OR after having an overview look
2. Too busy with equipment, need less to orient the user for first time use.

These elements can also be addressed by the instructional designer. Planning the scope and sequence of any learning activity is a challenge, but just as instructors modify lessons to differentiate learning experiences (Wormeli, 2006) VR experiences must also be modified to relate to the varied capabilities of each learner. Further discussion of designing for differentiation will follow in the recommendations section below.

The final flaw apparent from the data consists of innate hardware failures and limitations of the instructional designer's knowledge of programming language. In this study two participants had issues with the computers they used. The devices would not play the audio portions of the tutorial for them. Another learner had issues with the quality of images when zooming in, and the researcher witnessed some of the video clips and/or panoramas moving around on the participants when they changed the zoom on their web browser or when they used different web browsers (i.e. *Google Chrome, Internet Explorer, and Firefox*). The former issues were due to machine maintenance, and the latter issues were due to the researcher's minimal experience with writing code to mount the tutorial online.

The hardware issues are more difficult to control when delivering VR. Each user's machine will have varying hardware and software capabilities. In industry, the standard solution is to list minimum requirements to run software. Perhaps the designer can list similar requirements on a web site or in a syllabus developed for the users who will experience intended VR sessions. The issue with designer's knowledge can be addressed by developing future tutorials in a team setting, relying on experts to aid with specialized knowledge, and/or through further design experiences which would increase the researcher's knowledge and skill with writing the necessary code.

6. Gender differences expected from the literature were not evident in the present study.

The results from research questions four and five revealed no statistically significant difference between genders on either orientation/wayfinding performance or perception of cognitive load. The sample in this study consisted of surgical technology students from Tulsa Technology Center. According to the administration, historically, more females are enrolled in that program and the sample included only six males and 20 females. With these small sample sizes, it is hard to accurately reveal statistical trends (Keppel & Wickens, 2004) due to lack of adequate statistical power of tests of significance such as *t*-tests and ANOVAs, thus it is not surprising that the results expected from the literature were not upheld. Further studies would allow for the application of the current tutorial and future tutorials with larger populations allowing for greater statistical power and a better picture of the potential differences between genders involved with VR.

Implications

This study was designed to: (a) develop a theory-based tutorial on using VR/VEs; (b) evaluate experimentally the effectiveness of the tutorial; and (c) based on the findings of the experiment, determine if a theoretically sound checklist could be developed for instructional designers to employ when creating pre-immersion training materials for VR. The practical and theoretical implications from the results of the study are outlined in the sections that follow.

Practical Implications

First, the results of this study reinforce the findings of existing literature concerning the use of VR as a learning tool. The participants displayed a transfer of learning/training concerning curriculum experienced in the VE and reported difficulty in knowing what to do once they entered the VEs. The participants were also able to report on their perception of the cognitive load experienced while engaged with the interlaced components of VR (i.e. navigation and curriculum concerning the operating room). Second, the tutorial designed for the study did address the intended elements of the IVR (Fig. 1) and the VRGIS (Fig. 2) and reduced the perceived cognitive load experienced by new VR users. Unfortunately, the tutorial did not influence the wayfinding performance of users or alter their capabilities in regard to improving learning outcomes. Third, the study revealed that gender does not influence wayfinding or cognitive load for surge tech students. Fourth, the qualitative responses revealed that the timing of the VR experiences should be considered. Finally, the data revealed that refinement of the tutorial and the inclusion of an instructional designer may strengthen its connection and contribution to improved performance in a curricular VE by capitalizing on its cognitive load reduction capabilities.

Theoretical Implications

The Virtual Reality Global Immersion System for Learning developed by the researcher (Fig. 2) provides a model for the theory-based processes involved in training new VR users. The VRGIS model was developed as an outline for constructing the VR tutorial used in the study, and is intended to provide a foundation for driving the innovation of applying VR as a tool for learning in CTE, both for general education purposes and for experiences in working fields with limited access environments. The tutorial that was developed from the VRGIS framework reduced the cognitive load new VR users in the surgical technology program at Tulsa Tech; however the expected change in performance hypothesized was not realized. Theoretically, these results imply that reducing the inherent cognitive load experienced by new VR users does not successfully address the apparent challenges mentioned in the literature. This result allows future research to alter the focus from purely reducing cognitive load and work toward discovering other potential theories that might alleviate the "lost in space" phenomenon, navigation difficulties, and/or the lack of understanding of the learning purposes and goals of VE exploration reported by new VR users. In other words, improve upon the theory surrounding learning with VR by discovering what does not work as readily as what does help and combining the knowledge to advance the research. Instructional designers should reap the benefits of the tutorial's capability to reduce cognitive load and continue to examine the complexities of the processes involved in working and learning with VR to determine what might improve performance, or what will outright not work. For example, the physical and or emotional characteristics of VR users may have an influence on performance. The state-trait anxiety scale (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) may provide an excellent tool to examine such an influence. This study helped to eliminate increased cognitive load as a primary suspect for the source of the challenges VR presents. The following recommendations are included to describe the researcher's next steps and introduce the VR Checklist.

Recommendations

1. Further studies are necessary to test additional theories and alternate tutorial designs to improve the capability of pre-immersion training for the application of VR as a learning tool.

First, nearly all of the conclusions drawn from the data in this study support the need for further study of VR tutorial designs. These conclusions support the emerging trend in VR literature recommending research on pre-immersion training for various VR environments (Ausburn & Ausburn, 2010; Kim, 2005; Kroutter, 2010; Larson, 1999). The theories employed in this particular tutorial design only scrape the surface of the strategies and constructs that may possess the potential to propel VR into mainstream, productive application as a viable training tool. Additional studies would also allow for addressing further recommendations of the IVR, and expanding the literature base for differentiating VR training solutions across disciplines and/or career fields.

