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The Comparative Study On The Effects Of Virtual Reality In The Application Of Case-Based Learning Approach While Studying The Human Heart

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THE COMPARATIVE STUDY ON THE EFFECTS OF VIRTUAL REALITY IN THE APPLICATION OF CASE-BASED LEARNING APPROACH WHILE STUDYING THE HUMAN HEART

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DEDICATION

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. God has been the source of my strength throughout this program. I dedicate my study to one of my best friends, Gloria Chipman, who gave a new direction to this project and became a survivor of Mitral valve disease in her journey. I also dedicate this work to my beloved mom, dad and Dr. Rebecca Briley who have encouraged me all the way and whose encouragement has made sure that I give it all it takes to finish that which I have started. Thank you. My love for you all can never be quantified. God bless you.

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ABSTRACT

Nurses need a solid understanding of anatomy knowledge to perform nursing skills, to understand how diseases affect the body, to understand treatment for the patient and help them for documentation. While past research has focused on using virtual learning environments to teach anatomical structures of the human body, there has been limited research on how to teach clinical anatomy by using cases while using Virtual Reality (VR) technology. This quantitative research study aimed to investigate the effects of VR in the application of case-based learning approach on learners' performance. The researcher compared two delivery modes (VR mode and paper-based mode) to analyze the learning gains of the participants. The participants also subjectively rated the mental load they used while studying the material. The researcher recruited twenty-nine nursing students from Midway University. No significant difference in the mean scores of both groups found while studying the anatomical structure of the mitral valve and two clinical cases. Moreover, the results indicated implementing a case study of either VR or paper-based mode was associated with significant gains in achievement which is supported by the other studies on case-based learning approach. Moreover, for both groups, there were no significant differences found in their intrinsic, extraneous and germane cognitive load while learning the material. The recommendations for further research include a larger sample, long-term retention, and opinions of faculty and students on VR-learning environment while studying clinical cases.

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LIST OF ABBREVIATIONS

CBL	Case-based learning
CLT	Cognitive Load Theory
CTML	Cognitive Theory of Multimedia Learning
ECL	Extranous Cognitive Load
GCL	Germane Cognitive Load
ICL	Intrinsic Cognitive Load
HMD	Head-mounted Display
MR	Mirtral Regurgutation
MS	Mitral Stenosis
MV	Mitral Valve
3D TEE	Three-dimensional Transesophageal Echocardiography
TPACK	Technological Pedagogical and Content Knowledge
VR	Virtual Reality
VRLE	Virtual Reality Learning

CHAPTER 1

INTRODUCTION

Background

One of the main endeavors of educators is to find ways to enhance the outcomes of education. Effective education media assisting learning have been constantly sought by the researchers of educational technology. Virtual Reality (VR) can be identified as one of these media because of its unique attributes. VR simply can be defined as a technology that uses computer graphics to simulate or replicate an environment, often using sensory stimuli (visual, auditory, tactile, etc.) to lead users to perceive an artificial environment as real (Blascovich & Bailenson, 2005).

One of the unique attributes of a VR system is immersion; that is, learners wear a helmet, whose position is tracked, so that an image can be redrawn in real time, to continuously update the scene as their head position moves around in the virtual environment. They hold a device (a wand or a controller) with which to interact with the virtual environment, which is also tracked. They can also interact with this environment in various ways, by touching objects, picking them up and manipulating them (Winn, Windschitl, Fruland, & Lee, 2002). Bricken (1991) claimed that with the right hardware and a visually realistic virtual environment, VR environments has a potential to improve the student's ability to understand the content that the VR simulates.

There is a spectacular growth in the development of VR systems especially those with particular purpose applications in education. The VR applications developed have aimed at various groups of learners (children, university students, adults, pupils with cognitive or physical impairments, etc.) and cover a large variety of contents (science, the arts, math, engineering, medicine) and pedagogical targets (improved learning, instruction, and training) due to the benefits of VR technology in teaching. This has paved a way for gained recognition from researchers and instructional designers (Chen, Toh, & Wan, 2004). On one hand, some researchers embraced VR and recognized it as a beneficial instructional tool due to positive learning outcomes in geometry (Song & Lee, 2002), geosciences (Li et al., 2002), astronomy (Aoki, Oman, Buckland, & Natapoff, 2008), architecture (Youngblut, 1998), and engineering (Bell & Fogler, 1995). On the other hand, some educators are skeptical and cautious regarding the added value and appropriateness of VR applications for learning (Roussou, 2000) and believe that any technological tool including VR should begin with the questions: what are we teaching, to whom, towards what objective? (Dede, 1998).

Pantelidis (1995) listed some reasons to use VR in education suggesting it can: provide motivation to learn; enable observation from multiple perspectives; encourage diverse ways of thinking; allow learners to proceed through an experience at their own pace; and encourage active participation. Studies also showed that Virtual Reality Learning Environments (VRLE), that have been created by VR tools (Virtual Reality Environment, n.d.) can stimulate learning and comprehension because it provides a tight coupling between symbolic and experiential information (Bowman, Hodges, Allison, & Wineman, 1998).

Designers and evaluators of VR systems have many ideas about how VR can facilitate learning (Dede, 1996), but there is little information concerning which of the VR's attributes best enhance learners' understanding. It is crucial to underline the fact that, as with any other instructional technology tools, VR should not be seen as an ultimate remedy for all kinds of learning issues, despite the positive findings of some research mentioned above. Learning is a very complex process involving various factors such as individual characteristics such as visual-spatial ability (Wanzel, Hamstra, Anastakis, Matsumoto, & Cusimano, 2002; Kali, Y., & Orion,1996; Garg, Norman, Eva, Spero, Sharan, 2002; Levinson, Weaver, Garside, McGinn, Norman, 2007; Lufler, Zumwalt, Romney,& Hoagland, 2012; Nguyen, Mulla, Nelson, & Wilson, 2014; Nguyen, Nelson, & Wilson, 2012; Tavanti, & Lind, 2001), gender differences (Guillot, Champely, Batier, Thiriet, Collet, 2007; Hisley, Anderson, Smith, Kavic, Tracy, 2008) and prior knowledge (Gerjets, Scheiter, & Catrambone, 2004; Dochy, Segers & Buehl, 1999), all of which play a role in shaping the learning process and learning outcomes. Those factors have not been fully investigated in VR literature.

Statement of the Problem

As in much health profession education, nursing education evolves to support the clinical and professional roles of its students and to serve the best. Nurse educators struggle to find the best ways to prepare nursing students to care for patients in the increasingly complex healthcare environment. New nurses must be prepared to solve problems and think critically in order to provide high-quality care to patients, and they must be able to analyze data, interpret results, draw reasoned conclusions and make complex decisions (Bambini, Washburn, & Perkins, 2009). Preparing nursing students requires educators to use creative teaching strategies that engage the students in active learning, which increases their motivation, sharpens their thinking, deepens learning and strengthens collaboration in the classroom (Majeed, 2014).

Anatomy/physiology courses are believed to scaffold nurses' understanding of pathophysiology, clinical assessment and many nursing procedures (Jordan & Reid 1997); however, these required courses remain a difficult challenge for many nursing students due to the breadth and depth of new complex information presented (Courtenay, 1991). Not only nursing students but also newly qualified nurses claimed that they were fearful of the biological sciences and reported that they were having difficulties in applying anatomical and physiological information (Clancy, McVicar, & Bird, 2000; Tanner, 2003).

The importance of biological courses requires careful investment in effective learning and teaching methods in these nursing courses. The study of anatomy, for many nursing students and for many years, has relied heavily on surface learning of anatomy with text, and/or animal dissection (Johnson, 2010). Poor understanding or recall of anatomy and physiology or the inability to apply theory to practice may result in serious adverse outcomes for patients and contribute to the detrimental public perception of the nursing profession (Mayner, Gillham, & Sansoni, 2013).

Nursing educators need to explore different methods of delivery of these important topics. Any method which can emphasize and reinforce anatomical knowledge and particularly the relevance of anatomical learning to nursing students should be carefully studied (Davies, Murphy, Jordan, 2000; Jordan & Reid, 1997) because it is obvious nursing students consistently have difficulty understanding and retaining information on anatomy and struggle with the application of this content in clinical practice (Boelen & Kenny, 2009; White & Sykes, 2012). Since these areas underpin clinical practice and decision making (White & Sykes, 2012) it is important that nursing students are able to understand and retain the anatomical knowledge and apply it to practice.

Lectures are definitely a powerful method of delivering information to a large number of students quickly, but there has always been a need for an alternative to the traditional format in basic sciences education (Abbey, Arnold, Halunko, Huneke, & Lee, 2003). Although no single teaching method ensures a thorough understanding of a topic, various methods are being used in many institutes to reinforce lectures in teaching anatomy such as case-based learning (Walter, 2009) problem-based learning (Tiwari, Lai, So, & Yuen, 2006) and patient-centered learning (Vari et al., 2001).

Case-based learning (CBL) is commonly used in medical and other health sciences courses, and has been used in nursing education (Iqbal & Rubab, 2012; Grossman, Krom, & O'Connor, 2010). Real cases that nurses might encounter in a hospital are used to practice and apply basic scientific concepts in making clinical decisions and thinking critically in a patient-care scenario. Instructors find case studies in various resources including websites, experiences that they have, textbooks, etc. The real challenge for instructors is to align the medical case studies with their learning objectives and make the cases as real as possible to integrate them into their classroom settings. Moreover, finding a real patient to demonstrate all medical case would be a difficult job for educators. At this point, VR could be used as a virtualization tool which enables the instructor to create a virtual case based on a predefined problem and known answer (El-Razek, El-wahd, El-bakry, 2010). The VR technology allows to put students in a semi-real situation and the objective is to learn how to react in a particular situation.

Purpose of the Study

The purpose of this study is to investigate the effects of VRLE on nursing students' learning outcomes while studying human anatomy through case studies. Literature is abundant evidence that case studies offers several pedagogical benefits to students, including improvements in a) students' intrinsic motivation to learning (Facione, 2000; Ferrari & Mahalingam, 1998) , b) sophistication of critical thinking skills (Ennis, Millman& Tomko, 2005), c) retention of knowledge (Malau-Aduli, Lee, Cooling, Catchpole, Jose & Turner, 2013), d) encouragement of self-evaluation and reflection (Cliff & Wright, 1996), and e) effective collaboration interactions (Wenger, 1998; Webb & Palincsar, 1996). However, using VR as a learning tool to facilitate the case studies in a classroom has not been investigated yet. Since developing VR-based content and using VR tools are still more expensive and time-consuming than paper-based case learning module, it is important to identify any added value that accrues from visiting a VRLE, which might justify the extra expense and effort.

The Significance of the Study

Nursing instructors are constantly looking for effective ways to improve the learning experience of their students (Kaser, 1996). It is also important for instructional designers and VR software developers to actively reconsider which learning experiences play a substantial role in shaping students' learning and perhaps discard or reduce those that hinder learning. The high cost of VR tools, including VR headset and VR ready computer/laptop, make it inaccessible for most higher education institutions. When deciding on an instructional tool, an empirical research must be conducted to evaluate the educational value of the tool. At this point, this research will contribute to the understanding of how effective the VR tool could be in learning anatomical structures and clinical cases compared to a paper-based mode.

Too often, technology is purchased without a clear vision of how it is to be integrated into the mission of the university. Research suggests that technology projects should be implemented only after a planning stage, where administrators and other stakeholders develop clearly articulated standards and goals for technology use (Trotter, 2001). The research site for this study, Midway University, is willing to strengthen technological resources as it is clearly stated in their 2017 Strategic Plan (Midway University Strategic Plan, 2017). This research finding will help university administrators decide whether to allocate budget for VR lab in the university which can be used not only for nursing but also for criminal justice and psychology students.

To use technology effectively, teachers must understand how its use fits into the larger curricular and instructional framework (Coley, Cradler, & Engel, 1997). Instructional technology tools are most likely to be effective when there is a match between the software, the objectives of the instruction, the students' prerequisite knowledge and skills, and teachers' understanding of the needs of the learners (Valdez, McNabb, Foertsch, Anderson, Hawkes, & Raack, 2000). At this point, the researcher of this study worked with Anatomy& Physiology instructor, simulation lab director, and instructional technology designers at the Midway University to design instructional framework on how to integrate VR into classroom settings.

To summarize, the results of this study will create awareness of the potentials and/or weaknesses of the current VR technology for use in teaching and learning. This research will make a contribution by providing evidence for nurse instructors who want to apply case-based learning approach in their classroom by using VR technology.

Rationale of the Study

The Institute of Medicine and National League for Nurses have identified the need for nursing educators to develop technologies to prepare future nurses with clinical skills to care for their patients in the 21st century (IOM, 2010; NLN, 2012). Historically, nurse educators have used paper case studies and medium- or high-fidelity simulation to teach clinical skills; however, studies have revealed that virtual environments provided learning experiences that mimicked the genuine workplace in virtual form (Kapp & O'Driscoll, 2010; Kilmon, Brown, Ghosh, & Mikitiuk, 2010). In light of these findings, VRLEs could offer unrecognized opportunities for nurse educators when studying clinical cases. Nursing education is faced with the challenge to select, develop, and implement virtual learning environments that will advance future nurses' understanding of the content matter. The rationale of this study is to provide an evidence if VRLEs can contribute to nurses' knowledge by exposing them to the environments where they can learn clinical cases and anatomical structures.

Research Objectives

There are three primary objectives of this study:

1. The effect of the VRLE on learning human heart anatomical structure will be assessed.
2. The effect of the VRLE on learning clinical case studies in the application of case-based learning approach will be evaluated.

3. The cognitive mental load of the learners who are exposed to VRLE will be compared with the learners who are in traditional classroom environment.

Research Questions

Educators like any trainer or clinician need for research to evaluate the educational value of technological tools before they are integrated into the curriculum. Due to the evidence-based knowledge gains of using 3-D computerized models in the medical field (Nicholson, Chalk, Funnell, & Daniel, 2006; Estevez, Lindgren, & Bergethon, 2010; Levinson, Weaver, Garside, McGinn, & Norman, 2007; Ruisoto, Juanes, Contador, Mayoral, & Prats-Galino, 2012; Muller-Stich et al., 2013), it is hypothesized that VR will enhance understanding complex concepts of anatomy and give nursing students a new way of studying clinical cases that cannot be done in a regular classroom setting.

For this comparison study, twenty-nine nursing students were recruited to measure the effect of VR on learning. In order to see the efficiency of VR technology in case-based learning approach, the researcher compared VR designed learning material with those of the paper-based. VR group used Head-Mounted Display (HMD) and two controllers. Midway University's simulation lab which is used by nursing students in order to practice their nursing skills was allocated for VR group during this research. In order to evaluate the educational value of VR system in learning anatomy, factors such as the learner's characteristics on the learning process such as prior knowledge (Dongmei, Wilson, Rockhold, Lehman, Lynch, 2016), and level of mental effort (Fraser, Ayres, & Sweller, 2015) should be taken account. With these factors in mind, the following questions are addressed during this study. Each question will be identified by the null hypotheses (H_o) and alternate hypothesis (H_a):

Research Question 1: How effective can a VR be after studying Mitral valve (MV) anatomical structure when compared with a paper-based mode?

H_a: The VR mode group's mean scores of post-test are higher than the paper-based mode group's means scores after they have studied the anatomical structure of the MV.

H_o: There is no statistical difference in the VR mode group's mean scores of post-test and the paper-based mode groups' after they have studied the anatomical structure of the MV.

Research Question 2: How effective can a VR be after studying the MV diseases in the application of case-based learning approach when compared with the paper-based mode?

H_o: There is no statistical difference in the mean scores of post-test test among students who studied the MV diseases through the VR mode and the paper-based mode.

H_a: The VR mode groups mean scores are higher than the paper-based mode groups' after they have studied the MV diseases.

Research Question 3: Is case-based learning effective in teaching MV diseases regardless of the delivery mode?

H_o: There is no statistical difference in mean scores of pre-test and post-test of the learners' who studied the MV diseases.

H_a: There is a statistical difference in the pre-test and post-test of the learners' who studied the MV diseases.

Research Question 4: What is the perceived level of difficulty in students studying materials with VR versus the paper-based mode?

H_a: The intrinsic mental load among the VR group is lower than the paper-based group.

H_o: The intrinsic mental load among the VR group is equal to the paper-based group.

H_a: The extraneous mental load among the VR group is lower than the paper-based group.

H_o: The extraneous mental load among the VR group is equal to the paper-based group

H_a : The germane mental load among the VR group is higher than the paper-based group.

H_o: The germane mental load among the VR group is equal to the paper-based group.

H_a: The overall mental effort used by the VR group is lower than the paper-based group.

H_o: The overall mental effort used by the VR group is equal to the paper-based group.

Assumptions of the Study

1. All participants have clinical reasoning skills while dealing with clinical cases since clinical reasoning is a process that is continuously developed throughout each nursing course in all programs (Simmons, 2010).

2. During the assessment process, the assumption was that all participants would answer honestly and truthfully.
3. VRLE will be essential to the case-based learning approach because of the contextual nature of the VR and clinical cases.

Delimitations of the Study

This study focused on the effectiveness of VRLE in anatomy classes where clinical cases are taught. Technical difficulty, encouraging teamwork, attitudes of students and faculty towards VRLE, collaborative problem-solving, decision making skills, critical thinking skills, and the financially feasibility to design and develop these emerging technologies were not the focus of this study, since these have been the focus of much of the existing literature (Bai & Fusco, 2012; Kidd, Knisley, & Morgan 2012; McCallum, Ness, & Price 2011; McKenna & Jones, 2012; Rogers, 2011).