Second, additional studies would improve the generalizability of findings concerning laptop VR and improve the understanding of digital instructional design as it evolves in the 21st century. Larger samples from various CTE career paths should be included in future studies to inform VR training differentiation and lead toward discoveries in the application of technology to supplant weaknesses for training across career and industry fields. With a better understanding of the constructs that influence users' initial VR experiences and the scope of training required in CTE, more of the truth behind the relationships between the VR technology and variables such as age, gender, career training, etc. may be revealed, and VEs may realize their true potential as agents for learning.

Finally, the efficacy of placing laptop VR training in online environments can be expected to improve as technologies evolve and instructional designers gain experience with the medium. The images and mounting procedures utilized in this study are a foundation for expanding future CTE training solutions. The images and scripts applied in constructing the tutorial seem almost primitive compared to the current resources under development by the researcher, and that is natural. Future designs will not only expand instructional designers' capabilities and skills, but they will increase the potential entertainment value of training solutions, learner motivation and engagement, and improve VR resource development as better production techniques and developers from across industries adopt the training medium. Such expansion will also allow instructional designers to address the desires of learners as well as their needs. For example, qualitative responses from the subjects included:

1. I think it would also help to be able to mess around with the tools and things in the labs.

2. Could be more interactive. I would make the screen with the video larger or with the ability to make it into a full screen.

These adaptations are not strictly necessary for learning curriculum or job skills, however adding versatility and the ability to individualize learning experiences is a win for designers, trainers, employers, and learners alike since the motivated learner/worker performs better overall (Wormeli, 2006; Marzano, Pickering, & Pollock, 2001).

2. In future designs, curriculum assessments and wayfinding/orientation measurements need to be separated.

The VE for this study was constructed with curricular elements embedded in the environment itself. In this configuration, it was difficult to determine which factors may have independently influenced user performance since the design confounded the variables involved. Running separate assessments for each variable and working to design VEs that are separate from the curriculum portion of the content will help with future data analysis.

3. Wayfinding in VR environments needs to be more extensively examined.

Orientation, the foundation for wayfinding capability, was assessed in this study. Other aspects of wayfinding and additional forms of wayfinding assessment should be addressed and utilized in future studies. While the current tutorial design displayed statistically significant influence on part of the participants' perceived cognitive load, no significant differences were apparent in the orientation capabilities of the subjects based on treatment group. Future studies should reference alternate instructional design decisions which expand the navigational requirements within the VR experience and assess the differences those decisions may have not only on orientation, but on the aspects of memory, recognition, spatial orientation, and navigation as alluded to in the literature in order to improve users' wayfinding performance and further address the "lost-in-space" phenomenon experienced by new users.

4. The transfer of learning/training construct should be examined in greater detail.

Arguably, the definition of transfer of learning/training utilized in this study is limited in scope. A pre-test/post-test design does show some transference of rote knowledge however that does not truly meet the criteria necessary for adopting VR as a CTE training tool. For VR to bridge the diffusion of innovations gap and become fully realized as a valuable training tool, further evidence of the ability of VR to produce learning and productive work in the real-world is necessary. This may mean expanding the scope of future studies beyond an educational setting and working with industry professionals to analyze their training needs, implement VR training materials and solutions, and reflecting upon and evaluating the efficacy of that work. CTE programs have forged paths into these relationships with industry for years, and provide an excellent resource for the necessary collaboration VR requires to achieve fruition as a training medium. The researcher recommends further cooperative VR research studies with CTE, and intends to design future studies within the Oklahoma Career Tech system that address the skills employers desire based upon trends within industry.

5. Suggestions for further qualitative research

The surveys used in this study provided limited insight concerning the participants' experience while interacting with VR. To provide further depth and uncover other potential instructional design strategies to enhance the development of VR tutorials, the researcher recommends adding additional qualitative research strategies for future studies. For example, In-depth observations with four or five participants both pre- and post-assessment, field notes, checklists, or screen captures of the participants behaviors and actions, and/or interviews with focus groups or face to face with selected participants would all provide a better understanding of the phenomena new VR users face (Creswell, 1998; Patton, 2002).

Conclusion

VR possesses potential as a valid training tool for CTE. Unfortunately, wayfinding and cognitive load challenges combined with challenging curriculum present a substantial enigma for many new VR users. The key to tapping in on the innate potential to VR is pre-immersion training (Ausburn & Ausburn, 2010). This training should help the user assimilate VR environments as learning tools by introducing the controls, challenging the users to work through objectives by experimenting within the medium, and finally applying that knowledge to new tasks as described in the VRGIS (Fig. 2). Through this process the user will become more familiar with wayfinding and working with VEs as learning tools and transfer the learning from the VR into real world working applications. As a reference for future VR designers the VR checklist as conceived by the researcher follows.

The VR Checklist

This pilot tutorial study opens a line of inquiry into researching VR training solutions to meet the needs of industry and future workers. In this researcher's opinion, from this study and the literature it is apparent that the following instructional design theories should be included when designing VR tutorials and VEs for training in industry:

1. Use advance organizers: They work to support learning by preparing users' expectations, and clarifying the tasks ahead.
2. Use information chunking: Breaking information into smaller pieces assists the adaptation and acquisition of schema for improving performance.
3. Employ locomotional constraints: require that users complete a task or skill to an acceptable level before proceeding in the training experience.
4. Utilize video and multimedia instruction: As learners' exposure to technology and thus digital literacy grow, the tools used to train them must continue to adapt.
5. Design with a team: Most of the items for this study were designed and constructed by the researcher. Use the strengths of an instructional designer and other experts to improve your designs and ensure the quality of the production.

This list is brief and not intended to be exhaustive or the final word on VR tutorial design, but rather a beginning. Future studies will provide further insight to designing VR training systems, and these recommendations will be updated as this line of inquiry evolves.