Study Challenges

1. Midway University is not a research university, so it can be hard to recruit participants.
2. Nursing students have a tight schedule. Therefore, they might not be willing to take part in the study.
3. The university does not have space to set up the VR apparatus.
4. Writing a clinical cases that are to be used in medical education is a serious and structured process and it has a certain guideline to follow (Budgell, 2008). It requires certain skills such as clinical reasoning that the researcher does not have. Therefore, it's been a challenge for the researcher to create a scenario based on a clinical case report.

Definition of Terms

Virtual Reality: While there are many and varied definitions and interpretations of the term, for the purpose of this study, virtual reality refers to 3D HTC Vive headgear plus controllers (Albanesius, 2014).

Virtual Reality Learning Environment: In this study, the virtual learning environment is defined as an environment that is created with certain objectives in mind by using a 3D game engine and that perceptually surrounds the learner and increases his or her sense of presence or actually being within it.

Unity3D: a commercially available multiplatform game engine used for the production of 2D and 3D video games as well as non-game interactive simulations.

Head-mounted Display (HMD): a piece of equipment that a person wears over their eyes that allows them to experience images and sounds produced by a computer as if they were part of real life.

Clinical Anatomy: It is defined as anatomy in all its aspects - gross, histologic, developmental and neurologic as applied to clinical practice, the application of anatomic principles to the solution of clinical problems and/or the application of clinical observations to expand anatomic knowledge (American Association of Clinical Anatomists, AACA).

Clinical Reasoning: In this study, the term clinical reasoning to describe the process by which nurses collect cues (through physical examination, and studying symptoms), process the information (analyze data to come to an understanding of signs or symptoms; compare normal versus abnormal) come to an understanding of a patient problem (diagnosis), plan and implement interventions (treatments-complications), and evaluate outcomes (Kraischsk & Anthony, 2001)

Case-based learning: A case, problem, or inquiry is used to stimulate and underpin the acquisition of knowledge, skills, and attitudes. Cases place events in a context or situation that promote authentic learning. Cases are generally written as problems that provide the student with a background of a patient or other clinical situation. Supporting information is provided, such as the latest research articles, vital signs, clinical signs and symptoms, and laboratory results (Williams, 2005).

Mitral Valve: It is located in the left side of the heart between the left atrium and left ventricle. When the left atrium fills with blood, the mitral valve opens to allow blood to the left ventricle. It then closes to prevent blood from flowing back into the left atrium.

Mitral Regurgitation: It is leakage of blood backward through the mitral valve each time the left ventricle contracts (American Heart Association).

Mitral Stenosis: Mitral stenosis is a narrowing of the mitral valve opening. Mitral stenosis restricts blood flow from the left atrium to the left ventricle (American Heart Association)

3D Transesophageal Echocardiography (TEE): It is a catheter-based procedure to allow us to visualize the volumetric acquisition of structural heart diseases (Faletra et al., 2014).

Color Doppler: It is a noninvasive assessment of the presence and severity of mitral regurgitation.

Summary

This study helps to address the void caused by the limited amount of scholarly research available on VRLEs used in nursing education. Data was gathered through pre and post-test to provide an evidence on the learning gains of VRLEs. In addition, this study examines the cognitive load that the learners have experienced while studying the content matter in both virtual learning environment and traditional classroom settings.

CHAPTER 2

LITERATURE REVIEW

Virtual Reality

Virtual reality (VR) can be defined as a class of computer-controlled multisensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways. This technology usually includes a computer capable of real-time data, controlled by a set of data gloves and a position tracker, and using a HMD for visual output (Biocca, 1992). VR can also be defined as an environment created by the computer in which the user feels immersed, a perceptual and psychological sense of being in the digital environment presented to the senses (McLellan, 2003).

Several attempts have been made to describe different types of reality. One commonly quoted definition is the model introduced by Milgram and Colquhoun (1999) describing a continuum and a gradual transition as shown in Figure 2-1. The figure depicts the continuum from the real world to the virtual world, leaving space in between for augmented reality as well as for augmented virtuality and considering everything between these two worlds the mixed reality.

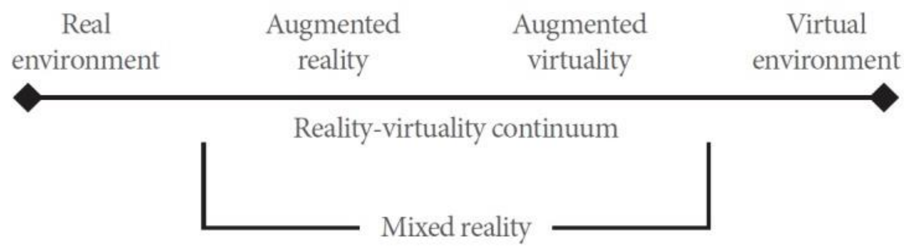

Figure 2-1: Reality continuum. From "A Taxonomy of Mixed Reality Visual Displays" by P. Milgram and F. Kishino, 1994, *IEICE TRANSACTIONS on Information and Systems*, *77*(12), 1321-1329.

Benefits of VR in Educational Settings

The possibilities provided by the use of virtual environments, such as 3D immersion, multiple perspectives and multisensory cues (Saltman, Dede, Loftin, & Chen, 1999) offer a number of potential benefits to education (Pantelidis, 1995, 1996, 2009). The engagement and excitement that is part of the VR phenomenon is an obvious candidate for exploitation in education (Bricken & Byrne, 1994). The motivation and mindful engagement (Salamon, Perkins & Globerson, 1991) of the virtual environment come not only from the novelty but from interactivity, realism, and immersion (Malone & Lepper, 1997). VR also is an empowerment technique that stimulates interest in any content matter, and it opens many new paths for learning (Pantelidis, 1995). Gay and Santiago (1994) reported that high schools have effectively used VR to stimulate interest in algebra, geometry, science, and the humanities.

The goal of VR is to enhance, motivate and stimulate students of certain events and at the same time also allow for students to experience hands-on learning (Shim, Park, Kim & Ryu, 2003; Bricken, 1991). But what is more appealing with regards to VR in education is the fact that it can allow learners to practice procedures without the risk involved. This can be applied in medical education without compromising the safety of a real patient (Bell & Fogler, 1995; Huang, Liaw, & Lai, 2016; Shim, et al., 2003). Using VR technology in surgical educations can assist surgeons to determine their competence level before actually operating on a patient (Ota, Loftin, Saito, Lea & Keller, 1995). The use of VR surgical simulation to reach specific target criteria significantly improved the operation room performance of residents during laparoscopic cholecystectomy. This transfer of training skills from VR to operation room sets the stage for more sophisticated uses of VR in assessment and training, allows for error reduction (Seymour, Gallagher, Roman, O'Brien, Bansal, Andersen, & Satava, 2002).

Labs in engineering education are designed to improve the practical knowledge of the students and their ability to solve problems independently (Abulrub, Attridge & Williams, 2011). VR technology can help engineering students apply their theoretical knowledge to actual industrial problems. This could reduce the cost of building the actual models and encourage the students to unleash their creativity and assess the value of their solutions. VR technology in this field could also reduce the risk of using hazardous materials in the teaching process and reduce the impact on the climate by eliminating the wasteful materials or any harmful mistakes made by the students (Abulrub et al., 2011)

VR learning offers the possibility to be tailored to learner's characteristics and needs. Learners are allowed to proceed through an experience at their own pace and during a time period that is not fixed by a regular class schedule. Furthermore, VR provides materials that do not break or wear out. It also focuses our attention on the tasks and elements at hand, excluding extraneous information and reducing distraction (Bricken, 1991).

Furthermore, VR allows for an intuitive way of learning by focusing on the first-person experience. This is particularly important in the learning process. Unlike third-person experience, first-person experience is subjective (Winn, 1997) and helps students generalize new knowledge in a more effective way to retain the knowledge (Youngblut, 1998). Moreover, it motivates students to further investigate what they are learning (Heim, 1993). As motivation increases, it is more likely that they learn new information with ease (Bryne, 1996; Gay, 1994; Nadan, Alexandrov, Jamieson, & Watson, 2011). Along a similar vein, Psotka (1995) believed that VR experience also has a high replay value that students can come back to discover new things and engage with content.

According to Moro, Stromberga, Raikos, and Stirling (2017) VR can be as valuable for teaching anatomy as tablet devices, but also promote intrinsic benefits such as increased learner immersion and engagement. These outcomes show great promise for the effective use of VR as a means to supplement lesson content in anatomical education. Moreover, Hoffman and Vu (1997) claimed that VR-based anatomy programs could allow their users to investigate structures in ways not possible in the real world. Those programs have the potential to make broad-based training experiences available to students at all levels, without the risks and ethical concerns associated with using animal and human subjects.

Educators should also be mindful when or when not use VR in their classroom. In order to benefit from the attributes of VR, teachers should assess the conditions and the nature of the teaching content. Pantelidis (1996) made the following suggestions as to when to use and when not to use VR in education. Teachers should consider using this tool when a simulation could be used; teaching or training using the real thing is dangerous, impossible, inconvenient, or difficult; a model of an environment will teach or train as well as the real thing; interacting with a model is as motivating as or more motivating than interacting with the real thing; travel, cost, and/or logistics of gathering a class for training make an alternative attractive and information visualization is needed so it can be more easily understood.

There are also situations where VR should not be considered, such as no substitution is possible for teaching/training with the real thing; interaction with real humans is necessary; using a VR could be physically or emotionally damaging; and using a virtual environment where a simulation is so convincing that some users could confuse model with reality (Pantelidis, 2009).

Limitations, Concerns, Issues &Possible Solutions of VR in Educational Settings

While VR has advantages as an instructional technology, researchers have also pointed out its limitations. One important issue is the high level of skills including 3D modeling, texturing, character animation and programming (Mantovani, Gaggiolo, Castelnuovo & Riva, 2003). Very high levels of programming and graphics expertise and expensive hardware and software are necessary to develop immersive VR along with considerable skill needed to use the VR application effectively in instruction.

Another concern related to VR is health issues including ocular problems, headache, and simulation sickness (Mantovani et al., 2003). Undoubtedly, the most commonly investigated in the literature of VR is simulation sickness (Golding & Gresty

2005; Treleaven, Battershill, Cole, Fadelli, Freestone, Lang, & Sarig-Bahat, 2015). In fact, it was reported that about 80–95 % of individuals interacting with an HMD experience some level of simulation sickness, with 5–50 % experiencing symptoms severe enough to end participation (Treleaven et al., 2015). As a result of those studies, it is recommended that individuals should be screened for motion sickness susceptibility and that those susceptible be warned of VR side effects (Stanney, Hale, Nahmens, & Kennedy, 2003). Taking into those studies on health issues, the researcher excluded the participants from this research who have motion sickness and serious vision problems.

Regarding the exposure time, Bownman, Gabbard, and Hix (2002) agreed that a lengthy experiment (anything over 30 minutes might be considered lengthy) must contain planned rest breaks in case of fatigued subjects. For this study, total VR exposure was purposely limited to 25 minutes. For each case, the participants were given a five-minute break.

In using VR, the user cannot see the surrounding physical world which can cause a safety issue that one must consider. Researchers ensure that participants will not bump into walls or other physical objects, trip over cables, or move outside the range of the tracking device (Viirre, 1994). To mitigate risk, one can make sure cables are bundled and will not get in the way of the user. Also, the user may be placed in a physical enclosure that limits movement to areas where there are no physical objects to interfere (Bowman et al., 2002).

Instructional design issues create another set of challenges for VR environments. Wong, Ng, and Clark (2000) claimed that a VR designer's understanding of a task, cognitive task analysis technique, and skill in translating these to a sound instructional design are critical for successful VRLEs. Along the same vein, Sulbaran and Baker (2000) also stressed the importance of solid instructional design, cautioning that the design must overcome the potential problems of overly complex navigation control and inconsistent or unengaging interface design. Due to this concern, Mantovani et al. (2003) emphasized that technology may be appropriate to be used as a supplement rather than a replacement of live instruction and experience. This view was also implied by Sulbaran and Baker's (2000) that virtual training is not meant to replace instructors, but rather to provide learners with a valuable alternative medium for conveying knowledge.

Educators are often disappointed because they cannot find software to meet a specific curriculum goal and the software usually not allow them to modify the content which constraints their activities (Wang, Ying, Xiong, Wang, & Dai, 2009), and VR application is not an exception. One way of ensuring that software is useful and usable in the classroom is to ask instructors what they want and to involve them in the process. The teacher-centered approach where teacher involvement and commitment to the project is crucial should begin at the very early stages of designing educational application. As Cates (1992) pointed out, "The history of the adoption of educational technology attests to the fact that teachers play a major role in the success of an innovation" (p. 5).

Involving the teachers from the beginning ensures not only that the software is valuable to them, but also that they may feel a sense of ownership over the end product and be more inclined to integrate it into their teaching schedule (Croise, Cobb & Wilson, 2002). Croise et al. (2002) took this teacher-center approach and created a framework for designing VR application and applied it to a secondary science class. They highlighted the fact that school-based evaluation and teacher-centered approach are important for gaining an understanding of how the software will be used and integrated into a school setting (Croise et al., 2002).

Although educators may be willing to incorporate VR into their teaching practices, the introduction of VR in the classroom may bring about multiple problems, including issues with funding, safety, teacher and student training, reshaping the curriculum, technological anxiety, and confusion (Bricken, 1991). The NAAEE (North American Association for Environmental Education) survey asked educators to identify the most significant barriers that might inhibit the use of VR in education. Lack of funds, fear that virtual reality experiences would replace or be substituted for real experiences, lack of technical training for educators and lack of evidence of VR's educational effectiveness were the most frequently chosen barriers for the teachers (Taylor & Disinger, 1997). According to Burkle and Kinshuk (2009), moving content from a static to a dynamic perspective, changing the lecture-centered to a more student-centered one, breaking the old image of the instructor as the only knowledge holder can be the other challenges teachers might face with the arrival of VR in educational settings.

Accessibility is another issue that should be taken into consideration when educators implement VR in a learning environment. Three user groups with accessibility concerns include the hearing impaired, the visually impaired, and those whose PCs do not have the computational power necessary to run VR applications. The more immersive the online environment gets, the more complex it becomes to use. Therefore, running any VR application requires strong computational power; many students may not have a computer that is fast enough and this creates a serious barrier (Quirk & Conway, 2011).

VR experiences also expose the limitations of the current network and the challenges facing network operators. 360° video applications require a lot of data. A low resolution 360° experience – which is available with most VR HDMs – requires at least 25Mbit/s for streaming. For resolutions comparable to HD TV the requirement jumps to 80-100Mbit/s. However, if you want the best "retinal" 360° video experience as much as 600Mbit/s is required (Mastrangelo, 2016). Not only urban but also rural schools and universities have concerns about adequate infrastructure and connectivity (Barack, 2015). Thus, high-speed internet requirement for VR experience creates a barrier.

Navigation and orientation are still a concern for VR developers. A poor navigation might hinder learning. A study conducted to investigate the educational use of 3D virtual worlds found that navigation and orientation in a virtual world are quite challenging for first-time users. Students need guidance on how to get around in the environment, what to do and where to go; hence, it is essential to give students enough guidance on orientation and navigation, including some suggestions on where to go and what to do in the virtual environment (Pfeil, Ang, & Zaphiris, 2009). Taken into consideration of this study finding, the researcher created the VRLE as simple as possible and the participants acted as an observer rather than a decision-maker.

The challenges of teaching students using novel ways and keeping them engaged in theoretical topics have been the most daunting task for educators especially in higher education. The novelty of the use of virtual worlds for education brings with it the challenge of developing pedagogical understandings around the relationship between the use of virtual experiences and the educational context (Burkle, & Kinshuk, 2009).

Educators should ask crucial questions to check if VR is the best educational technology tool to meet the learning outcomes in their classroom. These questions include:

- Is the content spatial in nature?,
- Is the content impossible to seeing the real-world? (Winn, 2002),
- Does the lesson objective require seeing something from an immersed perspective? (Bowman & McMahan, 2007),
- Is VR application integrated with spoken instructions and other instructional materials? (Meissner and Bogner 2013),
- Have students received an overview and expectations for a VR system (Lim & Tay 2010)?, and
- Can the educator start, stop, run, and navigate simulations fluidly without any support? (Keengwe and Onchwari 2011).

3D Anatomical Models in VRLEs

As Luursema, Vorstenboch and Kooloos (2017) put it plainly, in a virtual environment allows for interaction with virtual objects similar to interaction with real objects. In the case of anatomy learning, this promises versatility and flexibility in the presentation and exploration of anatomical objects, less expensive than dissection facilities (Yammine & Violato, 2015). However, full VR is technologically challenging and has not yet been implemented (Luursema, et al., 2017). There have been a few comparative studies to assess medical students' perception and performance in VRLEs; however, more studies are needed to decide on whether to integrate 3D anatomical models in VRLEs into the curriculum.

A study conducted to assess whether utilize virtual reality is as effective as 3D tablet-based applications and whether these modes allow enhanced student learning, engagement, and performance on skull anatomy. No significant differences were found between mean assessment scores in virtual reality or tablet. During the lessons, however, VR participants were more likely to exhibit adverse effects such as headaches, dizziness, or blurred vision (Moro, Stromberga, Raikos, & Stirling, 2017).

Recently, the effectiveness, satisfaction, and motivation associated with VR simulation in teaching medical students neuroanatomy have been investigated (Stepan, Zeiger, Hanchuk, Del Signore, Shrivastava, Govindaraj, & Iloreta, 2017). The participants studied structures through either online textbooks or the VR interactive model. There was no significant difference found in anatomy knowledge between the two groups on pre-intervention, post-intervention, or retention quizzes. The VR group found the learning experience to be significantly more engaging, enjoyable, and useful and scored significantly higher on the motivation assessment.

Comparison studies between 3D models in VR environments to 2D models certainly assist medical education in finding the right tool for visualization. However, with the recent arrival of VR technologies more comparative studies are needed. I believe this research study will add another layer to determining whether VR technology is an effective learning tool for anatomical education.