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APPENDICES

APPENDIX A
IRB APPROVAL

Oklahoma State University Institutional Review Board

Date:	Wednesday, January 23, 2013
IRB Application No	ED131
Proposal Title:	Development and Quasi-Experimental Evaluation of a Laptop Virtual Reality Tutorial
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 1/22/2014

Principal
Investigator(s):

Ryan Burkett 2138 Berkshire Dr Ponca City, OK 74604	Lynna Ausburn 257 Willard Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI, advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Shelia Kennison, Chair
Institutional Review Board

APPENDIX B
PARTICIPANT INFORMATION SHEET DESIGNED BY THE RESEARCHER

PARTICIPANT INFORMATION
OKLAHOMA STATE UNIVERSITY

Title: Development and Quasi-Experimental Evaluation of a Laptop Virtual Reality Tutorial

Investigator(s): Ryan Burkett, M.Ed. Educational Administration

Purpose: The purpose of this study is to test a theory-based tutorial on using Virtual Reality Environments and to determine if a theoretically sound checklist can be developed for instructional designers to employ when creating VR training materials.

What to Expect: Participation in this research will involve completion of three surveys. The first survey is a pre-test of the Surgical Environment Assessment. Following that assessment, you will interact with a Virtual Environment. If you are in the experimental group, a tutorial will prepare you for using the virtual environment to review. If you are in the control group, you will not receive the preparatory training and you will move directly into the virtual environment. Following these activities, the second survey is a post-test of the Surgical Environment Assessment. The third survey is the Operating Room Wayfinding Assessment Instrument. It will ask you questions about your experience with virtual environments, how familiar you are with the environment after participation, and how you feel about the experience overall. It should take you about 60-70 minutes to complete these tasks.

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered in daily life.

Benefits: You may gain an appreciation of how research is conducted, and the satisfaction of contributing to the improvement of VR as an instructional tool. You may also benefit from future use of VR by your instructors.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time, without penalty. This assessment will in no way affect your grade in your course, and your participation or non-participation in this study will have no repercussions for you as a student. The study you are offered an opportunity to participate in will aid in the development of future laptop virtual reality curricular materials. You will not be identified by name in the study. All information about you will be kept confidential and will not be released. All forms will have identification numbers, rather than names, on them. Once collected, the data will be used only for research purposes, be accessed only by the primary principal Investigator, and will be reported only in aggregate. The data will be kept for 2 years from the completion of data collection in July of 2013. After that, the data will be destroyed.

Contacts: You may contact the researcher at the following address and/or phone number, should you desire to discuss your participation in the study and/or request information about the results of the study: Ryan Burkett, M.Ed. 2138 Berkshire Drive, Ponca City, OK 74604, (580)-763-0322. As an additional point of contact, the researcher's Advisor may also be contacted: Lynna Ausburn, Ph.D., Willard Hall, Dept. of Teaching and Curriculum Leadership, Oklahoma State University, Stillwater, OK 74078, (405)-744-8322. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

If you choose to participate: Please, click NEXT if you choose to participate. By clicking NEXT, you are indicating that you freely and voluntarily and agree to participate in this study and you also acknowledge that you are at least 18 years of age. A copy of this consent page will be provided as you leave the assessment room. Please indicate your preference below:

APPENDIX C
SURGICAL ENVIRONMENT ASSESSMENT

Surgical Environment Assessment

Please select the item with the best answer from the questions below

***1. Enter the number from your paper slip.**

***2. Airborne contamination is reduced by re-circulation of filtered air at a rate of:**

- ○ 10- 12 air exchanges per minute
- ○ 10- 12 air exchanges per hour
- ○ 15- 20 air exchanges per minute
- ○ 15- 20 air exchanges per hour

***3. Each operating room has positive air pressure to**

- ○ maintain temperature
- ○ maintain humidity at 60%
- ○ keep corridor air out
- ○ filter dust particles

***4. Holds sterile basin with sterile water or saline**

- ○ Mayo stand
- ○ Ring stand
- ○ Case cart
- ○ Back table

***5. Holds sterile instruments; positioned across the sterile field**

- ○ Back table
- ○ Prep table
- ○ Mayo stand
- ○ Anesthesia screen

***6. Provides area for extra sterile instruments not used on the mayo stand**

- ○ Prep table
- ○ Kick Bucket
- ○ Back table
- ○ Linen hamper

***7. The best reason to keep traffic to a minimum in the operating room is to:**

- ◯ Avoid delay of procedure.
- ◯ Reduce noise.
- ◯ Prevent contamination of the sterile field.
- ◯ Avoid disturbing the patient.

***8. The proper humidity of an operating room is:**

- ◯ 20-25%
- ◯ 40-45%
- ◯ 30-35%
- ◯ 50-55%

***9. Used as a receptacle for discarded items to be laundered**

- ◯ Linen hamper
- ◯ Case cart
- ◯ Trash container
- ◯ Biohazard receptacle

***10. Used as a receptacle for soiled, counted sponges**

- ◯ Case cart
- ◯ Kick bucket
- ◯ Trash container
- ◯ Linen hamper

***11. Used by a member of the scrub team who requires additional height to be functional**

- ◯ Kick Bucket
- ◯ Foot stool, platform, or lift
- ◯ Mayo stand
- ◯ Ring stand

***12. Which is perhaps the most important safety attachment to the OR table?**

- ◯ Safety Strap/Belt
- ◯ Leg holder
- ◯ Shoulder Brace
- ◯ Anesthesia Screen

***13. Which of the following best describes the function of the mayo stand?**

- ◯ It is used as an ancillary piece of furniture
- ◯ The sterile basins rest on this piece of furniture
- ◯ The scrub works from this stand
- ◯ It holds the instruments not used on the sterile field

***14. Which of the following is important regarding environmental control in the OR to minimize contamination**

- excluding outside traffic and separation of clean and contaminated areas
- providing a work area between the operating rooms
- providing only one hallway for all traffic to minimize space
- wiping all surfaces of the OR with bleach between cases

***15. Which of the following is NOT a required surface material for the operating room?**

- nonporous
- waterproof
- fire resistant
- porous

***16. Which of the following table parts is used to separate the anesthesiologist's area from the sterile field?**

- Anesthesia Screen
- Shoulder Brace
- Mayo Stand
- Headpiece

***17. While a surgical case is in progress:**

- Doors remain open so staff can easily move in and out
- Doors should remain closed
- Doors remain open to circulate air
- Doors may be opened or closed

***18. Identify the image above.**

- Back Table
- Prep Table
- Mayo Stand
- Surgical Table

✱19. Identify the image above.

- ◯ Back Table
- ◯ Prep Table
- ◯ Mayo Stand
- ◯ Anesthesia tray

✱20. Identify the image above.

- ◯ tourniquet
- ◯ anesthesia screen
- ◯ safety strap
- ◯ tape

***21. Identify the image above.**

- graduate pitcher
- fluid warmer
- prep stand
- double ringstand

***22. Identify the image above.**

- mayo stand to hold prepsolutions
- prep stand to hold iv solutions
- iv stand to hold iv solutions
- anesthesia screen to hold anesthesia supplies

✱23. Identify the image above.

◯ kickbucket, holds clean dressings

◯ linen hamper, holds soiled linen

◯ kickbucket, holds soiled sponges

◯ trash hamper, holds paper trash

✱24. Identify the image above.

◯ steris

◯ autoclave

◯ laser

◯ monitor

✱25. Identify the image above.

- ◯ prep stand
- ◯ back table
- ◯ mayo stand
- ◯ kickbucket

✱26. Identify the image above.

- ◯ laser cart
- ◯ EKG machine
- ◯ docking station
- ◯ anesthesia machine

Next

Please answer the following questions providing as much detail as possible. We hope to improve this tutorial in order to advance the use of laptop virtual reality in education. Your input is extremely valuable and greatly appreciated!

***27. Talk about the tutorial and the experiment. Did the tutorial help you when preparing for the assessment? If so, how?**

***28. What changes would make the tutorial more effective? Would you recommend the tutorial?**

***29. Please make any additional comments.**

Prev Next

APPENDIX D
OPERATING ROOM WAYFINDING ASSESSMENT INSTRUMENT

Operating Rooms Learning Exercise

***1. Number from paper slip:**

[ ]

***2. What is your age?**

[ ]

***3. What is your gender?**

[ ]

***4. How would you rate your technology skill?**

- ◯ Novice
- ◯ Moderate
- ◯ Power User

***5. Have you experienced any virtual reality before?**

- ◯ Yes
- ◯ No

Instructions

This exercise is designed to see how much you learned about the operation room (OR) scenes you studied in the computer-based presentation you have just completed. Please answer EVERY question, even if you are not sure of the answer.

***6. When you enter this OR from the doorway and look around, you see that the sterile mayo set-up is located:**

- ◯ Ahead and to your left
- ◯ Ahead and to your right
- ◯ Behind you
- ◯ Immediately to your left

***7. You are now standing at the head of the bed, facing the doorway. The sterile back table holding the instrumentation is located:**

- ◯ Ahead and to your left
- ◯ Near the foot of the bed
- ◯ Ahead and to your right
- ◯ Next to the IV pole

***8. The IV pole is located:**

- ◯ Directly ahead of you at the foot of the bed
- ◯ Next to the door
- ◯ To your left
- ◯ To your right

***9. The item that is located immediately to behind you is the:**

- IV pole
- Sterile mayo set-up
- Sterile back table with laparoscopic instrumentation
- Anesthesia machine

***10. You now move to the foot of the bed and are standing facing where the patient would be. The sterile back table and instruments are located:**

- Behind you
- To your left
- To your right
- You would be unable to see it at all

***11. To check the IV pole from where you are standing, you should look:**

- Ahead of you to the right
- Behind you
- Ahead of you to the left
- Over your right shoulder

***12. You now move to the side of the bed with the door to your left. To view the video monitor, you should look:**

- Across the bed
- Behind you
- To your left and ahead
- To your right and ahead

***13. The sterile back table with instruments is located:**

- Across the bed
- Behind you
- To your left
- To your right

***14. You turn to face the back table. The kick bucket is now located:**

- Behind you
- Behind the video monitor
- On the opposite side of the bed
- To your left

***15. You now move and are standing on the other side of the bed, with the door at your right. To check the IV pole you should look:**

- Across the bed
- Behind you
- To your left and ahead
- To your right and ahead

***16. The sterile mayo set-up is located:**

- Behind you
- Out of your field of view
- Across the bed
- To your right

***17. The video monitor is located:**

- Across the bed
- On your side of the bed, to your left
- On your side of the bed, to your right
- Out of your field of view

***18. You will now move around the OR and locate important items. As you stand at the side of the bed with the door to your left, the 2 items on the same side of the bed as you are:**

- Back table with laparoscopic instruments and IV pole
- IV pole and video monitor
- Kick bucket and footstool
- Video monitor and mayo stand

***19. As you stand at the head of the bed facing the door, the 2 items located closest to you are:**

- IV pole and back table with laparoscopic instruments
- Kick bucket and IV pole
- Video monitor and sterile mayo set-up
- Video monitor and IV pole

***20. As you stand at the head of the bed facing the doorway, the item you cannot see is:**

- Anesthesia machine
- Back table with laparoscopic instruments
- Linen Hamper
- Kick bucket

***21. Make a list below of items that were included in the operating room:**

***22. Please choose the answer below that best describes how confident you feel that you have a clear understanding of the details of the operating rooms you have studied and have accurately answered the questions in this exercise.**

- I have no confidence in my understanding of the operating room and my answer accuracy.
- I have a little confidence in my understanding of the operating room and my answer accuracy.
- I have moderate confidence in my understanding of the operating room and my answer accuracy.
- I have good confidence in my understanding of the operating room and my answer accuracy.
- I have absolute certainty in my understanding of the operating room and my answer accuracy.