Theoretical Foundation of the Study-Cognitive Load Theory

Cognitive Load Theory (CLT) is a scientific approach to the design of learning materials, so that they present information at a pace and at a level of complexity that the learner can fully understand. According to CLT (Sweller, 1998), effective learning occurs if instructional conditions are aligned with human cognitive architecture. The term cognitive load refers to the total amount of mental effort being used by the working memory (Ayres & Paas, 2012; Sweller, 1998). The theory provides a useful framework for cognitive learning on the basis of the limitations in working memory (Sweller, 1998).

CLT distinguishes three different types of contributions to total cognitive load. *Intrinsic cognitive load*, *extraneous cognitive load* and *germane cognitive load*. Intrinsic cognitive load (ICL) relates to the difficulty of the subject matter (Cooper 1998; Sweller and Chandler 1994). More specifically, material that contains a large number of interactive elements is regarded as more difficult than material with a smaller number of elements and/or with a low interactivity. Low interactivity material consists of single, simple, elements that can be learned in isolation, whereas in high interactivity material individual elements can only be well understood in relation to other elements (Sweller 1994; Sweller, van Merriënboer, & Paas, 1998). An important premise regarding intrinsic load is that it cannot be changed by instructional treatments.

CLT sees the construction and subsequent automation of schemas as the main goal of learning (Sweller et al. 1998). The construction of schemas involves processes such as interpreting, exemplifying, classifying, inferring, differentiating, and organizing (Mayer, 2002). The load that is imposed by these processes is denominated germane cognitive load (GCL). Instructional designs should try to stimulate and guide students to engage in schema construction and automation and in this way increase germane cognitive load.

Extraneous cognitive load (ECL) is associated with processes that are not directly necessary for learning and can be altered by instructional interventions. How to reduce

ECL in a reasonable way has been studied vastly. The researchers found empirical evidence on the ways to decrease ECL; all those principles are called multimedia design principles and based on the Cognitive Theory of Multimedia Learning (CTML) (Harp & Mayer, 1998).

The principles for designing effective multimedia presentations are based on CTML (Mayer, 2002). CTML and CLT provide a well-researched account of how people learn from words and pictures (Sweller et al, 1998). These theories suggest there are two distinct channels in the human information processing system, of which one processes information presented in a visual or pictorial format and the other processes information presented in an auditory or verbal format. This is also known as the dual-channel theory of multimedia learning (Paivio, 1990; Clark, & Paivio, 1991).

Each channel has predetermined limited capacity to process incoming information (Baddeley, 1997). The cognitive process of learning progresses through distinctive pathways of the human memory system. Sensory memory is exposed to an unlimited amount of incoming information presented as verbal and pictorial stimuli, but only a limited number of the incoming stimuli can be processed through either channel at any given time. The selected information progresses through the system to reach the working memory area in the nervous system. There, the information is organized into distinct cognitive representations. This phase is a rate-limiting step in the system and consumes a significant amount of time, until an appropriate cognitive representation emerges that faithfully represents elements of the selected verbal and pictorial stimuli. Then, the newly constructed cognitive representations can be integrated with relevant prior knowledge activated from long-term memory, and ultimately stored in the long-term memory of learners (Mayer, 2002) (Figure 2-2).

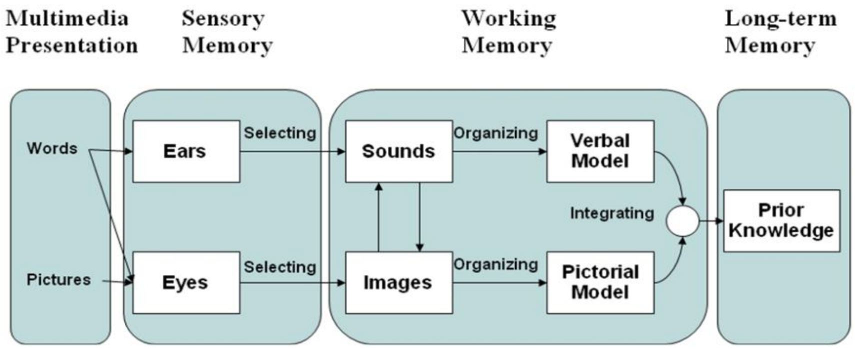

Figure. 2-2: Cognitive theory of multimedia learning. Adapted from *Multimedia Learning*, by R. Mayer, 2001, Cambridge University Press. Washington, DC: American Psychological Association. Copyright 2001 by Cambridge University Press.

How to design multimedia presentations based on the principles of CTML has been extensively studied and publicized by Mayer (Maye, & Moreno, 2010; Mayer, Heiser, & Lonn, 2001). To guide the process of learning, Mayer emphasized that educators need to design the instructional message in a manner that will facilitate students' cognitive learning processes. In 2007, the Association of American Medical Colleges' Institute for Improving Medical Education (AAMC-IME) issued a report entitled *Effective Use of Educational Technology in Medical Education* which highlighted the importance of multimedia learning and suggested that medical educators should utilize multimedia learning principles when designing instructional presentations for medical students.

For this study, the 12 Principles by Mayer guided how to design a VRLE. Upon designing the environment, the researcher gave a rubric (Appendix A) to two instructional designers working at Midway University to evaluate the VRLE based on Mayer's Multimedia Principles. Cohen's κ was run to determine if there was an agreement between two instructional designers' agreement when they rated VRLE. There was a strong agreement between the two designers' agreement, κ = .81, $p < .0005$. Table 2-1 presents the principles that were used for this study.

Table 2-1: 12 Principles for designing effective instructional multimedia materials. Adapted from "Using Multimedia for E-learning", by R. Mayer, 2017, *Journal of Computer Assisted Learning*, *33*, 403-423.

Goal 1: Eliminate external distracters

Principles: Coherence Principle- Exclude extraneous words, pictures and sounds

Signaling Principle- Highlight essential material

Redundancy Principle- Do not add on-screen text to narrated animation

Spatial Contiguity- Place printed words next to corresponding graphs

Temporal Contiguity- Place corresponding narration and animation at the same time

Goal 2: Encourage learners to establish 'mental frames' for the material

Principles: Segmenting Principle- Present the material in user-paced segments rather than as a continuous unit.

Modality Principle- Present words as narration instead of printed text.

Pre-training Principle- Prepare/ read ahead of time

Goal 3: Facilitate integration of new material

Principles: Multimedia Principle- Present words and pictures rather than words alone

Personalization Principle- Employ conversational style rather than formal style

Voice Principle- Employ friendly human voice rather than a machine voice

Embodiment: Show on-screen agents that use human-like gestures.

Framework for Instructional Technology Design for the Study- TPACK

In order to assess the research questions put forth by this study, there needs to be a method by which to measure whether or not the technology integrated into the lesson plan has a positive impact on the dependent variables. For this study, the researcher chose TPACK as a framework to design the Mitral Valve lesson plan. Shulman (1987) proposed that every teacher needs to equip themselves with adequate content and pedagogical knowledge (PCK) so that they can better facilitate the teaching and learning processes taking place in class. He further suggested that teachers should not only master the content of the subject area being taught but also have sufficient knowledge of classroom strategies, application of learning theories, and differentiation techniques.

Along with the development of technology in the field of education, Mishra and Koehler (2006) proposed a new scheme. In this new scheme, Shulman's proposal of pedagogy and content knowledge – PCK – is expanded to include technological knowledge and becomes known as technological pedagogical content knowledge or TPCK. In its later development, TPCK becomes TPACK. As Thompson and Mishra (Roeblyer & Doering, 2010) argued that the insertion of the "A" letter will better represent the interdependence of the three domains of knowledge (T, P, C). There are seven components comprising this new TPACK framework. Schmidt et.al. (2009) and Baran, Chuang, and Thompson (2011) briefly explain these components as follows:

1. Technological knowledge (TK): Technological knowledge is the knowledge about various technologies ranging from the simplest, such as pencil and paper, to more sophisticated ones, such as digital technologies like digital videos, interactive whiteboards as well as the Internet.

2. Content knowledge (CK): Content knowledge refers to the knowledge of the content area or the subject matter having to be taught or learned. This knowledge encompasses all the facts, ideas, concepts, and theories related to the specific content area.
3. Pedagogical knowledge (PK): PK refers to the knowledge of various methods and strategies of teaching and learning as well as of its processes taking place in the classroom.
4. Pedagogical content knowledge (PCK): PCK is the knowledge of how to teach and help students learn a specific content in multiple ways equally effective for them.
5. Technological content knowledge (TCK): TCK can be defined as the knowledge of how various technologies can be manipulated to help students practice and learn concepts in a specific content area in new meaningful ways.
6. Technological pedagogical knowledge (TPK): TPK refers to the understanding of how various technologies can be integrated into teaching as well as of how those technologies can change the way teachers teach for the better.
7. Technological pedagogical content knowledge (TPACK): TPACK encompasses the knowledge teachers should have in order to be able to integrate technology into their teaching in any content area. By having this knowledge, teachers should possess a thorough understanding of the intricate relationship between the three basic domains of knowledge (TK, CK, and PK) and, hence, be able to teach contents using appropriate methods and technologies (Figure 2-3).

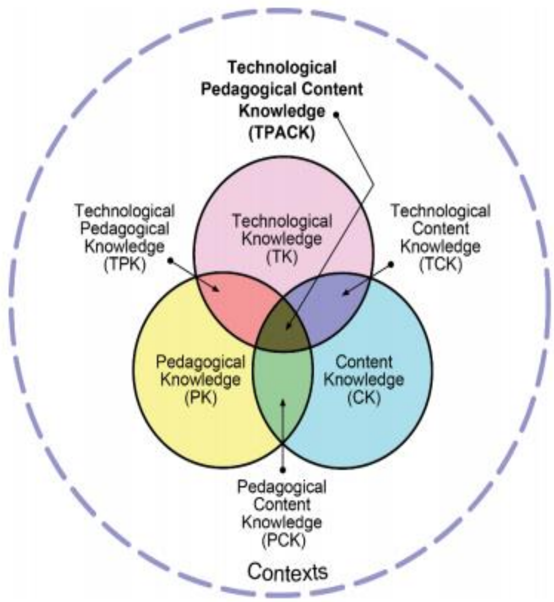

Figure 2-3: The technological pedagogical content knowledge framework. From "Using the TPACK Image," by TPACK.org, 2011 (http://tpack.org/).

As Churchill et al. (2011) argued, since TPACK is much more than simply adopting technology in classroom practices, teachers should be able to establish an effective pedagogy that uses technology and demonstrate how the technology can change the nature of the content by redressing problems and reconstructing knowledge. In short, teachers implementing the TPACK framework should have a good understanding of pedagogical techniques that use technologies in constructive ways to teach content (Mishra & Koehler, 2006).

The reason for the selection of this particular tool is that VR creates a learning environment where a learner can receive sensory information to learn the content. Stimulation of senses plays a key role in creating a VRLE. The research has shown that increasing the number of senses stimulated in a VR simulator can dramatically enhance a user's sense of presence, and their memory for the encounter/experience (Gallace, Ngo, Sulaitis, & Spence, 2012). The multisensory feature of VR system is believed to increase the retention level. For this study, visual and auditory senses were aimed to stimulate so that the participants could feel themselves in the hospital and being taught by a cardiac nurse. TPACK framework for the learning session with VR is illustrated in Figure 2-4.

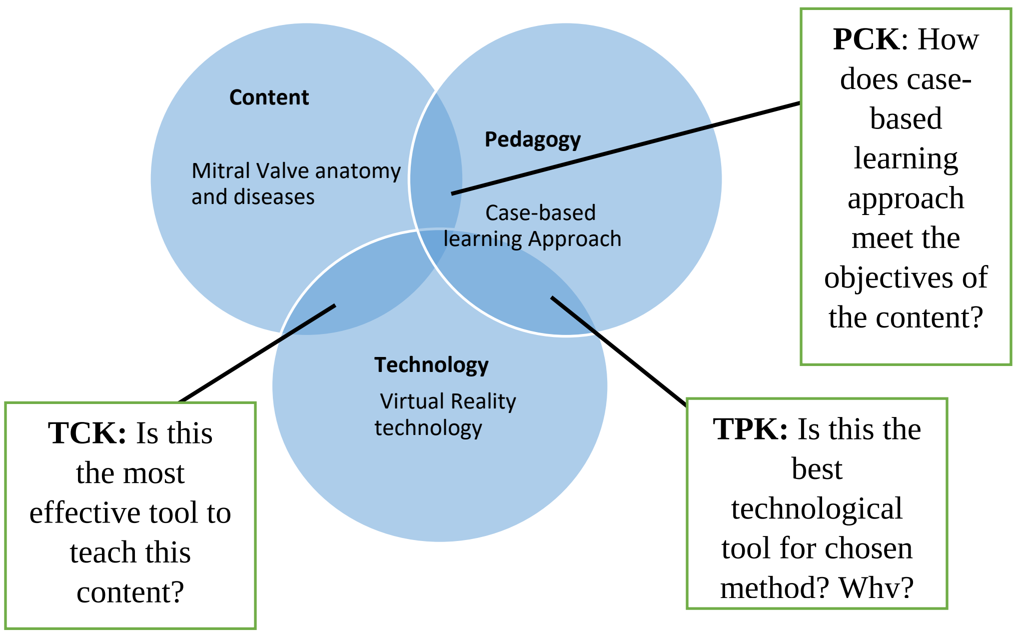

Figure 2-4: The TPACK framework in anatomy class.

The content matter chosen for this study is the heart. The researcher had several meetings with Midway Nursing faculty and decided that human heart is the most important and the most challenging part for the students to grasp anatomical structure and apply the information to their hospital environment. Upon deciding the topic, the researcher gave a test to a small sample size of participants to specify which section of the heart they were challenged the most. The test results showed that the students had difficulty in Mitral valve (MV) that is located between the right atrium and the right ventricle. The researcher worked with an experienced cardiac nurse and Midway University nursing instructors to prepare the content.

The MV requires an understanding of the normal anatomy and how this complex structure is altered by disease states. The MV is composed of several structures working in synchrony to open during diastole and close in systole effectively within the high-pressure systemic environment. Morphological changes of the valve can affect mechanical integrity resulting in abnormal leaflet closure and regurgitation of blood back into the left atrium causing loss of ventricular pressure and forward flow (McCarthy, Ring, & Rana, 2010). With greater than 2.5 million people affected in the US alone, mitral valve disease is one of the most common valve diseases with considerable prevalence, particularly in the growing elderly population (Cleveland Clinic, 2018). Due to the frequency of mitral valvular disease and the results of the pilot study, the researcher chose two cases for this study. One case was about an old lady who was hospitalized due to the complications caused by mitral annular calcification. The other case was about a veteran who was admitted to the emergency unit due to severe Mitral Valve Regurgitation (MR).

As a pedagogy a case-based learning (CBL) approach was chosen to meet the objectives of the lesson. According to Lowenstein and Bradshaw (2001), CBL help learners learn an authentic case to identify patient problems, think about solutions, and decide how to deal with clinical situations. CBL demands active participation from learners, and it supports professional practice goals by encouraging learner-teacher interactions (Bano, Arshad, Khan, & Aqeel Safdar, 2015). It also offers students opportunities to discuss real-life situations and nursing challenges in a safe environment (Chen & Lin, 2003).

Case-Based Learning as a Teaching Method (Pedagogy)

Levin (1995) defined CBL as "the practice of using cases as a pedagogical tool" (p. 63). CBL has been used in medical fields since at least 1912, when it was used by Dr. James Lorrain Smith while teaching pathology in 1912 at the University of Edinburgh (Sturdy, 2007). Although there is not a set definition for CBL, an excellent definition has been proposed by Tistlewaite et al. in a review article. In their 2012 paper, a CBL definition is "The goal of CBL is to prepare students for clinical practice, through the use of authentic clinical cases. It links theory to practice, through the application of knowledge to the cases" (p. 422). The successful case has four distinctive features as follows: clear learning objectives, a concise and informative scenario, straightforward and didactic questions and an emphasis on information readily available to the students (Cliff & Wright, 1996).

According to the National Centre for Case Study Teaching in Science, cases should: be authentic (based on real patient stories), involve common scenarios, tell a story, be aligned with defined learning outcomes, have educational value, stimulate interest, create empathy with the characters, include quotations in the patient voice to add drama and realism and have general applicability (Herreid,1997, p.70).

The learning theories applied to CBL derive mainly from adult learning and inquiry-based learning approaches. Thus, CBL promotes a deep learning approach (Hofsten, Gustafsson, & Haggstrom, 2007; Singh, & Bhatt, 2011), with active (Chan, Hsu, & Hong, 2008) and meaningful (Hakkarainen et al., 2007) learning. By emphasizing the active and interactive components of the learning process, CBL blends aspects of the cognitive constructivist models of teaching and learning (Mayo, 2004) that "lends itself to authentic, active, and pragmatic applications of theory to [ ]practices, as well as to investigations of a variety of [ ] issues, perspectives, and contexts . . ." (Sudzina, 1997, p.199).

It enables students to see the direct relevance (Koh, Chia, Jeyaratnam, Chia, & Singh, 1995) and logical direction (Krockenberger, Bosward, & Canfield, 2007) of the information to be learnt for their goal of clinical practice, so that they are more highly motivated (Bano, Arshad, Khan, & Aqeel Safdar, 2015) and are more likely to remember such information (Hong, Chan, Lim, & Chan, 1998). CBL facilitates the development of reflective thinking and deeper conceptual understanding (Schwartz, Egan, & Heath, 1994).