***23. Please choose the answer below that best describes the mental effort required for learning about the operating room environment.**

- very very low mental effort
- very low mental effort
- low mental effort
- minimal mental effort
- neither high nor low mental effort
- some mental effort
- high mental effort
- very high mental effort
- very very high mental effort

***24. . Please choose the answer below that best describes the mental effort required in answering the questions in this exercise.**

- ◯ very very low mental effort
- ◯ very low mental effort
- ◯ low mental effort
- ◯ minimal mental effort
- ◯ neither high nor low mental effort
- ◯ some mental effort
- ◯ high mental effort
- ◯ very high mental effort
- ◯ very very high mental effort

***25. Please choose the answer below that best describes the mental effort required to navigate in the virtual environment.**

- ◯ very very low mental effort
- ◯ very low mental effort
- ◯ low mental effort
- ◯ minimal mental effort
- ◯ neither high nor low mental effort
- ◯ some mental effort
- ◯ high mental effort
- ◯ very high mental effort
- ◯ very very high mental effort

***26. VR Presentation Group:**

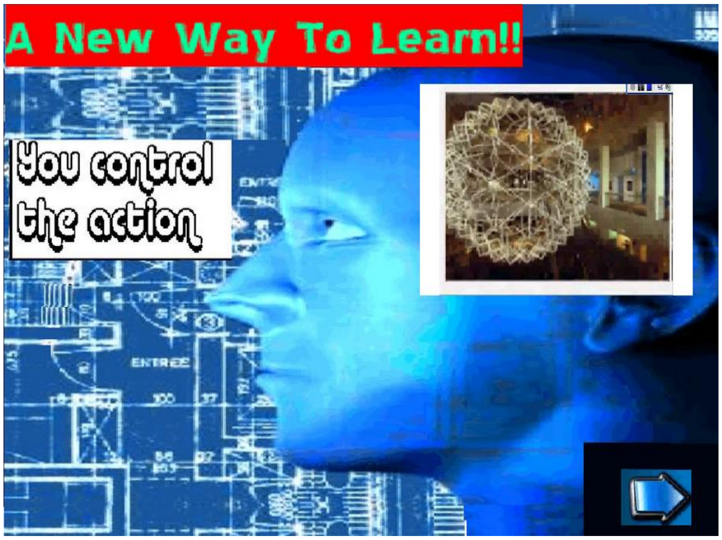
- ◯ Tutorial Group (blue slip)
- ◯ Non-tutorial Group (white slip)

Next

Appendix E
Tutorial Outline

Snapshots of each screen, notes on the content, and the transcript for audio segments follow:

Welcome to the desktop virtual reality tutorial. In the lower right hand corner, you will see a blue arrow next to the words click to continue. There will be one of these buttons on every slide that advances the presentation. Go ahead and click the button now to continue your journey

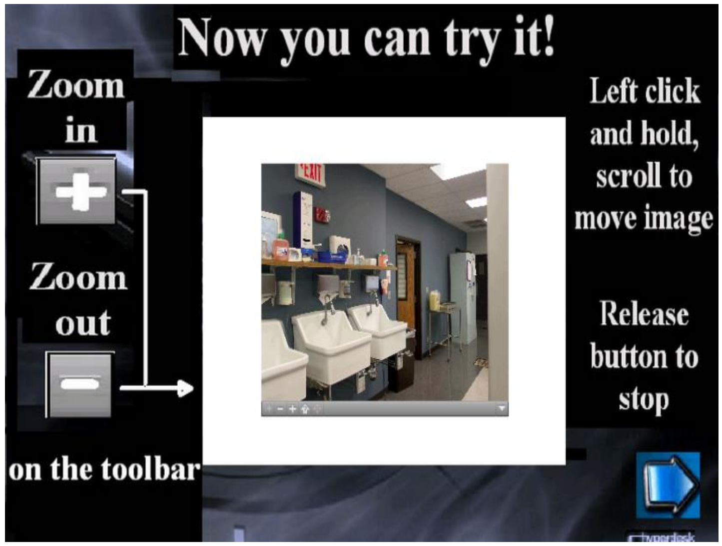


(Inset video of VR movie panning)
Desktop virtual reality or VR is a new method for presenting information in a format controlled by the learner. Through this tutorial, users will learn to operate the various controls in order to effectively use VR as a learning aid. When you are ready, click the arrow in the lower right hand corner of the screen to continue.