Advantages of CBL. The rapidly changing nature of the healthcare system presents nurses with varied complex practice issues with no clear solutions. These health care problems require nursing students and nurses to have clinical reasoning (Bambini, Washburn, & Perkins, 2009). Educators have to equip nursing students with skills that promote their reasoning to solve complex issues. Using CBL prepares students for clinical reasoning which has become an essential outcome in most schools of nursing today. Nursing faculty strives to prepare nurses who have clinical reasoning in order to elicit and interpret information, integrate multiple sources of data; solve clinical problems, make a sound clinical judgment and provide a logical scientific rationale for their decision-making process (Gentner, Loewenstein, & Thompson, 2003).

CBL seeks to contextualize learning (Bano et al., 2015) and to enhance the transition of nurses to practice. This instructional approach adds great value to the nursing education experience since the unfolding process emulates the work environment. CBL develops the ability to practice competently in a variety of healthcare situations (Lippincott Nursing Education, 2017).

CBL also promotes active learning. John Dewey (1916) discussed how education occurred through experience and that the learner had to be actively involved in the process for true learning to occur. With a true implementation of case-based methodology, the learner works through the problems of the case and gains knowledge through actively applying content to the case itself. CBL defers students from relying on rote memory (Bano et al., 2015), but instead uses inquiry to direct students toward a system of learning. This can encourage students to develop experiences with concepts that otherwise would have been lost through the learning process of memorization (Cliff & Wright, 1996).

Attitudes of Students and Educators towards CBL. The majority of student feedback in relation to their CBL experiences was very positive. Common words used to describe their opinion were: liked/highly satisfied /stimulated/ motivated/ challenged/ helpful/ appreciated (Dijken, Thévoz, Jucker-Kupper, Feihl, Bonvin, & Waeber, 2008; Bowe, Voss, & Thomas Aretz, 2009; Braeckman et al., 2009; Critchley, Kumta, Ware, & Wong, 2009), fun (Horsch, Balbach, Melnitzki, & Knauth, 2000), real-life relevance (Anderson & Helberg 2007), gained in confidence (DeMarco, Hayward, & Lynch, 2002), felt achieved objectives (Koh, Chia, Jeyaratnam, Chia, & Singh, 1995), helped apply knowledge (Siow, 2005), involved deeper learning approach (Schwartz et al., 1994), helped in learning factual material (Schwartz, Egan, & Heath, 1994), enhanced learning (Street, Eaton, Clarke, Ellis, Young, Hunt, & Emond, 2007), promoting learning gains (Bonney, 2015) and an effective means to learn concepts (Struck & Teasdale 2008) and to retain them (Kulak, Newton & Sharma, 2017). It was a valuable learning experience (Kassebaum, 1991) and they wanted more (Anderson & Helberg 2007).

Students showed a positive attitude towards CBL. Kunselman and Johnson (2004) concluded from student responses that "the case method is an effective way to enhance student learning" (p. 87). Case studies are useful in helping students to remember details and facts (Beyea, 2004) In Mayo's (2004) study, the majority of students indicated that CBL stimulated academic challenge, bolstered personal interest and involvement in the subject matter and offered a sharply realistic perspective from which to apply course content. Students commented that they thought there was a good link between cases and real-life practice (Simonsohn & Fischer 2004) and that they preferred CBL to more traditional presentations (Struck & Teasdale, 2008).

Educators were also positive (Kaufert, Wiebe, Schwartz, Labine, Lutfiyya, & Pearse, 2010) and enjoyed CBL while getting through a list of learning objectives, and in so doing, providing enhanced guidance to the learning session (Koh et al., 1995; McLean, 2016); it was welcomed as an addition to conventional teaching methods (Reimer et al., 2006). In spite of positive reaction to the educators, there are major barriers medical educators professors could face using the CBL. Faculty could find the CBL programme time intensive (Jamkar, Yemul, & Singh, 2006; Shing & Bhatt, 2011), particularly in terms of preparation (Hansen & Krackov, 1994). Then there is the question of content coverage: The case approach often does not permit instructors to cover as much material as is possible with lectures. Finally, some teachers don't want to give up center stage (Billings and Halstead, 2005). Students have their issues, too. They have grown up with the lecture method. This can be especially threatening to the pre-professional health students who do rather well with the lecture method (Herried, 2007).

Ways of presenting the cases. According to Herreid (1994), there is a host of other ways to tell the case in the classroom: lecture method, whole class discussion, small groups, individual case instruction and direct-case method. A direct-case method was chosen for this research study because this technique is a favorite of teachers of anatomy and physiology course (Herried, 2007).

A direct-case analysis helps students deepen and solidify their understanding of anatomical and physiological facts, concepts and principles. One of the most interesting approaches is to use dialogues. Dialogues have 'inherent dramatic power that appeals to students' (Herried, 2007, p. 240). At the end of the dialogue, students either write a paragraph on the topic or answer the questions. Due to the nature of VR technology used for this study dialogue format was chosen as a way to present the content information.

Because the intent of the direct case method is the mastery of mitral diseases for this study, the cases are content driven. They are built around specific learning objectives. Furthermore, the cases are highly directed. In this study, the learner was asked a series specific questions related to the cases. By answering these questions a student was forced to learn the facts. Being directed, the cases are not open-ended. Many medical school cases are close-ended, whereby the patient has a particular complaint, the correct diagnosis is essential (Herried, 2007). There is a single specific answer expected for nearly all of the questions. Although open-ended cases enforce intellectual development to the solution of a problem, such format can also cause confusion and cognitive frustration if students do not have enough background knowledge to handle the openendedness of this method. Close-ended and direct-case method are necessary for lack of enough information students such as in this study.

Conceptual Framework

There is an increasing body of research supporting VR as an important emerging educational technology (Hew & Cheung, 2010; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis 2014) with a number of experimental studies demonstrating the ability of 3D VR instruction to create positive learning outcomes when compared with control groups taught in 2D (Ketelhut & Nelson, 2010; Merchant et al., 2014). Despite the relationship between educational technology usage and student achievement, the technology itself does not directly cause learning (Winn et al., 2002). Instead, technology helps facilitate learning. At this point, educators should see VR as a facilitator and keep various factors in mind while integrating the tool into their curriculum.

The factors that affect the learning outcomes and experience can be both domain specific and domain general. In anatomy learning domain-general factors that affect learning outcome are prior knowledge and level of mental load. These factors define the conceptual framework of this research. The conceptual framework for this study shown in Figure 2-5 presents the variables for determining the effect of the VR as an educational technology on learners' performance.

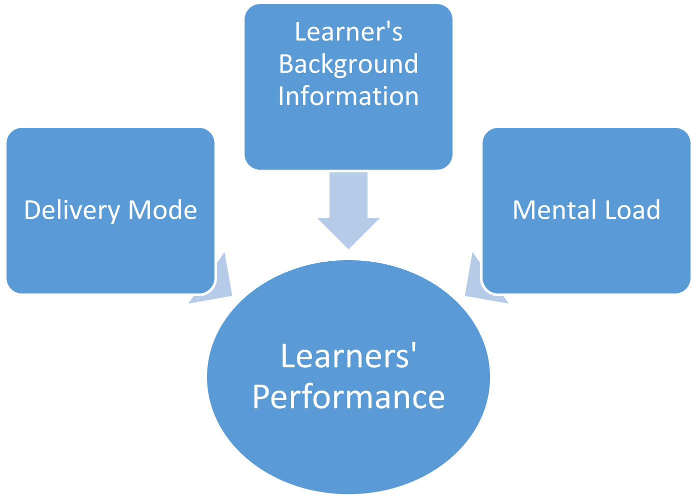

Figure 2-5: Conceptual framework of the study.

Since the study aimed to measure the effects of VR mode compared to paper-based mode, the independent variable is the delivery tool. Tools of delivery refer to how the total educational content is delivered. In CBL, delivery mode can be classified as follows: 'live' (this can be a description, a patient, or a simulated patient), web-based (the case and content are web-based), a paper-based (where an instructors deliver the class written notes describing a patients' symptoms and test results along with history), and mixed modalities (more than two modalities are used during the presentation of a case).

The majority of students prefer web-based cases (Krockenberger, Bosward, & Canfield, 2007; Morrow, Sepdham, Snell, Lindeman, & Dobbie, 2010; Drakeford, Davis, & Van Asperen, 2007; Boeker, Müller, C., Klar, R., & Lutterbach 2005). However, satisfaction is reduced if there are problems with the learning platform (Hakkarainen, Saarelainen, & Ruokamo, 2007), such as poor navigation, happen (Boeker et al., 2005). In McLean's (2016) review article, the most common method of delivery is live presentation (49%), followed by web-based (20%) and then mixed modalities (19%).

Prior knowledge plays a key role in analyzing the effect of the case-based learning as a teaching method. New incoming information is integrated with the surroundings in relation to pre-existing knowledge about the world (Brod, Bergner & Shing, 2013). A critical condition to acquire new information is the presence of previous knowledge. In the absence of that knowledge, memory is believed to be poor (Alba & Hasher, 1983), as supported literature describing experimental studies (Ausubel, 1960, Ausubel & Fitzgerald 1961; Brandsford & Johnson, 1972). This notion is also applied to educational settings such as higher education where courses have prerequisites. Learning new subjects is either facilitated by certain specific background knowledge, or is difficult or impossible without such knowledge (Hoz, Bowman, and Kozminsky, 2001).

Not only all learning theories but also psychological models of learners' achievement support the crucial role of prior knowledge in the acquisition of new ones. Prior knowledge was defined by Elliott (1993) as the experience and knowledge a person brings to a learning situation, which greatly influences how the learning material is comprehended, interpreted, and recalled. Jonassen and Grabowski (1993) described prior knowledge as the ability, knowledge, and skills possessed by the learner before instruction.

Bloom (1976) claimed that the student's prior knowledge overrules all other variables and explains between 31% and 64% of the variance in studies of learning domain-specific contents. Prior knowledge has a large influence on student performance, explaining up to 81% of the variance in posttest scores (Dochy, Segers & Buehl, 1999). There is a well-established correlation between prior knowledge and reading comprehension (Langer, 1984; Long, Winograd, & Bridget, 1989; Stevens, 1980). Thus, prior knowledge is associated with beneficial academic behaviors and higher academic performance. In this study, the researcher designed a test (pre-test) to measure the participants' prior knowledge. The difference in the mean scores in pre and posttest was aimed to measure the effectiveness of the delivery mode and the teaching method.

Summary

Chapter 2 provided comprehensive review about the benefits of the VR technology in educational settings along with its limitations, concerns and issues. The Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML), as a theoretical foundation of the study, were explained and the types of cognitive load were examined. TPACK was detailed discussed as an instructional design framework. This framework provides instructors with opportunities to apply their technological knowledge, pedagogical knowledge and content knowledge in an integrated manner. Along with the goal of nursing department at Midway, CBL approach was chosen as an instructional strategy to present the content matter. Keeping the purpose of this research study in mind, the conceptual framework was discussed at the last section of this chapter. Chapter 3 will focus on recruitment, sampling, research design and data collection procedure.

CHAPTER 3

METHODOLOGY

This chapter describes the methodology adopted in this research. The chapter starts with the description of the research site and population. Next, it includes a detailed explanation of the research design, instruments to collect data, apparatus used in the study, and the data collection procedures.

Description of the Research Site

Midway University, a private, non-profit liberal arts college, has been chosen as a research site for this study due to its distinguished nursing program. It was founded in 1847 by Dr. Lewis L. Pinkerton, as the first school in the United States to serve orphaned and disadvantaged women. Through the years the school evolved and became Pinkerton High School, Midway Junior College, Midway College and on July 1, 2015, Midway University. In May 2016, Midway's Board of Trustees voted unanimously to begin admitting male undergraduates for the first time in the school's history in Fall 2017. The total number full-time students enrolled in Fall 2018 is 1,668. Among undergraduate students, 68% is female, 32 % male, 20.4 % out-of-state and 8.6% international (Midway University).

Population and Sample of the Study

The participants of this study were recruited in the nursing department. 131 nursing students are enrolled in Fall, 2018. Associate of Science in Nursing (ADN) nursing degree is offered as part of undergraduate programs and in an accelerated format in the evening at Midway campus. Students who successfully complete an ADN degree at Midway University are eligible to take the National Council Licensure Examination (NCLEX-RN). Successful completion of this examination allows the graduate to practice nursing as a Registered Nurse (RN). The undergraduate nursing program curriculum has a dual focus. Classroom theory emphasizes the technical and theoretical aspects of nursing, while concentrated, supervised clinical laboratory experiences allow students to practice your skills at several health care agencies in Central Kentucky.

Throughout their program nursing students must take NSG (Nursing and Clinical) 115, NSG 120, NSG 210, NSG 225 and NSG 230. The program also requires supporting courses from Biology and Psychology including Anatomy and Psychology I-II, Microbiology, Microbiology Laboratory and Human Growth and Development. Students are required to take nationally-normed tests throughout the curriculum and to make a satisfactory score on such tests. In the last semester of the curriculum, students are required to take a comprehensive exam and to make a satisfactory score on such an exam prior to graduation/taking the licensure exam.

Sampling Method

The sample of this study was randomly selected from all undergraduate students currently enrolled in Midway University. There were be two study groups: VR-based group and paper-based group. Twenty-nine participants were randomly be assigned to either VR mode or paper-based mode. Random assignment distinguishes a rigourous 'true' experiment from less rigorous 'quasi-experiment'. As Creswell (2002) pointed out, by randomization, a researcher provides control for extraneous characheristics of participations that might influence the outcome. The paticipants who were willing to involved in this study sampled from NSG 120, NSG 210, and Anatomy and Physiology courses.

Recruitment

The Midway University granted permission by signing a letter and the approval of Midway University's Institutional Review Board (IRB). This letter was submitted to Eastern Kentucky University's IRB for approval to begin the study. Upon fulfillment of this procedure, the recruitment flyer was put on the Nursing Dept. bulletin board at Anne Hart Raymond Center. Moreover, the researcher took permission from the nursing faculty to make an in-class announcement to encourage students to take part in the study. The recruitment process began in the 2018 summer and ended mid-Fall semester 2018. Participants who had serious vision problems and a tendency to motion sickness were excluded from the study.

Research Design

A two-group pretest-posttest design was employed in this study (Figure 3-1). The permission from the Dean of Nursing and the nursing instructors were the prerequisites required to execute this research. The researcher worked closely with Instructional Design and Technology unit of Midway University. The necessary permission to set up HTC Vive at the simulation lab was granted.

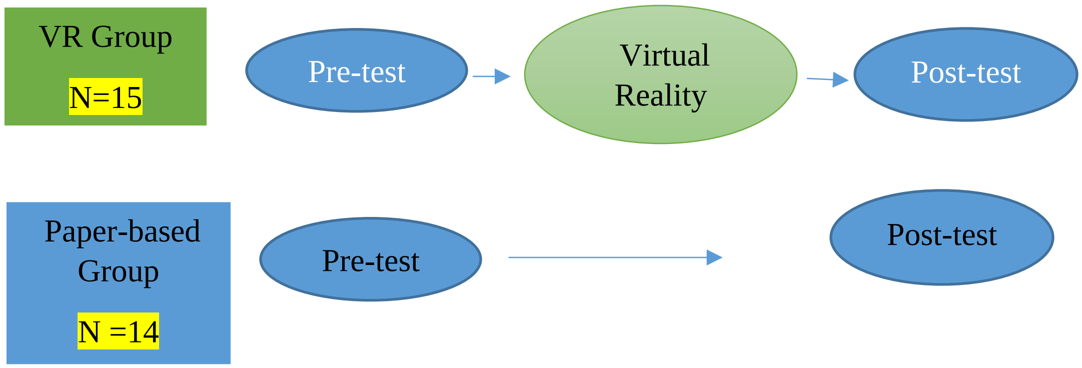

Figure 3-1: Research design of the study.

Variables

Independent variables, dependent variables, a controlled variable in this research design are as follows:

Independent Variable- Since the study aimed to measure the effects of virtual reality mode compared to the paper-based mode, the independent variable is the type of delivery tool used in the presentation of the information. Independent variable has two modes: virtual reality mode and paper-based mode. Although analyzing the effect of teaching method was not the primary objective of this study, the researcher wanted to investigate the effectiveness of CBL by comparing pre- and post-test scores of both groups after studying the MV diseases. Therefore, the prior knowledge of the learners' was the second independent variable to investigate the effect of the teaching method.

Dependent Variable- Learners' posttest scores were used as a dependent variable to measure the effect of the delivery mode for this study.

Data Collection Procedure

Paper-based Group

1) The participants were given Informed Consent Form and they signed them.

2) The participants filled in a demographic survey (Appendix B) questions with 6 items. The survey is designed both to gain participants characteristics information (e.g. age, gender and class standing) and to evaluate how familiar the participants are with the VR concept. The survey was administered through a pen-paper method.

3) Administration of Pre-test (Appendix C)

The researcher explained the purpose of the Pre-test. The participants finished the test in 10 minutes.

4) Reading the Class Notes

The researcher wrote the objectives of the lesson on the board and explained them to the participants. The participants studied the class notes in 30 minutes (Appendix D). The notes had two parts: MV anatomical structure and two case studies of MV diseases.

5) Administration of Post-Test

After having a 10-minute break, the participants took the post-test. The participants finished the test in 10 minutes.

6) Mental Load Subjective Rating Scale

Participants were asked to rate their mental effort during the learning process (Appendix E). It took two minutes to finish their survey.

VR-based Group

1) The participant was given Informed Consent Form and she/he signed it.

2) The participant filled in a demographic survey

3) Administration of Pre-test

The researcher explained the purpose of the Pre-test. The participant finished the test in 10 minutes.

4) The researcher explained the objectives of the lesson to the participant.

5) Studying anatomical structure of MV and the related diseases.

First, the researcher helped the participant wear headset and then gave the instructions on how to use controllers. He/she studied the anatomical structure of MV via using 3D4Medical software for 10 minutes. The participant took a 5-minute break. Upon the break, the participants wore the headset again to study the first clinical case. The case is on Mitral stenosis (MS) which is commonly seen among elderly population. The simulation took 13 minutes.

The participant took another 5-minute break to study the second case study. That case is about Mitral Regurgitation (MR). The simulation took 14 minutes.

6) Administration of Post-Test

After having a 10-minute break, the participant took the post-test and finished the test in 10 minutes.

7) Mental Load Subjective Rating Scale

The participant was asked to rate his/her mental effort during the learning process. It took two minutes to finish the survey.

Instruments

Pre-Posttest. The test involves 15 questions. The first question was designed to test the learner's knowledge on the anatomical structure of the MV. The learner was asked to draw and label the four components of MV. The main reason why the researcher chose to ask the participants to draw rather than gave a MV picture and let them label was that it is easy to use cues from the terminology (e.g. mitral leaflet, mitral annulus, chordae tendineae and papillary muscles) to label the MV even if one does not have a solid knowledge.

From the second question to sixth, the learner's knowledge of MS (e.g causes, symptoms, complications and treatment) was measured. From the seventh to eleventh, the questions were designed to measure the knowledge on MR (e.g. causes, symptoms, complications and treatment). The last four questions were the application of the knowledge. The total score of the exam 35 points (See Table 3-1).

Table 3-1: Organization of the questions and points.

Anatomical Structure of Mitral Valve 4 points	Annulus- 1p
	Leaflets- 1p
	Chordae Tendineae- 1p
	Papillary Muscles- 1p
Definitions of valvular diseases 2 points	Stenosis- 1p
	Regurgitation- 1p
Causes 5 points	Stenosis- 2p
	Regurgitation- 3p
Symptoms 6 points	Stenosis- 3p
	Regurgitation- 3p

Table 3-1 (continued)

Complications 6 points	Stenosis- 3p
	Regurgitation- 3p
Treatments 4 points	Stenosis- 2p
	Regurgitation- 2p
Clinical Applications 6 points	Stenosis- 3p
	Regurgitation- 3p
Heart sounds	Stenosis- 1p

Only two questions were multiple choice style of questions. The questions were aimed to recall the information rather than recognize. The nature of the questions was open- ended. The researcher gave three instructors the exam questions and asked them to categorize questions requiring low or hot thinking skills based on Blooms Taxonomy. Questions that required the higher order thinking skills were the last four questions of the text. The interrater reliability for the raters was very high (Agreement= 98%, Cohen's Kappa= .96).

Cognitive load scale. Participants rated their perceived difficulty level of the content during the learning process. There were 4 items to rate their mental effort they invested during learning the MV. The rating scale has been adopted from Paas (1992) and Cierniak, Scheiter, and Gerjets (2009), Ayres (2006) and Salomon (1984) studies. The scale is a direct subjective scale. The first three six-point scales were aimed to measure the different types of cognitive load separately (ICL, ECL, GCL) and the last scale measured the overall mental load.

The participants were asked to rate the difficulty level of learning the content, that was their ICL rate. To measure ECL, they rated how difficult it was to learn with the material, and for GCL, they rated how much they were concentrated during learning the content. The last scale is an overall mental load rating scale. Paas's (1992) nine-point mental effort rating scale has been used intensively (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Van Gog & Paas, 2008) and has been identified as reliable and valid estimators of overall mental load (Ayres, 2006; Paas, Ayres, & Pachman, 2008; Paas et al., 2003; Paas, Van Merriënboer, & Adam, 1994).

Validity and Reliability of Instruments

Cognitive load scale. Participants rated the amount of mental effort they invested in completing a task on a 9-point Likert scale, ranging from "very, very low mental effort" to "very, very high mental effort. The scale's (Paas, 1992) reliability (alpha > .8) and convergent, construct, and discriminate validity have been demonstrated (Gimino, 2000).

Pre-Posttest. Content validity of test items was established through revision and review by two faculty members of Midway University Nursing program. All of them are familiar with the lecture topic and have had lectured on it for several years. The questions were created with the help of Anatomy and Physiology teacher of Midway University and the researcher used *Guyton and Hall Medical Textbook of Medical Physiology Edition 12th* by John E. Hall, *Textbook of Medical-Surgical Nursing* by Brunner & Suddarth, and *Pathophysiology of Heart Disease: A Collaborative Project of Medical*

Students and Faculty by Leonard Lilly. Also website related to mitral valvular diseases were used such as Mayo Clinic, Cleveland Clinic, CardiServ.net, The Mount Sinai Hospital, and American Heart Association.

External Validity of the Study

External validity refers to the extent to which the results of the research are able to be generalized to other situations. The sample participants in the study are the students from the Department of Nursing, Midway University. Therefore, a number of concerns need to be considered when generalizing from the study.

First, for the clinical reasoning skill, the students involved in this study were well exposed to the use of 3D cardiac image and heart sounds. Therefore, if the study was extended to other disciplines, such as occupational therapy, where some might not be familiar with analyzing 3D cardiac results, they may face difficulties in using the application. Second, the content of the material was designed for cardiac nurses. The terminology, diagnostic and treatment approach might be different in other nurse practioner specialties such as family nurse practioner, adult gerontology nurse practitioners, neonatal nurse practitioners, etc. Last but not least, the content was designed for undergraduate Nursing students. Nursing Department may have different objectives, goals, and expectations for their graduate students such as more active learning, reflection and critical thinking skills.

Apparatus

HTC Vive. In this study, HTC Vive was used as a hardware apparatus to present the content. The HTC Vive is a VR headset that comes with two motion controllers that are tracked by two Lighthouse sensors. This allows for full 3D positional tracking of both controllers and the headset anywhere in the room. The controllers have an analog trigger button, a circular trackpad, two side buttons and a menu button. The controllers can be used to both track the position of the user's hands, e.g. for grabbing things in a VR environment, as well as be used as a pointer for menus and similar interfaces. They are wireless and battery powered (Figure 3-2).

Figure 3-2: HTC Vive headset. From "Oculus Rift Vs HTC Vive: Which Should You Pre-order?," by Popular Science, 2016 (https://www.popsci.com/oculus-rift-vs-htc-vive-which-should-you-preorder)

During the learning session, the two wireless infrared Lighthouse cameras were attached to the tripod stands so that the participant safety and the equipment maintenance were secured during the VR experience. In order to mitigate the effects of dizziness, participants were in a sitting position. Moreover, a headset was used for 3D sounding systems that enhanced the feeling of immersion in the hospital setting in the VRLE.

3D4Medical. The learners studied the anatomical structure of MV by using commercial software, 3D4Medical. The application presents a particular body part as a 3-D model that can be moved freely in space. A user can "pin" (mark) anatomic structures. The researcher chose this app due to its realistic and accurate visualizations of cardiac. This 3D app was used at Stanford University School of Medicine and was chosen by faculty for its use and functionality specifically because the 3D app allows the users to rotate, cut, and label different components of a realistic 3D heart; it was positively received by medical educators and medical students (Ringle, 2011; Rath, 2012).

Virtual Desktop. Virtual Desktop is an app that takes a standard Windows desktop and fully drops it into VR. It renders an entire Windows desktop, and anything that is run on it. It recreates a screen or screens as a giant display. The ability to alter the virtual screen's size, distance, curvature and position and easily load in 360º content. Currently, there is no software for VR-based heart anatomy. Therefore, the researcher utilized Virtual Desktop to create a VR experience while using the 3D4Medical software.

Unity3D. Gaming technology plays a significant role in developing software for 3D modelling technology with the capability of VR reality. For example, Unity 3D and Unreal Engine are a common platform in the gaming industry that support the VR technologies. For this study, the researcher used Unity 3D. It is a 3D application for real-time and multimedia. It is also 3D and physics engine, which is used to create game, animation and interactive contents with audio, video and 3D objects.

The main factor for choosing Unity for this research was the agreements between the Unity 3D technologies and HTC Vive for the use in Virtual Reality. Another reason was the extensive support by default Steam Valve software of HTC VIVE for Unity. Last but not least, it is a free game engine with a huge community hub and has tutorials on how to design 3D games and virtual platforms. Unity 2018.1.5 was used to design the two case studies. The researcher does not use any coding skills while designing the virtual environment for the two case studies. The main goal was to allow any instructor who does not have programming background to see VR technology is more accessible than they have anticipated.

Lesson Plan for VR-based Learning Environment for this Study

As mentioned before, the TPACK framework is based on three primary forms of knowledge. Therefore, the first step should be to understand the primary forms of knowledge in the context of this lesson.

- **Content Knowledge (CK)**—what are we teaching and what is our own knowledge of the subject? For this lesson, the researcher had a solid understanding of the anatomy of MV and related diseases.
- **Pedagogical Knowledge (PK)**—how do our students learn best and what instructional strategies do we need to meet their needs and the requirements of the lesson plan? In this case, the researcher read the best practices for teaching anatomy.
- **Technological Knowledge (TK)**—what digital tools are available to us, which do we know well enough to use, and which would be most appropriate for the lesson at hand? For this lesson, the participants studied the anatomy of MV and the clinical case-studies. Therefore, a software that allowed the 3D model of MV was found and the researcher designed a VRLE to contextualize clinical cases related to MV diseases. Since anatomy of MV has a three-dimensional structure, VR technology was selected. Moreover, creating an immersive hospital environment necessitated the use of VR as well.

While the ultimate goal is to be viewing a lesson and strategy through the lens of TPACK, focusing on where each knowledge intersect with other knowledge is crucial.

- **Pedagogical Content Knowledge (PCK)**—understanding the best practices for teaching Mitral valve anatomy and clinical case studies to Midway nursing students. The researcher did read articles on the strategies to teach clinical cases to find the best teaching method that the students are familiar with. And she discussed with the Midway University Nursing faculty about the teaching strategies they use in their classes.
- **Technological Content Knowledge (TCK)**—knowing how the Virtual learning environment can enhance learning the content and how Midway nursing students can interact with it. In the VR learning environment the students interact with the 3D MV anatomical model- zoom in and out, rotate and using controllers to target the components of the MV. While studying clinical cases the students do not interact with the environment and interfere with the story flow. Their role is to listen to the head nurse in the cardiology unit. Since the learners do not have a solid understanding of the content, the research though it would be frustrating for learners to give full control of their learning process especially in a digital environment where they are not familiar with.
- **Technological Pedagogical Knowledge (TPK)**—understanding how to use VR technology as a vehicle to the learning outcomes using CBL approach. VR is a valuable tool for storytelling by creating an environment with characters and their actions. The feature of contextualizing is also one of the key characteristics of CBL where learners are exposed to real-case scenarios. The ultimate goal of VR

is to make the digital environment as real as possible at this point authentic clinical cases could be a perfect material for any VRLEs.

- **Technological, Pedagogical, and Content knowledge (TPACK)-** bringing all primary knowledge together to integrate VR technology to create a learning environment for the Midway university nursing students who have not experienced VR before and have a little background knowledge on the MV anatomy and the related diseases by using CBL approach.

Abbitt (2011) stated that teachers planning to integrate technology into their lessons should have profound understanding of how to use technology in ways that are contextually authentic and pedagogically appropriate. Harris and Hofer (2009) suggested that the process of planning a lesson can be described in five basic instructional decisions. These decisions mainly concern with:

1) Analyzing learners

2) Determining the goals of the learning,

3) Choosing the most appropriate methods that can be used to enhance students' learning experience (Pedagogy),

4) Selecting and sequencing appropriate activities,

5) Selecting technology tools, and

6) Determining how students can be assessed based on the learning goals and their achievement.

The process of developing a lesson adopting the TPACK model is likely to follow these steps described above. The researcher designed the lesson plan for the content material (Table 3-2).

Table 3-2: Lesson plan.

Midway University Nursing Department Goal	• Prepare graduates to provide safe, evidence-based, patient-centered care that reflects clinical judgment • Enhance clinical reasoning skills
Course Objective	• Sts have a firm grasp of anatomic terms used in regards to the body, the location of major organs and cavities of the human body, specific anatomy and physiology terms, anatomical functions and locations of cells of the body, and anatomical structures of all systems of the body.
Lesson Goal	• Get learners to be familiar with mitral valve structure and clinical cases related to the diseases
Learning Objectives	Sts should able to draw and identify the anatomical structure of the mitral valve to define Mitral Stenosis, to list the causes, symptoms, complications, and treatments of Mitral Stenosis, to define Mitral Regurgitation, to list the causes, symptoms, complications, and treatments of Mitral Regurgitation, and to evaluate a patient's current symptoms to make a clinical judgment for a diagnosis.

Table 3-2 (continued)

Learner's Behavior	**VR-based Group** The first part- Anatomy of Mitral valve: The learner sits on a chair comfortably. He/She wears the headset and holds controllers. He/she zooms in and out, rotate and target the components of four parts of the anatomical structure of the Mitral valve and read the labels. The second part- Clinical Anatomy: The learner sits on a chair, wearing the headset. He/she is in the hospital setting and listens to the cardiac nurse instructions and conversation with the patients. **Paper-based Group** The first part- Anatomy of Mitral Valve: The learners study the structure of the MV by using the image. The image was a screenshot from the 3D4medical software that the VR group study. The second part- Clinical anatomy: The learners sit on a chair and he/she reads the written case studies. They can highlight the information if she/he thinks that is necessary.
Teaching Methods (Pedagogy)	Case-based learning Case #1: Mitral Stenosis; Case #2: Mitral Regurgitation Nature of the case: Direct-case method in a dialogue format
Technology Tools	**VR Group** *Hardware:* Virtual Reality Technology (Headset, Two Trackers, Two Controllers, and One headphone) *Software:* 3D4Medical, Virtual Desktop and Unity 3D *What is/are the reason(s) for using these tools?* • Create an authentic hospital environment where nurses can be exposed to clinical cases that their textbook cannot provide so that they can learn MV diseases in a natural context. • Provide nurses with a 3D anatomical model of MV by which they can zoom and rotate to understand the anatomical structure.
Formative Assessment	Students take an exam after they have studies the content. The total score of the exam is 35. It is a paper-pen test with 13 open-ended and two multiple choice questions.

Overview of Workflow of the Study

The researcher followed the steps below to design the VR-based learning environment for this study:

1. *Select a content*- First, the researcher had a meeting with nursing instructors about the anatomical structures that their students are struggling to grasp and that their understanding is crucial in their working environment for patient care. The heart was selected as a content matter.
2. *Administer a test on human heart*- Then, the researcher created a test on human heart to specify which part of the heart the students have little information. At the end of the test MV was found to be less known subject among the small sample.
3. *Search for an available app for 3D VR Anatomy*
4. *Select an appropriate pedagogy (teaching strategy) and teaching philosophy to present the content matter*- The researcher read the literature review on teaching strategies that used in medical education that aligned with Midway University Nursing program common goals. Upon talking to the anatomy and physiology instructor, CBL approach was chosen.

    The researcher was inspired by the Bedside teaching philosophy by Sir William Osler (1849-1920), a renowned clinician-teacher. His quote "To study the phenomena of disease without books is to sail an uncharted sea, whilst to study books without patients is not to go to sea at all." (1903) shaped the direction of this study. As opposed to reading off a blackboard, teaching in the presence of patients allows the learners to use nearly all of their senses such as hearing, vision, smell and touch to learn more about the patient (Ahmed, 2002; Landry, Lafrenaye, Roy, & Cyr, 2007). The researcher assumed VR can be used to create a hospital setting adding patients' emotional states in their current situation to enliven Osler's philosophy of medical education.

The researcher used two analogies in both clinical cases to help the learners to visualize both MV anatomical structure and mitral valve stenosis. The power of analogy in teaching complex concepts in science (Dagher, 1998; Gentner, 1998; Mastrilli, 1997; Brown & Salter, 2010) and anatomy (Bruce Sundrud, & Hueftle, 2009; Krieger, 2017) has been supported by several studies. 'Parachute' analogy was used to explaining the patient with mitral regurgitation about the severity in his condition and 'Fish mouth' analogy was used to describe the calcification around the patient's mitral valve annulus.

5. *Select for clinical cases on Mitral Valvular diseases*- The researcher visited American Heart Association website, read books about the sections related to MV diseases, and had informal phone conversations and email exchanges with a patient who was having issues on her MV. After those investigations, MR and MS were chosen as subjects of the clinical case studies.
6. *Write two dialogues based on two clinical cases*- Dialogue format was found to be more natural and appropriate in the VR-based learning environment (Appendix D). Upon writing the dialogues, a retired cardiac nurse from Duke Hospital was asked to read and to assess the accuracy of the information.
7. *Record the role plays*- The researcher arranged a quiet space and set up the recording device for the dialogues. The theatre instructor of Midway University was asked to help to give a voice to the characters in the play.

8. *Find images and heart sounds related to the clinical cases*- A 3-dimensional (3D) transesophageal echocardiography (TEE) of MS, a 2D color Doppler of severe MR and 360º view a hospital room were found to be embedded into the VR environment.
9. *Design the VR environment*- The researcher utilized Unity 3D to present two clinical cases.
10. *Evaluate the VR environment*- After designing the VR environment, the researcher asked two instructional designers to evaluate the learning environment based on Mayer's 12 Multimedia Principles. Required arrangements were made upon the evaluation.

Clinical Cases and the Structure of the VR-learning Environment Design

The VR-learning session starts with the Angela, a cardiac nurse at Frankfort Hospital, introduces herself to the Midway University nursing student. Then, she briefly explains the learner about the patient's history, complains, and physical examination results. Later, she invites the learner to the patient room and allows her to observe the conversation with the patient. At the end of the session, Angela sums up each case.