Please
Watch
and
Listen

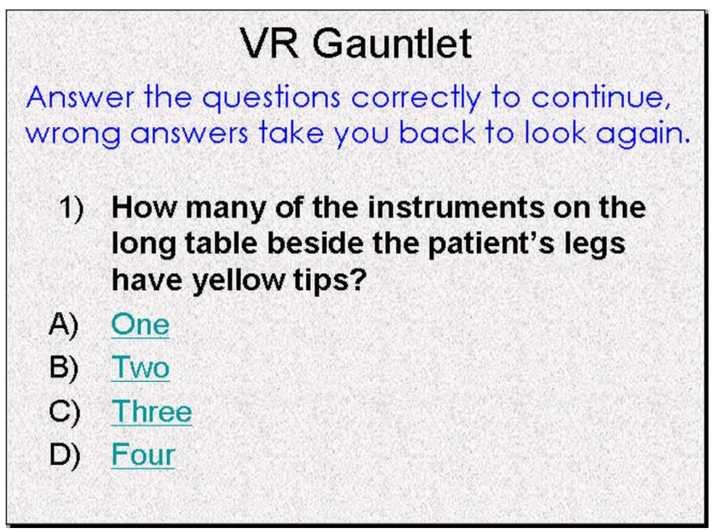
(Video plays walking the user through the controls)

We begin hands off. As you see, on this page, we offer a demonstration video which illustrates the uses for the controls in the VR environment. If you place your mouse in the middle of the screen and left click, as you move the mouse left, you will notice the image moves to the left as if you were standing in the center of the room. If you left click and move to the right, you notice the image moves to the right. The same is true for up and down movement. If you left click and move up, the view moves up, if you left click and move the mouse down you will view down. These controls are how we move around inside the VR panorama. Once we find something we want to look at, such as the top shelf here, we can't really see much detail. This is where the tool bar will come in handy. You will notice there is a minus sign which is zoom out and a plus sign which is zoom in. We will work with these two primarily right now. If we click the plus sign, we start to zoom in and now we can see greater detail. Such as the manufacturer of the scrubs is Ultradex. You can also zoom out and view more of the world you are immersed in. These features come in handy in several locations. Over here, we see a bulletin board. Let's see what we can find. We zoom in, we may have to adjust the view while were zooming, but you start to get greater detail and now we can see this picture. We see there are scissors, and some tweezers, and a few other items. Once we are done there, we may want to zoom back out so that we remember we are still looking at a bulletin board. There are a few other controls and we'll talk about them later. Sometimes the panorama will look a little different, but all panoramas will have these same tools. For instance, if I click the panorama open in QuickTime you will notice the controls are enlarged this will be the general format for a panorama; however for the purposes of the web unfortunately, we have these smaller tools. When you are ready click the arrow in the corner of the screen to try out these new tools.



(Embedded Panorama that the participants can manipulate)

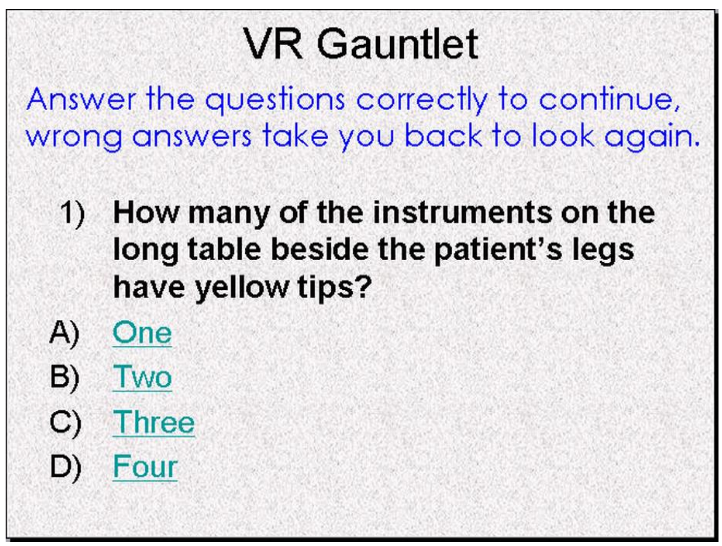
For this task you may scroll and zoom to examine the image. Just a tip, the next slides will ask questions to determine your skill with using the controls. There are also tips on either side of the window that will help you remember what the controls do. When you are prepared, click the next button in the lower right hand corner to continue on to the test.



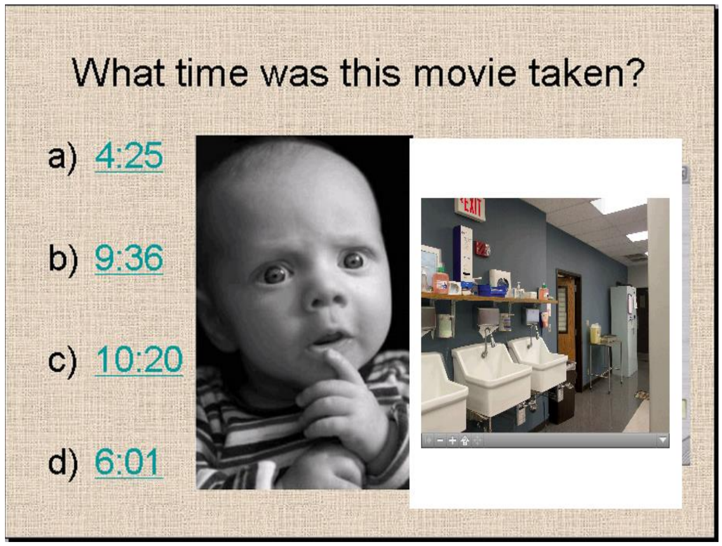
Now for the questions; you must answer the questions correctly to continue in this training program. Wrong answers will take you back to look again at the previous screen. The trick is we don't expect you to get the first answer right. How many of the instruments on the long table beside the patient's legs have yellow tips? We ask that you click on the answer one, which we know is wrong, so that you get an opportunity to go back and look at the VR again. Go ahead and click one now

(Embedded Panorama that the participants can manipulate)