The heart sounds, 3D TEE, and Color Doppler are presented in the learning environment. The story takes place at a room in Frankfort Hospital. A 360º view of a hospital room is used to give the feeling of immersion. The picture of Angela and the patients are also presented. There is an also whiteboard on which the important takeaways of the learning session is written. In the original design, there hadn't been a whiteboard but it was added to the learning environment upon the feedback from the participants during the pilot study. The characters in the story are fictional but the case study on MR was inspired by a true story of a patient. Figure 3-3 presents the structure of the storyline of the cases.

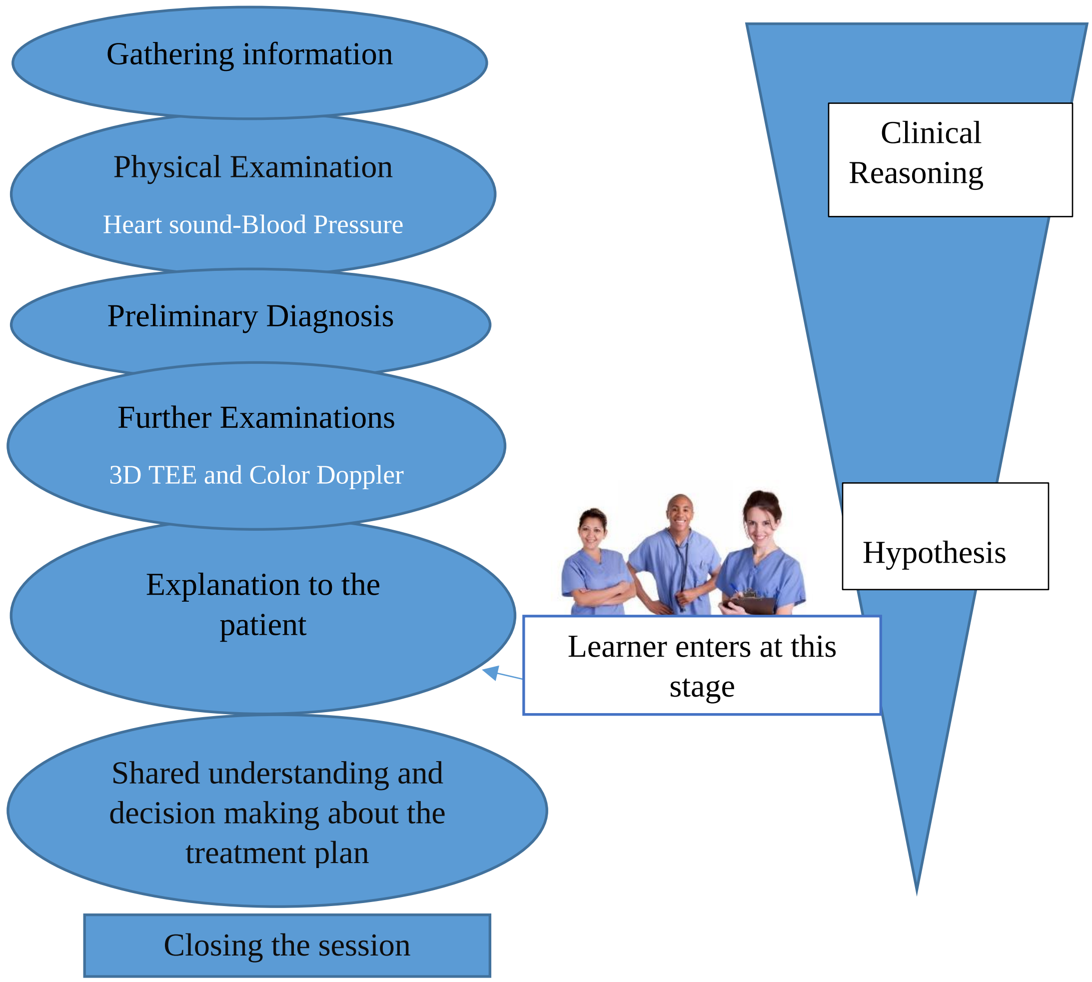

Figure 3-3: The structure of the case study. Adapted from "Communication Skills," by Laurence Biro, Calgary - Cambridge Guide to the Medical Interview – Communication Process, n.d. (https://laurencebiro.com/communication-skills/).

<u>The first case-Mitral Stenosis:</u> A 76-year-old female patient is admitted to the hospital with several complaints including chest pain, irregular heartbeats, difficulty in breathing and feeling fatigued. The nurse listens to her heart and hears an opening snap after the

second heart sound. The low pitched rumbling murmur starts after the opening snap and lasts until mid-diastole. For further diagnosis, 3D TEE is performed. According to the 3D TEE valve assessment, the mitral annulus diameter is 1cm. The diagnosis is mitral stenosis. Upon interviewing with the patient, it is found the patient did not have rheumatic fever.

The second case-Mitral Regurgitation: A 83-year-old US Army veteran is admitted to the emergency with the several complains including difficulty in breathing, having swollen ankles and feeling fatigued and lightheaded. The nurse listens to her heart and hears a holosystolic murmur. For further diagnosis, 3D echocardiography and Doppler color flow mapping are used to assess the severity of mitral regurgitation.

Summary

In this chapter, the researcher discussed the research design and data collection procedure along with the sampling method and recruitment. Apparatus used in the study were explained. Lesson plan for the VR-based learning environment for this study was described in detail under the framework of TPACK. Then, the researcher listed the workflow of the study. In the last section, the researcher went into more about the structure of the VR learning environment along with the two case studies. In the next chapter, the results of the study with the hypotheses of the study are presented.

CHAPTER 4

RESULTS

Overview

One of the aims of this study was to obtain empirical data to investigate the effects of a VR-based learning environment on learning outcomes as compared to the paper-based. The learning outcomes were measured by the performance achievement in post-test scores after the learners studied the content. In addition to the learners' performance, cognitive load during the learning process was also studied to investigate the effects of both delivery mode on individuals' perceived difficulty level.

This chapter reports the results from the data analysis of the comparative study. The analyses were carried out through various statistical techniques such as descriptive statistics analysis, the independent-samples t-test, and paired sample t-test. This chapter first describes the characteristics of the sample and the distribution of learners. It then presents the assumptions that are met to use the specific statistic test and results of the hypotheses testing are followed. Lastly, a summary of the findings to the research questions is presented.

Characteristics of the Sample

This study started in the summer of 2018 in May and lasted through the midterm of the Fall semester, 2018. Although 39 participants signed for the study and 29 of them committed to complete the study. The main reason for dropping the study was the tight schedule and they couldn't arrange 45 minutes before or after their class hours. Moreover, only 10 participants showed up to take the second posttest which was aimed to measure the long-term retention and to take the visual spatial test. Therefore, the researcher had to make adjustments on the original research objectives of the study which was to test the long-term effects of the VR tool taking into account of learners' spatial ability.

Fourteen of the participants' age was between 18-22, seven participants were between 23-27 and eight participants were between 28-35. Majority of the participants (34.5 %) were junior followed by a sophomore (31.0%) and senior (27.6%) and freshman (6.9%). Since the relationship between gaming and VR learning outcome has been found correlated in some studies (Vogel, Greenwood-Ericksen, Cannon-Bowers, & Bowers, 2006; Kafai, 2001), the study analyzed the participants' frequency of their gaming and their VR experience. According to the descriptive statistics, the majority of the participants did not play video games (Table 4-1). Also, more than half of the participants (75.9%) did never or almost never experience with VR. Almost 79 percent of participants did not study anatomy by using a 3D Anatomy software (Table 4-2).

Table 4-1: Percentage of the frequency of video game playing.

Frequency	Percent
Once a day	3.4
Once a week	10.3
Once a month	13.8
Once a year	20.7
Never	51.7

Table 4-2: Percentage of the frequency of study 3D anatomical models.

Frequency	Percent
Never	55.2
Almost never	24.1
Occasionally	20.7

Distribution of Learners

The 29 participants were randomly divided into two groups. Each group was assigned to one of the two delivery types of content matter: VR mode and paper-based mode. A total of 15 participants were in the VR mode whereas 14 participants were in the paper-based mode. Since Midway university became co-ed recently, there was only one male participant took part in the study.

Testing for Hypotheses

Research Question 1: How effective can a VR be after studying Mitral valve (MV) anatomical structure when compared with a paper-based mode?

H_a: The VR mode group's mean scores of post-test are higher than the paper-based mode group's means scores after they have studied the anatomical structure of the MV.

H_o: There is no statistical difference in the VR mode group's mean scores of post-test and the paper-based mode groups' after they have studied the anatomical structure of the MV.

In order to test the hypothesis, independent t-test was used. Before running this statistic test, certain assumptions should be met. According to Pallant (2007), the following assumptions are:

Assumption #1: The dependent variable should be measured on a continuous scale. The dependent variable of the study was the post-test scores. The first assumption was met.

Assumption #2: The independent variable should consist of two or more categorical groups. In this study, there were two different delivery mode: VR mode and paper-based mode. This assumption was met.

Assumption #3: A researcher should have independence of observations, which means that there is no relationship between the observations in each group or between the groups themselves. This assumption was met.

Assumption #4: There should be no significant outliers. The assumption was met (Figure 4-1).

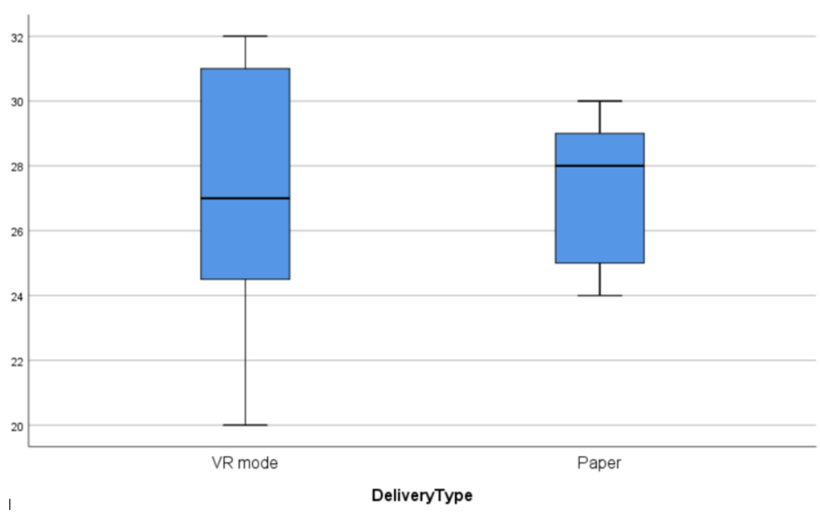

Figure 4-1: Boxplot of post-test scores across the two delivery modes.

Assumption #5: The residuals should be approximately normally distributed for each category of the independent variable. The Shapiro-Wilk test (Table 4-3) was used to assess the normality of the distribution for the dependent variable for the VR mode and paper-based mode. A non-significant test (*Sig*. values greater than 0.05) indicates normality. As such, posttest has a normal distribution for the VR mode (p = .113) and paper-based mode (p = 0.63).

Table 4-3: Test of normality.

	Delivery Type	Statistic	df	Sig
Post-test	VR-based Mode	.905	15	.113
Post-test	Paper-based	.882	14	0.63

Assumption #6: There needs to be homogeneity of variances. In order to test this assumption in Levene's test for homogeneity of variances was used. Levene's test indicated that the assumption of homogeneity of variances was violated, $F(1, 27) = 7.48$, $p = .011$.

Upon meeting all assumptions above, independent t-test was conducted to explore the effects of the delivery modes on the performance achievement as measured by the posttest. The independent variable was the delivery modes, that is, VR mode and paper-based mode. The dependent variable was the posttest scores of MV anatomical structure. Table 4-4 presents the independent t-test results. There is no a significant difference found in the post-test scores for participants in VR group (M= 3.40, SD=1.40) and paper-based group (M=3.79, SD=.426), $t(16.72) = -1.01$, p=.325. Therefore, the null hypothesis is accepted and the alternative hypothesis was rejected.

Table 4-4: Independent t-test results on mitral valve anatomical structure.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	3.40	1.40	-1.01	16.72	.325
Paper-based	14	3.79	.426			

Research Question 2: How effective can a VR be after studying MV diseases in the application of CBL approach when compared with paper-based mode?

H_o: There is no statistical difference in the mean scores of post-test test among students who studied MV diseases through VR mode and paper-based mode.

H_a: The VR mode group's mean scores is higher than the paper-based mode group's means scores after they have studied mitral valvular diseases.

Independent t-test was conducted to explore the effects of the delivery modes on the performance achievement as measured by the posttest. The independent variable was the delivery modes, that is, VR mode and paper-based mode. The dependent variable was the posttest scores of mitral valvular diseases. Table 4-5 presents the independent t-test results. There is no a significant difference found in the post-test scores for participants in VR group (*M*= 23.73, *SD*=4.20) and paper-based group (*M*=23.71, *SD*=2.01), *t*(20.42)= .016, p=.988. Therefore, the null hypothesis is accepted and the alternative hypothesis was rejected.

Table 4-5: Independent t-test results on mitral valvular diseases.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	23.73	4.20	.016	20.42	.988
Paper-based	14	23.71	2.01			

Research Question 3: Is case-based learning effective in teaching MV diseases regardless of the delivery mode?

H_o: There is no statistical difference in mean scores of pre-test and post-test of the learners' who studied the MV diseases.

H_a: There is a statistical difference in the pre-test and post-test of the learners' who studied the MV diseases.

Paired sample t-test was conducted to explore the effects of case-based learning on the performance achievement as measured by difference between the pre and posttest. The independent variable was the pre-test scores and the dependent variable was the posttest scores of mitral valvular diseases. Table 4-6 presents the paired sample t-test results. There is a significant difference found in the pre-test scores (M= 10.76, SD=4.42) and post-test scores (M=23.72, SD=3.27), $t(28)$= -12.25, p=.000. Therefore, the alternative hypothesis was accepted.

Table 4-6: Paired sample t-test results.

	n	Mean	SD	*t*	df	Sig
Pre-test Scores	15	10.76	4.42	-12.25	28	.000
Post-test Scores	14	23.72	3.27			

Research Question 4: What is the perceived level of difficulty in students studying materials with VR versus the paper-based mode?

H_a: The intrinsic mental load among VR group is lower than the paper-based group.

H_o: The intrinsic mental load among VR group is equal to the paper-based group.

In order to find the difference in intrinsic load experienced between two groups, independent t-test was run. Table 4-7 shows the results. Independent t-test indicated that there was no significant difference between the mean scores of VR-based mode rating scale (*M*= 3.60, *SD*= .986) and the paper-based mode (*M*= 3.07, *SD*=.829), $t(27) = 1.55$, p = .131. Both groups found the learning mitral valve 'somewhat' difficult'. Therefore, the null hypothesis was accepted.

Table 4-7: Independent t-test results of intrinsic load.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	3.60	.986	1.55	27	.131
Paper-based	14	3.07	.829			

H_a: The extraneous mental load among VR group is lower than the paper-based group.

H_o: The extraneous mental load among VR group is equal to the paper-based group.

In order to find the difference in extraneous load experienced between two groups, independent t-test was run. Table 4-8 shows the results. Independent t-test indicated that there was no significant difference between the mean scores of VR-based mode rating scale (*M*= 2.33, *SD*= 1.047) and paper-based mode (*M*= 2.64, *SD*=.745), *t*(27) = -.911, p = .370. Both groups found learning mitral valve with their related delivery mode 'just a little bit' hard. Therefore, the null hypothesis was accepted.

Table 4-8: Independent t-test results of extraneous load.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	2.33	1.047	-.911	27	.370
Paper-based	14	2.64	.745			

H_a: The germane mental load among VR group is higher than the paper-based group.

H_o: The germane mental load among VR group is equal to the paper-based group.

In order to find the difference in germane load experienced between two groups, independent t-test was run. Independent t-test indicated that there was no significant difference between the mean scores of VR-based mode rating scale (*M*= 4.53, *SD*= .743) and paper-based mode (*M*= 4.21, *SD*= 1.051), *t*(27) = .949, p = .351. Both groups concentrated 'pretty much'. Therefore, the null hypothesis was accepted. Table 4-9 shows the results.

Table 4-9: Independent t-test results of germane load.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	4.53	.743	.949	27	.351
Paper-based	14	4.21	1.051			

H_a: The overall mental effort used by VR group is lower than the paper-based group.

H_o: The overall mental effort used by VR group is equal to the paper-based group.

In order to find the difference in overall mental load experienced between two groups, independent t-test was run. Table 4-10 shows the results. Independent t-test indicated that there was no significant difference between the mean scores of VR-based mode rating scale (M= 6.20, SD= .676) and paper-based mode (M= 6.79, SD= 1.36), $t(27) = -1.47$, $p = .151$. Both group learners used 'rather high mental effort' while learning the MV. Therefore, the null hypothesis was accepted.

Table 4-10: Independent t-test results of overall mental load.

Delivery Mode	n	Mean	SD	*t*	df	Sig
VR-based	15	6.20	.676	-1.47	27	.151
Paper-based	14	6.79	1.36			

Summary

This chapter was allocated to the statistical tests results of the effectiveness of VR learning environment compared to traditional learning settings on studying Mitral valve anatomical structure and related diseases. No significant difference in mean scores of post-tests was found between two modalities. Moreover, the participants' cognitive load levels while studying the content were also analyzed. Again, no significant difference was found across the types of cognitive load. However, the results indicated implementing a case study of either VR or paper-based was associated with significant gains in achievement. The results reported in this chapter are discussed in Chapter 5.

CHAPTER 5

FINDINGS, IMPLICATIONS, AND CONCLUSION

Overview

The aims of this study were to determine does, and how VR learning environments influence the learning outcomes of the learners does. It investigated the learning effectiveness of a VR-based learning environment and developed an instructional model for evaluating how VR enhances the learning outcomes. Another layer of this study analyzed the learners' cognitive load, which is their perceived difficulty level, while learning the content in VR learning environment.

The effects of two learning modes, the VR-based learning environment (VR mode) and conventional classroom learning method (paper-based mode) on the learning outcomes were studied. An instructional design model was developed by using TPCAK framework. The learning effectiveness of the learning modes was assessed by the differences in mean scores of posttest.

The sample consisted of 29 nursing students, aged between 18 and 35 years old from Midway University. The independent variable was the learning mode (VR and paper-based mode) and the dependent variable was the performance achievement. Moreover, the effect of the cognitive load on the learners' performance was analyzed.

In order to find the learning effectiveness of VR based environment, the testing instrument was designed to aim to assess learners' knowledge of the anatomical structure of MV and two mitral valvular diseases. The anatomy of the Mitral valve was presented in a 3D way. Mitral valvular diseases were taught by CBL teaching method, which learners are familiar with in their classroom environment. Both posttest scores of the anatomical structure of MV and diseases presented in two learning modes were not found statistically significant in this experimental study as presented in Chapter 4.

Interpretation of the Study Findings by Using Previous Studies

Comparative Studies on 3D Anatomical Models versus Textbooks. The studies focusing on comparison between traditional teaching media and 3D models are abundant in literature and they revealed mixed results. In a study Codd and Choudhury (2011) compared 3D models of the forearm muscles against dissection and textbooks. Neither the 3D model nor the traditional methods experimental groups performed significantly better. Using 3D larynx model was not shown to be superior to written lecture notes in its efficacy in teaching anatomy (Hu, Wilson, Ladak, Haase, Doyle, & Fung, 2010). Also in hepatobiliary anatomy, interactive 3D module received higher satisfaction ratings from students yet it neither enhanced nor inhibited learning of hepatobiliary anatomy compared to traditional textbooks (Keedy, Durack, Sandhu, Chen, O'Sullivan, & Breiman, 2011). Consistently, other studies found no differences between 3D anatomy models and traditional teaching or 2D images (Donnelly, Patten, White, & Finn, 2009; Yeung, Fung, K., & Wilson 2012; Metzler et al., 2012), which showed consistency with this study's findings.

Recently, the effectiveness, satisfaction, and motivation associated with immersive VR simulation in teaching medical students neuroanatomy have been investigated (Stepan, Zeiger, Hanchuk, Del Signore, Shrivastava, Govindaraj, & Iloreta, 2017). The participants studied structures through either online textbooks or the VR interactive model. There was no significant difference found in anatomy knowledge between the two groups on pre-intervention, post-intervention, or retention quizzes. The

VR group found the learning experience to be significantly more engaging, enjoyable, and useful and scored significantly higher on the motivation assessment.

Some studies found significant difference between 2D and 3D. Nicholson, Chalk, Funnell, & Daniel (2006) reported the use and study of a 3D model of the ear produced significant learning gains among students on post-test material. Beermann Tetzlaff, Bruckner, Schoebinger, Muller-Stich, Gutt, and Fischer (2010) presented students with 2D CT images or 3D representations of the liver. The results showed the 3D representation resulted in significant improvements during identification of complex liver anatomy. In Settapat, Achalakul, and Ohkura (2014) study results reported that students using the 3D tool had a higher percentage of correct answers when asked to locate brain structures compared to 2D. Additionally, students felt that the material was easier to learn in 3D and indicated that 3D visualization was preferred for education to the standard 2D image tools.

Similar studies comparing 3D to 2D material have found significant performance improvements for other anatomical structures including the brain (Estevez, Lindgren, & Bergethon, 2010, Levinson, Weaver, Garside, McGinn, & Norman, 2007; Ruisoto, Juanes, Contador, Mayoral, & Prats-Galino, 2012) and the liver (Muller-Stich et al., 2013), trunk and limb (Hoyek, Collet, Rienzo, Almeida, & Guillot, 2014), human skull (Hilbelink, 2007), dental education (Boer, Wesselink & Vervoorn, 2016), and temporal bone anatomy (Venail, Deveze, Lallemant, Guevara, & Mondain, 2010). The memorization tasks of naming anatomical details on structures and placing their corresponding location on realistic 3D display models were found better than doing this on 2D displays (Tavanti & Lind, 2001). Yammine and Violato (2014) revealed 3D anatomical visualization compared to 2D resulted in improved factual knowledge, improved spatial knowledge and significant increase in user satisfaction.

Although these studies showed an impact on learning mainly on short-term basis (Nicholson et al., 2006; Marsh, Giffin, & Lowrie, 2008; Abid, Hentati, Chevallier, Ghorbel, Delmas, & Douard, 2010; Hoyek, Collet, Rienzo, Almeida, & Guillot, 2014), the effect of 3D visualization on long term memory were also examined in several studies. Marsh et al. (2008) developed Web-based learning modules that compared animated 3D models with animated 2D graphics in embryonic development and assessed the students' long-term retention. At 16 months, the 3D model group had a higher score than did the 2D group, and they suggested the 3D modules may be more useful if used toward the later stages of learning. In another study, the long-term retention of a 3D educational computer model of the larynx compared with written instruction was studied and no significant difference was found in mean scores and change in scores between short- and long-term retention on the laryngeal anatomy test (Fritz, Hu, Wilson, Ladak, Haase, & Fung, 2011).

Bergman, Van Der Vleuten, & Scherpbier (2011) believed that those inconclusive findings concerning the influence of different anatomy teaching tools on student knowledge may be related to the fact that tools like computer models are more helpful in learning complex anatomical structures (e.g. the inner ear, bones of the skull or the brain). Students may get a better understanding of complex structures from desktop 3D computer models, which enable zooming and rotation, whereas less complex structures (e.g. abdominal organs) can easily be studied from a textbook or cadaveric material. The other reason for inconsistent results may be the fact that various factors influence performance level of students learning with 3D anatomical models. Brewer, Wilson, Eagleson and de Ribaupierre (2012) suggested the 3D visualization along with anatomy labs could be effective learning tools for students with no previous exposure to the subject, and/or who have poor spatial abilities.

Comparative Studies on the Delivery Mode of Case-Based Learning. In this study, CBL was selected as a teaching method based on TPACK framework of instructional design with technology. The contextual nature of CBL made it possible for VR delivery mode to be integrated in the learning process. The overall purpose of CBL is to facilitate learning through the application of knowledge in real-world contexts. Not only are the students actively participating in the learning experience, but they are doing so in a manner that will be the context in which they will be required to perform tasks in real life. Thus, the learning is directly applicable to the context within which the learned task exists. Herreid (1994) stated this as "learning how to grapple with messy real-life problems … 'It's a rehearsal for life'" (p. 44). Barrows (1986) described the importance of structuring learned material in a way that is directly applicable to true practice. This aspect lends itself very well to nursing education.

Many different modes exist in formatting of case-based learning experiences including the type of case used. VanLeit (1995) describes four different types of patient cases that can be used in allied health professions. These include fabricated paper-based patient cases, real or mock patients who have been videotaped, actual simulated patient cases with either classmates or standardized patient actors, and real patient cases. Even though learners gain much through interaction with an actual patient, the scenario and outcomes of the case experience are difficult to control. The use of live patients can be easily implemented in most nursing education as their part of their last year internship. The most commonly utilized would have to be the paper case since it is easily executed. Here cases are either created from scratch or adopted/adapted an existing case to meet the learning objectives of the case-based learning experience. In this study, the two clinical cases were created from scratch to be aligned with learning objectives.

Neistadt, Wight, and Mulligan (1998) performed a qualitative study looking at the use of specific paper cases they designed as clinical reasoning case studies in occupational therapy curricula. They found that through the utilization of these cases that students felt as though they demonstrated better understanding of clinical reasoning. Neisadt et al.'s study yielded the results that were consistent with this research study. When compared the mean scores of pre and posttest in clinical application, there was an increased found in both delivery modes. There was statistical difference in mean scores of pre (M=.13; SD=.626) and posttest scores (M=2.48; SD=1.163) of VR group, $t(27)$= 8.899, p=.000, and in the mean scores of pre (M=.52; SD=1.163) and posttest (M=2.35; SD=1.265) of paper-based group, $t(27)$=5.85, p=.000. In the same vein, Gentner, Lowenstein, and Thompson (2003) performed a series of studies looking at the impact of the use of paper cases in clinical reasoning and found that there was a significant increase.

In addition to the paper-based case learning approach, some studies also focused on video-based case studies. Balslev, De Grave, Muijtjens, and Scherpbier (2005) compared the use of video case and paper case on the learning gains and found that in the verbal clauses recorded during case discussions of participants' scores in video-cases were significantly greater in those students who read the paper-based cases. Chau et al.

(2001) looked at the effects of using video-based case versus paper-based in nursing on both knowledge and critical thinking. A pre-test/post-test design was used and mixed findings showed that there was a significant increase in knowledge of the learners after the case intervention, but there were no statistically significant differences in critical thinking skills.

Along with paper and video-based cases, the effect of the simulated cases were also studied. The advent of new technology continues to offer more advanced ways of simulating patient encounters. These human patient simulators are high-fidelity avatars that can mimic real- life patient scenarios. Students are able to interact with these patient avatars in specially developed case based learning experiences. One study compared traditional case-based learning with that of human patient simulation for a specific content area (Schwartz, Fernandez, Kouyoumjian, Jones, & Compton, 2007). The fact that there was no significant difference in the exam scores of either group of learners demonstrates that paper cases are viable options for programs that do not have such high fidelity simulators.

Web-based case studies are getting more commonly used due to the online learning management systems. Zachow, Schneider Lebeau, and Galt (2017) designed four web-case interactive case studies for undergraduate medical students. The survey results showed that the use of these interactive case studies was considered to be a worthwhile use of study time and participants found them very were appropriate and helpful. The same positive feedback from participants was found in another study (Wilson et al., 2006).

Along with the participants' perceptions, knowledge gain from web-based case studies was investigated. Recently, Guimaraes et al. (2018) conducted a comparison study on paper-based and web-based case studies found mixed results from two learning sessions. In the first session, pen-and-paper group students scored significantly better than computer-group students in the theoretical examination whereas, in the second session no statistically significant differences were examined. Web-based case studies also were found to increase interaction, group learning, and clinical skills (Ali et al. 2018). However, some comparisons between online and pencil-and paper (Bonham, Deardorff, & Beichner, 2003; Allain & Williams, 2006; Riffell & Merrill, 2005; Chan, Sit, Wong, Lee, & Fung, 2016) found no significant gains over the paper-based case studies.

In this study, the researcher used VR technology to facilitate case-based learning compared to paper-based. Since VR technology is still in its infancy, there has been no study found to compare the effectiveness of VR with paper-based. Only recently Cleveland Clinic announced that they partnered with Zygote Medical Education to develop and deploy a Virtual Reality (VR) based clinical anatomy curriculum. They suggested that practical clinical case studies will be used to explore anatomy content from all seven anatomical regions of the human body in an engaging and meaningful virtual environment (Cleveland Clinic, 2018).

According to Saleewong, Praweenya, and Kuhakran (2012) when case-based learning is implemented online, instructors should be aware that pedagogical activities can be either limited or fostered by conditions associated with technology tools employed. Technology such as VR can offer cognitive support for students' thinking by helping them to represent evolving ideas, concepts, and solutions. At the same time, technology can burden students since they have to manage tasks and tool functions simultaneously in the learning processes (Lee, 2009). With this fact in mind, the researcher also was interested in the participants' mental load level during learning process.

Studies on Cognitive Load. Cognitive load is comprised of three components: intrinsic, extraneous and germane load. Intrinsic load is defined by the elements specific to a given task and reflects the inherent difficulty of that task. According to Sweller, van Merrienboer and Paas (1998) the work of processing the intrinsic load can be lessened by the learner's prior knowledge with the content. In this study, the mean scores of pre-test was found 11.86. The participants' ICL mean score was found 3.34 in a scale of 6.00. That is, the participants found studying mitral valve somewhat hard. Therefore, Sweller et al.'s assumption wasn't supported by this study's finding. A Pearson product-moment correlation coefficient was computed to assess the relationship between ICL and participants' background knowledge and there was no correlation found between two variables, $r=-.166$, $p=.389$.

The researcher used segmentation principle to reduce the intrinsic load of the learners. The segmented principle found effective and revealed positive results in some studies (Mayer & Moreno, 2002; Mayer& Chandler, 2001; Mayer, Dow & Mayer, 2003; Moreno, 2007). By following the segmentation principle, the researcher divided the lesson into three segments. In the first segment, the participants' studied anatomy of mitral valve and they were given a 5-minute break. Upon the break, they studied the first clinical case study on Mitral Stenosis and were given a 5-minute break. In the last segment, the participants studied the second case study on Mitral Regurgitation. Two case studies were presented in the same framework. It started with dealing with a patient's symptoms, then presenting 3D TEE results followed by diagnosis and treatment along with complications if it isn't treated. Therefore, the researcher could support the fact that segmentation can play a role in reducing the intrinsic load.

Extraneous load is the working memory consumed during task completion that is imposed on learners by the structure of the activity. The educator can have the most direct influence on decreasing extraneous load through tight tailoring of the curriculum. The mean score of the extraneous load in the study was 2.48. That is the participants who studied the MV by VR found less difficult (M=2.33) than paper-based group (M=2.64). The researcher applied Mayer's 12 Principles of learning with multimedia and worked with the instructor designers to receive feedback. The results of this studied supported by many studies that applied the principles of multimedia learning (Mayer, Heiser, & Lonn, 2001; Mautone & Mayer, 2001; Mayer, Mathias, & Wetzell, 2002; Ginns, 2005; Mayer, Fennell, Farmer and Campbell, 2004; Mayer, Sobko, & Mautone, 2003;Mayer & DaPra, 2012; Mayer, Dow, & Mayer, 2003). In order to facilitate the greatest amount of learning, instructional designers must provide adequate levels of intrinsic cognitive load, reduce extraneous cognitive load, and enhance germane cognitive load (Meissner & Bogner, 2013).

The germane cognitive load, which derives from the amount of cognitive or working memory resources that the learner devotes to dealing with the intrinsic cognitive load (Meissner & Bogner, 2013; Sweller, 2008). In other words, germane cognitive load occurred because free working memory resources were actively devoted to learning.

According to Hasler, Kersten & Sweller (2007, p. 725), the deeper cognitive processing of the instructional information in terms of a higher germane cognitive load is likely to result in better learning performance. Consistent with Hasler et al.'s claim the participants of both groups showed significant difference in the mean scores of posttest. However, specifically VR as a tool did not help germane load increase against paper-based mode.

Over all mental effort for this study between VR mode (M=6.20) and paper-based (M=6.79) was found to be almost the same. In other words, in both groups the learners invested rather high mental effort while studying mitral valve. According to Fraser et al. (2012), cognitive load between 3 and 6 out of 9 is associated with maximal learning experience and a score above 7 results in declined performance. In our study, cognitive load was near optimal. Educators who take the time to craft a scenario with cognitive load in mind will be more successful in optimizing the amount of strain imposed on learner working memory.

Limitations of the Study

There are some limitations that may restrict the probability of generalizing the findings of this study. First, though performance achievement is a significant indicator of learning outcomes, only a small proportion of variability in performance achievement was explained. Student performance achievement is influenced by a myriad of other factors including personal goals (Yi & Im, 2004), cognitive styles (Witkin, 1976), and computer attitudes (Teo, 2008). A short exposure to VR might not be sufficient to gauge students' performance achievement.

Second, the findings were limited to the context of heart anatomy specifically on mitral valve. The results obtained here are primarily dependent on the context of anatomy learning. Different learning content may arouse different results. Another limitation is related to the test questions used, in that most of the questions cover only the lower two levels of Bloom's taxonomy (Knowledge and Comprehension). Although there were 4 questions that measured higher levels of cognitive learning, that was not enough to reach a conclusion that VR-based case studies enforce higher thinking skills.

The results of this study are essentially non-generalizable due to the small sample size involved of only 29 students. Larger sample sizes would certainly be needed in future research. The reason for the small sample size was the nursing students' tight schedules. Their classes started at 6:30 pm and most of them came to class just right after work so they couldn't find time to take part in the study. Willingness to participate in the study may have been influenced by students' initial comfort level with technology. Although using technology in the classroom is the part of Midway University's Strategic plan (Midway Strategic Plan, 2017), the researcher didn't expect all the instructors wanted to collaborate with her. Since the VR is not the part of the curriculum of the course, the participants may not have taken the project serious.

During the learning process, the participants in the VR group have a limited interaction with the learning material. One of the biggest limitations of the VR-based learning environment used in this study was participants were passive while learning the material. Active learning improves students' outcomes. There is a well-established evidence base supporting the use of active learning. The benefits to using such activities are many, including improved critical thinking skills, increased retention and transfer of new information, increased motivation, improved interpersonal skills, and decreased course failure (Prince, 2004; Owens, Sadler, Barlow, & Smith-Walters, 2017; Cavenagh, 2016).

Recommendations for Further Study

To enable effective and proper infusion of such technology into an education setting, more fundamental research, such as design-based research that aims to generate theories on virtual reality learning, should be further encouraged. This study focused on only one part of the learning which is retention. However, there are wide opportunities for VR simulations that are designed for skills development which can be beneficial to nursing students.

It is no doubt that the hardware that makes the VR experience technically and psychologically immersive is here. When it comes the 3D content for educational purposes, things are slowly moving. The main reason might be the lack of communication and partnership with 3D content developers and expert on knowledge (in this case teachers). VR applications must be seen as a combination of various disciplines: computer science, human-computer interaction, graphic design, instructional design, multimedia learning, educational technology, and psychology. To build a common goal and find a common language is challenging in this kind of multidisciplinary approach. There is a need for a framework on building an internal partnership with a department to design 3D educational content for VR technologies.