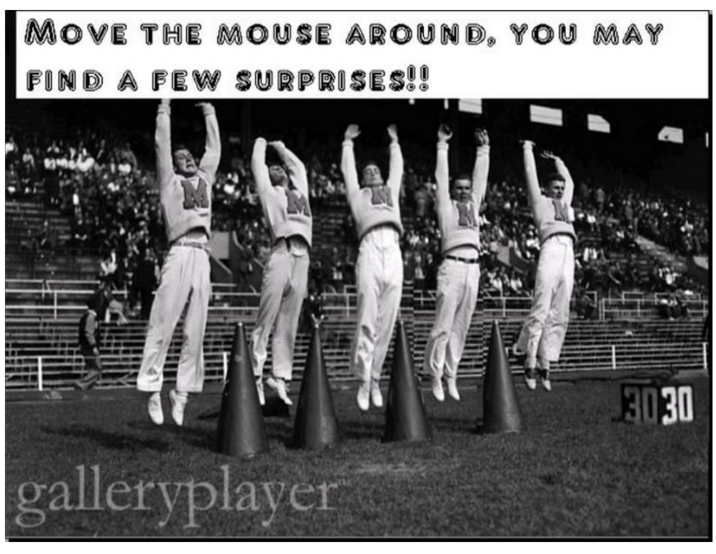
All right, we know we got that one wrong, but now we have a chance to go back and see if we can find the right answer. Go ahead and click on the VR image one more time. Scroll and zoom to look around and see if you can find the right answer. The question was how many of the instruments on the long table beside the patient's legs have yellow tips? Remember when you are done click the next arrow at the bottom right of the screen to return to the question.



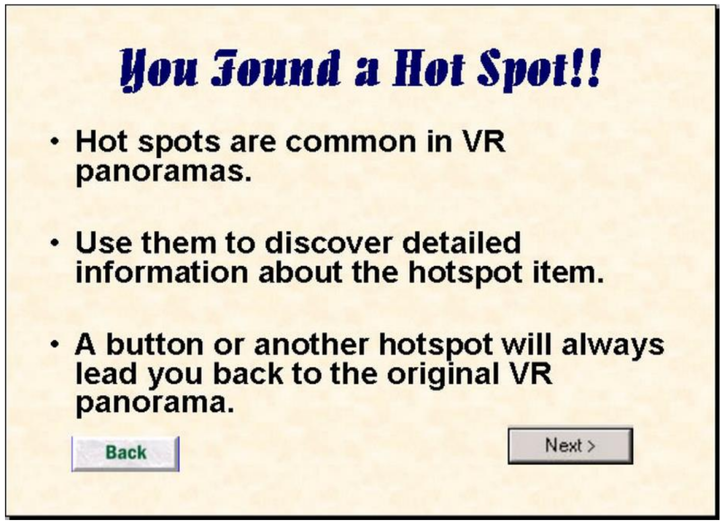
(This page allows the user to select their answer. Wrong answers link back to the panorama screen with the message; oops, you didn't quite get it that time. You may scroll and zoom to look around and see if you can find the right answer. Remember when you are done; click the next arrow at the bottom right of the screen to return to the question. The correct answer leads the user to the next page)



(Embedded Panorama the participants can manipulate. Wrong answers lead to a page with the same images and links reloaded with the Oops… audio clip. The Correct answer takes the user to the next lesson) Congratulations! You answered the first one correctly there were two yellow tipped instruments on the table. Now for the next question, a little bit more challenging; what time was this movie taken? Again you may choose one of the options listed. Click on four twenty five, nine thirty six, ten twenty or six o one. Remember that a wrong answer will take you back so that you have a second chance to view the VR and find the right answer. Good luck!



Now you've got it. That's two questions right. On this slide you can mouse around a little bit and see if you find a few surprises. You may notice that some items highlight when you mouse over them. Go ahead and click on one of these now. (Both of these links lead to the next page)



You found a hot spot. Hot spots are common in VR panoramas. You use them to discover detailed information about the item that was hot spotted. There will always be another button or a hot spot to take you back to the original VR panorama. From this slide you may either click back to go look for more hot spots, or click next to continue with the tutorial.

(Video plays walking the user through the controls)
The final demonstration; you will see our crime scene in front of you. On the tool bar the right button is a little house with a question mark in the center of it. If you click on this, you will see blue squares appear in the scene. These are our hot spots. As we click on one of these, with a left click, you will see the image changes. You will also see two more hot spots. In this case, one that leads to the telephone, and one that leads back out of the picture. On the one that leads out of the picture, you will notice that it says to new pan one movie on the bottom of the tool bar. So if you click this square, you would go to new pan one movie, which is our original scene. Similarly, if you hover over the top box, to phone pan displays in the tool bar. This will take you in for a closer look at what is happening near the telephone. If we click it our image changes again and we can now get some more detail on the telephone. The blue hot spot up here takes you back to the original scene, as is noted on the tool bar. Back at the home screen, as you pan across you will

see several hotspots in different locations. For example, if we hit this hot spot you will see fingerprints on the water glass. The hot spot may actually be in your way right now. If you click the hot spot button again, you will notice the hot spot turns off allowing you to see the finger prints more clearly. Remember that you can toggle the hot spots on and off at will to help you get better detail of the scene. As we click the hot spot to return to our original scene. You are invited to continue on to the next screen and try out your new found hot spot skills. In addition, we will have a few more questions just to make sure you're really on track. Remember to click the blue next button at the bottom right of the page to continue.

(Embedded Panorama that the participants can manipulate)

Now for the real test; it's your turn to try it out. Here's our famous crime scene once again. Take some time to familiarize yourself with moving between the hot spots in this scene. When you're ready; click the next button in the lower right hand corner to continue.

(Embedded Panorama the participants can manipulate. Wrong answers lead to a page with the same images and links reloaded with the Oops… audio clip. The Correct answer takes the user to the next question)

Three questions left; for the first one, on the telephone whose number is listed on the speed dial? You can of course scroll and zoom around to see if you can find the answer. Go ahead and find it now.

(Embedded Panorama the participants can manipulate. Wrong answers lead to a page with the same images and links reloaded with the Oops… audio clip. The Correct answer takes the user to the next question)

You got it. Two questions left. How many baggies are on the coffee table? Get her done.

(Embedded Panorama the participants can manipulate. Wrong answers lead to a page with the same images and links reloaded with the Oops… audio clip. The correct answer takes the user to the final instruments used in the study.)

You got it. You're getting good at this. Last question; and this one's for all the marbles. Find the mannequin on the chair. What number is on the mannequin's neck? Sounds easy doesn't it? See if you can find it now.

(After the assessments for the study, the last link takes you to this thank you page.)
This completes your training in the virtual reality tutorial. Thank you for taking the time to help us with our research. Your contribution is greatly appreciated. Now it is time to test out your skills in a real environment and see what you can learn. Good Luck.

APPENDIX F
Qualitative Data Thematic Groups

Talk about the tutorial and the experiment. did the tutorial help you when you entered the training environment? If so, how?

Positive	Mixed	Negative
Yes, it explained how to navigate through what would be there and how to use the different features that are there.	To some degree - since I already had some OR experience	It was a little confusing because it asks about stuff we had not even mentioned or learned about before
Yes, the tutorial instructed students to navigate through the program and gave students an insight into the functionality of the program.		I didn't have a tutorial, I just had pictures to figure on my own
Yes, it showed me how the room was set up and where everything was.		No, because I didn't have the video tutorial
Yes, showed how to navigate & use the different features.		No.
Sort of. It gave me an idea of what might be there		No.

What changes would make the tutorial more effective?

No changes	Changes
There are no changes that I feel the tutorial needs	I would do the tutorial after the class know the OR equipment.
None that I can think of at this time.	Have a basic understanding of the OR first.
Nothing	Not sure; I recall having difficulty with the navigation of the tutorial
None	

Would you recommend the tutorial?

Positive	Negative
Yes, the tutorial facilitates the student and makes the program user freindly.	No
Yes, But not during the second week; later would be better.	No
Yes, I think it would be helpful with navigation.	No
Yes, but after some basic info	
Sure	
Yes	
Yes	
Yes	

Do you believe that virtual reality experiences would be beneficial to your program or similar career training programs? Why or why not?

Beneficial	Non-beneficial
Yes, it helps explore the OR without actually having to go into one. It would be helpful in remembering what was seen in one and/or prepare for going into and OR. It gives basic knowledge of what is there.	No, I didn't find it helpful
Yes, it would show others some of the things you find in the OR and how it is set up	No
Yes, for photographic memory people	No
The virtual reality experience gives the person who has never been in the operating room an impression of what to expect.	
Yes, helpful to explore the OR so it is somewhat familiar	
Yes, it is relevant to the subject or career	
Sure, it's more interactive than just a video	
Yes, if I had a tutorial	

How real did the virual environment feel to you?

Real	Not Real
I felt the virtual environment was as realistic into the surgical culture as could be expected.	It was a little confusing because it asks about stuff we had not even mentioned or learned about before
On a scale of 1-10 it was probably about an 8	3D helped a lot but it would have been better to step foot in.
Somewhat real	Similar to a good video game; nothing can replace the real thing.
Real	It feels like an old video game.
	I didn't like it
	Didn't get it
	No

Do you have any questions or comments about the experience?

Yes	No
I am very thankful that Mr. Burkett has selected the surgical technology program as the subject of his experiment. There is not any virtual reality experiences available to students. This would be a very worthwhile tool to make available to students before they actually go to their surgery rotation.	No
Overall very useful for students to learn/refresh what they are studying.	No
It will be helpful to most I think since students seem to be more visually oriented now.	No
	No
	No
	No
	No
	No

Talk about the tutorial and the experiment. Did the tutorial help you when preparing for the assessment? If so, how?

Positive

Yes it helped with learning, it had the information that helped me find the hot spotsto tell me where the answers were.

yes, it gave visualization of equipment zooming in

yes, taught how to navigate around the virtual room.

yes, some It gave me a point of view without being in the room

yes, gave an overview of the OR

yes, instructions were clear

yes it did

Yes

Mixed

Yes and no. It would probably be more useful if we knew what quesitons where asked at the end or had an idea. the vr is very good but if your not told what you need to look for its hard to be accurate at the end.

I am not comfortable with navigating the virtual environment. It was helpful but the technology was something I had to overcome

Negative

When taking the tutorial I didn't know I really needed to pay attention to details so I didn't find the tutorial too useful.

The sound was missing. otherwise, I think it would have.

no

What changes would make the tutorial more effective? Would you recommend the tutorial?

Recommended

Yeah id recommend the tutorial. Id also recommend it be used after a class had been to the room and had a better idea of the items in the video. This class has not learned any of them so when asked at the end where certain things are i dont believe it will be as accurate.

felt pressure to hurry and keep up with younger classmates; tutorial itself was fine - the user needs help

I would recommend using it. I would also suggest a walk around with it so that you can get a whole experience of what they room looks like from all angles

be more clear when it came to zooming in. yes.

no changes, yes I would recommend it.

kmow what to be looking for. Yes I would recommend it

Yes I would recommend it

none and yes

Not Recommended or Referenced

Let the viewer know to pay close attention to details you may see while watching the tutorial before the questions.

I would make the screen with the video larger or with the ability to make it into a full screen.

sound could be enhanced

Could be more interactive

No

Please make any additional comments:

Pertinent	Non-pertinent
actually had I known that there were going to be questions pertaining to how much I remembered seeing, I probably wouldn't have went through it quite so fast	I have no other additional comments :-)
I like it but it should be broken down into sections of the OR after having an overview look	Good luck!!! This was fun
too busy with equipment, need less to orient the user for the first time use	great experiment
Although tutorials may be nice for the advances in todays society, I would much rather be learning hands on and actually in the environment.	Good Luck!
I think it would also help to be able to mess around with the tools and things in the labs	none

VITA

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