The relationship between self-efficacy and VR could also be investigated. So far many research has focused on learner's knowledge gain, perception and motivation. There are a few studies on teachers' perception, and attitudes toward using VR technologies. It would be interesting to see the predictive relationship between technological self-efficacy and tendency to use VR in classroom settings. Technological self-efficacy (TSE) is "the belief in one's ability to successfully perform a technologically sophisticated new task" (McDonald & Siegall, 1992, p. 467).

As for research methodology in this study, the quantitative research design was used. In the future researchers may want to use qualitative research. Learners' opinions and attitudes along with teachers' perceptions on why and how to use in VR in a classroom setting will contribute to the educational value of this tool. In addition to the overall perceptions of user experience, presence is seen as two components related to successful interactions in virtual spaces. Participants could report factors that contributed to their feelings of presence in the space. They could also write about how they feel about the patients in the VRLE to assess the effect of the VR on empathy. Last but not least they might be asked to report on the things that they like and dislike about using the VRLE in their classroom settings.

There are other various research methodologies which can fit in VR research. One of these could be an interdisciplinary approach which is concerned with the integration of theory, methods or knowledge from two or more traditionally distinct disciplines (Walker, 2011). It is a process in which researchers work jointly, but from each of their respective disciplinary perspectives, to address a common problem/goal. Chou and Wong (2015) designed a framework for how a project is done from different perspectives from various disciplines through using an interdisciplinary approach. This approach may be useful for VR application design process.

In this study as a teaching strategy, a CBL approach was used. The nursing students in Midway who study Anatomy and Physiology course are familiar with this approach. Although it is done in an unstructured way, the instructor brings case studies to the classroom and encourages her students to watch a TV show called Grey's Anatomy to have in-class discussions. For the future studies, other teaching strategies such as problem-based learning approach could be utilized in VR-based learning environments.

Since educators can add audio and visual elements in a VR learning environment, the VR can also be used to evoke some feelings such as empathy. It is especially important for nursing education. Empathy is central to the nursing role and has been found to be associated with improved patient outcomes and greater satisfaction with care (Scudde, 2012). In this study, in both clinical cases, the learner listened to the patient and their concerns. This feeling cannot be evoked while reading the textbooks. For the future research, empathy that is evoked by VR environment can be studied.

This study was designed for a two-group research design comparing paper-based to the VR-based group. In the future, researchers could add the third group. This group might use desktop-based learning material. Desktops or tablets are widely used in classroom settings. Therefore, it will be necessary to assess the educational value of VR when it is compared to a desktop or a tablet-based learning environment.

In this study, the VR tool was used to measure the learning performance. However, the tool has a great potential to be utilized in complicated surgeries and more complex emergency training. The use of this technology in the operating room is still very new, however, and perhaps the most poignant use case for VR at the moment is prior to procedures, for planning and training purposes. VR imaging might give specialists more conviction when heading into difficult procedures.

The experimental group learned the anatomical structure of the Mitral Valve in a 3D model in which they zoomed and rotated. However, their knowledge was measured in 2D paper-based environment. There is a need for designing not only learning but also for assessment in 3D content. The researcher observed some participants having difficulty in drawing mitral valve anatomical structure on 2D paper after being exposed to a 3D learning environment. For this study, the 3D assessment could have been done by providing learners with 3D Mitral Valve and asking them to drag and drop the labels using the controllers.

Last but not least, originally this study was aimed to measure the long-term retention level of the content. However, due to the tight schedule of nursing students, the researcher was not able to reach this goal. Therefore, for the future research long-term learning gains of VR-based learning environment should be investigated.

Educational Implications and Lessons Learned

The study has important implications for instructional designers and educators. An important finding is that great VR features alone might not achieve the desired learning experience. The study results once again prove the crucial value of teaching method. Regardless of how innovative and sophisticated learning and teaching tools, they are less effective without existing of the evidence-based teaching strategies in a lesson plan. In this research, the effect of the CBL on learning of the MV is statistically significant. There was significant learning gain after the participants study the material both in VR and paper-based. After a 10-minute break, the retention rate was 78 percent. This finding was supported by the Ebbinghaus Forgetting Curve.

According to Ebbinghaus Forgetting Curve, after six days one only retain almost 25 percent of information unless we do rehearse it: 20 minutes = 58.2% 1 hour = 44.2% 1 day = 33.7% 6 days = 25.4% 31 days = 21.1% (Ebbinghaus, 1885). Ebbinghaus discovered the exponential nature of forgetting, describing the formula of forgetting by:

$R = e\ (-t/S)$

where *R* is memory retention, *S* is the relative strength of memory, and *t* is time.

A significant increased learning gain can be explained by the contextual nature of case-based learning and using schemata theory. For decades, cognitive scientists and psychologists have discussed the schema theory of human memory (Piaget 1926; Bartlett 1932; Ausubel 1967). The underlying idea of this theory is that humans, as they receive incoming information, organize it around their previously developed schemata, or "networks of connected ideas" (Slavin, 1988). Several methods have been advocated as schema activators, or ways to foster more meaningful learning. David Ausubel (1960) championed the "advance organizer" as the best way for teachers to activate the appropriate schemata of students so that more conscious clustering of new information with existing ideas could take place.

In this study, the researcher studied the 'organizers' to present the new information in a way that the learners' are familiar with. Upon reading textbooks and talking to the instructors, the researcher came up with a cognitive organizer or a framework. Even though the learners had a little prior knowledge at the beginning (*M*=11), at the end of the learning session this increased by 130 percent (*M*=23). The first phase of analyzing learners' cognitive schema before writing a clinical case helped the researcher to put the context in a meaningful framework for the learners (Figure 5-1).

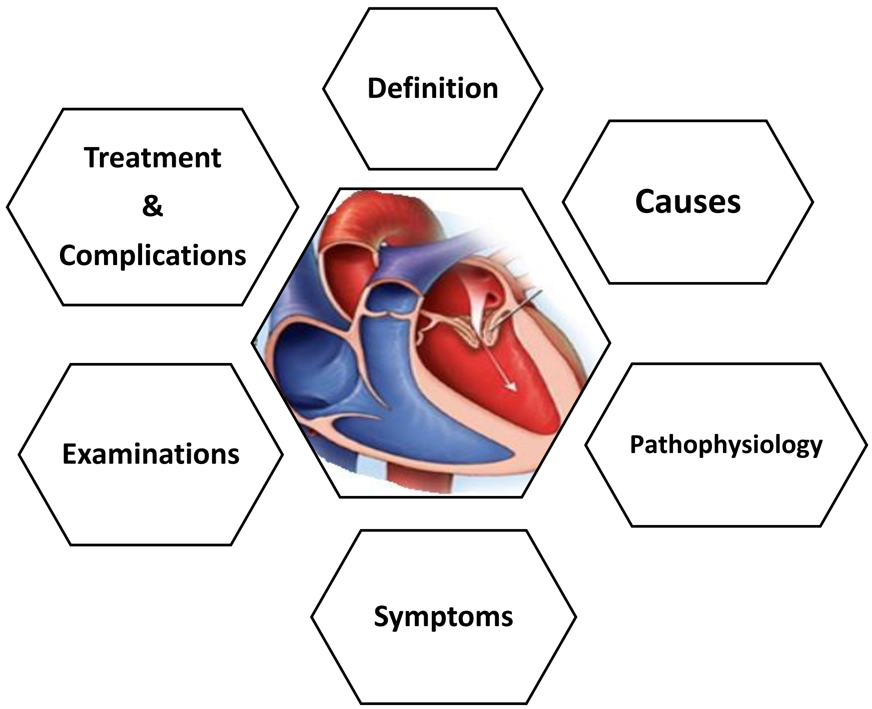

Figure 5-1: Framework of the concept.

To keep the retention rate as high as possible is one of the main goals of educators. This study's learning sessions represented as passive learning (observing and listening to the cardiac nurse) based on Dale's Cone of Experience (1946). The base of the cone is characterized by more concrete experiences, such as direct experiences (real-life experiences), contrived experiences (interactive models), and dramatic participation (role plays). Direct purposeful experiences represents reality or the closet things to real, everyday life. The common theme among these levels is learners are "doing." The middle of the cone is slightly more abstract and is characterized by learners realistically "observing" the experience. These levels are differentiated from the lower levels of the cone because students do not interact directly with the phenomenon. Levels in this section of the cone include demonstrations, field trips, exhibits, motion pictures, and audio recordings or still pictures. The peak of the cone is the most abstract where the experiences are represented non-realistically by symbols, either visual or verbal. (Figure 5-2).

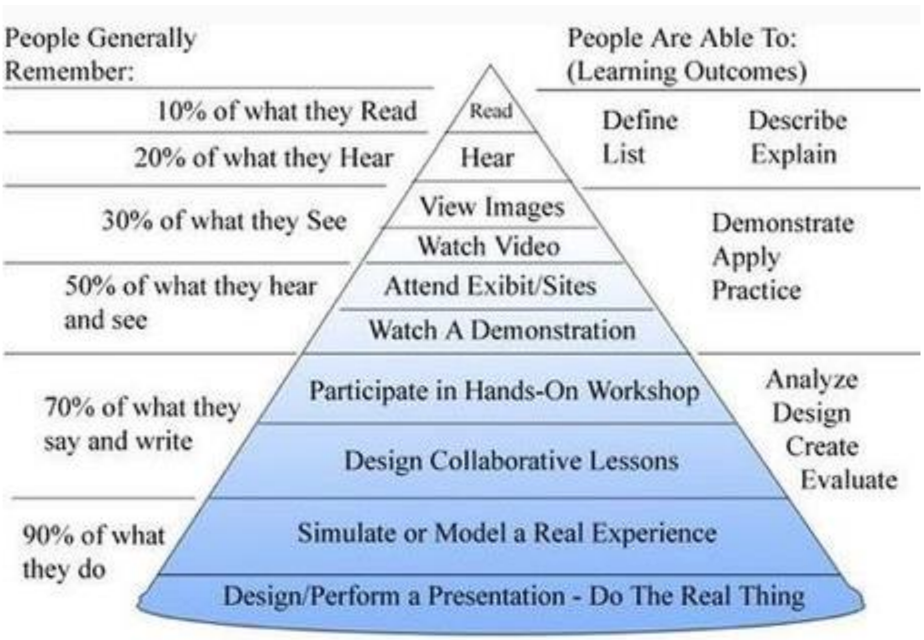

Figure 5-2*:* Dale's cone of experience. From "Learning Theories in Secondary Education," by Scoopt it, 2014 (https://www.scoop.it/t/learning-theories-in-secondary-edcuation-2014)

The cone charts the average information retention rate for various methods of teaching. The further you progress down the cone, the greater the learning and the more information is likely to be retained. It also suggests that when choosing an instructional method it is important to remember that involving students in the process strengthens knowledge retention. It reveals that "action-learning" techniques result in up to 90%

retention. People learn best when they use perceptual learning styles. Perceptual learning styles are sensory based. The more sensory channels possible in interacting with a resource, the better chance that many students can learn from it (Diamond, 1989). According to Dale (1969), instructors should design instructional activities that build upon more real-life experiences. Dale's Cone of Experience is a tool to help instructors make decisions about resources and activities. For this lesson, the instructor may use in-class discussions and ask students to write role-plays collaboratively that can be used in other VRLEs. Those learning activities may increase the learning performance.

It takes time for learners to get used to the VR learning environment. Extra time needed for structural tutoring if a learner's role in VR settings is more than being an observer. In this study, the participants were just an observer because the majority of them had not any experience with VR before the study. The researcher thought that the more interactive the VR learning environment, the more confusing it would be for the learner, which can hinder the learning process. As a rule of thumb, if an educator starts using VR in their classroom, they should begin with giving the learners less control especially if the students do have a little knowledge on the content matter and have little experience with VR learning environment.

While much more research needs to be done in order to further explore how to effectively use VR for teaching anatomy, there are some lessons that can be extracted from the experience gained in this study.

1. Successful technology integration is achieved when the use of technology is supporting the curricular goals, and helping the students to effectively reach their goals. When technology integration is at its best, a learner or a teacher doesn't stop to think that

he or she is using a technology tool. And students are often more actively engaged in projects when technology tools are a seamless part of the learning process. A teacher should make a wise decision before selecting a tool like VR. It's important to always start any conversation about technology selection with objectives. What is it that you and/or your students should be able to do? Once you have your goals and objectives clearly in mind, the next step is to take an inventory of your current technology use as well as look at your environment for incorporating the new technology. What tools are you and/or your students already using? What are you comfortable with? Pick a few (5 or less) available options and try the tools yourself to see which you and/or your students like best, are easiest to use, and meet your needs. What are the pros & cons of each? What support is available? How does each integrate into the existing workflow and/or lesson? Clarify for yourself and/or your students how the tool will and won't be used. Are you using the right tool for the right problem?

2. Collaboration is the key to a successful VR-based learning environment. The researcher worked closely with Midway University instructional design and IT unit, the Nursing instructors, a retired cardiac nurse, the director of the simulation lab and a theater instructor. The Instructional designers helped with the appropriate design framework and theoretical foundation. Upon the researcher designed the learning environment they were willing to rate the system by using Mayer's 12 Multimedia Learning principles. The nursing instructor assisted the researcher with evaluation of testing instrument (pre-posttest), and the retired cardiac nurse helped the accuracy of the two cases on Mitral valvular diseases. The theater teacher gave voices to the characters in the dialogues

related to the two cases. The director of the simulation lab provided the researcher with a space for VR setting and recruitment of participants.

3. The researcher observed some unwillingness from some instructors and students to try out the new technology. It would be naïve to expect all instructors and students adopt this technology without any resistance. The educational technology adoption resembles a pencil as McKeown (2007) beautifully described. In the pencil metaphor she identifies six types of users: the *Leaders* (first to adopt technologies, document and share practice—warts and all), the *Sharp Ones* (they watch the leaders, grab the best bits, learn from mistakes and do great stuff.), the *Wood* (they would use tech if someone else sets it up and shows them how-to and keeps it running), the *Hangers-On* (they know all the lingo, attend the seminars but don't do anything), the *Ferrules* (they hold tightly onto what they know. Tech has no place in their classroom.), and the *Erasers* (they endeavor to undo much or all the work of the leaders). One of the strategies that help the instructors and students welcome the technology is to address their challenges and struggles. Once technology leaders can identify them and help them to do what they want to do (but better) then address their primary motivation to engage.

The researcher identified the problem (clinical cases and 3D anatomical model that a teacher/students might not find in their textbooks) and talked to the instructors who are open to using technology in their courses. Their positive experience and remarks did help the researcher recruit participants.

4. The researcher used TPACK instructional design framework in this study. During the adaptation of this model to the lesson plan, she realized an important element which keeps all primary knowledge on technology, pedagogy and content together was missing.

And that is educational philosophy. The medical educational philosophy of Sir William Osler, a Canadian physician and one of the four founding professors of Johns Hopkins Hospital (Figure 5-3), gave another meaning to TPACK design.

Figure 5-3: William Osler attending a patient. From "William Osler Photographs," by Fine Art American, 2016 (https://fineartamerica.com/featured/william-osler-attending-a-patient-national-library-of-medicine.html)

Osler's bedside teaching philosophy although it has been declining because of various reasons (time constraints, patients not being in bed and noise on the ward, poor clinical skills and knowledge of students), it has been described as one of the ideal clinical teaching modalities can be combined to provide a holistic approach in the diagnostic process and in patient care (Petersen & Ten Cate, 2014) Osler quoted "Medicine is learned by the bedside and not in the classroom. Let not your conceptions of disease come from words heard in the lecture room or read from the book. See, and then reason and compare and control. But see first." This famous quote emphasizes the importance of observation in medical education. In VR-learning environment, the learner can be an observer and can witnesses the process of diagnosis and how to approach to a patient.

Conclusion

In conclusion, this research makes a contribution by bringing educators who want to utilize VR one step closer to understanding the potential of VR technology to support and enhance learning. The findings contribute to the understanding of the learning outcomes of a VR-based learning environment and the merit of using VR technologies for learning. The instructional framework used in the study, TPACK, has been empirically tested. The framework and VR- based lesson plan are intended to guide the future development efforts of a VR-based learning environment.

Moreover, the development of case studies in a VR environment was rewarding as well as challenging. Even without coding background an educator can design a VR learning environment and embed fictitious data and interviews. This can provide a supplementary learning tool for students when they may not experience during their internship or even while studying from their textbook. The primary contribution of this study is that it provides researchers and educators with a starting point for more extensive research and more effective integration of VR technology into the classroom.

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APPENDICES

Appendix A: Rubric for Mayer's 12 Principles of Multimedia Learning

Principles	**Exemplary** **3**	**Proficient** **2**	**Emerging** **1**	**Unsatisfactory** **0**
Signaling	All important information was emphasized	Most of the important information was emphasized	Some important information was emphasized	No important information was emphasized
Redundancy	No redundant material (text not included with narration)	Significantly few redundant materials	Some redundant material was removed, most was not	Overloaded with redundant material
Spatial Continuity	All descriptions was presented close to the pictures	Most the descriptions was presented close to the pictures	Some of descriptions was presented close to the pictures, most was not	None of descriptions was presented close to the pictures
Temporal Continuity	Narration and animation place at the same time	Most of the narration and animation place at the same time	Some of the narration and animation at the same time	No narration and animation were placed at the same time
Segmenting	All the information was segmented	Most of the information was chunked	Some of the information was chunked, most was not	All the information was presented in a long paragraph
Pre-training **(Design-based)**	Navigation was intuitive and learning tools were user friendly-No tutorial sessions needed	Navigation was somewhat intuitive and learning tools were somewhat user friendly	Navigation and learning tools were user friendly- Tutorial sessions were needed	Tutorial sessions were necessary
Personalization	All material was presented conversationally rather than formally	Most of the material was presented conversationally rather than formally	Some of the material was presented conversationally	All material was presented formally rather than conversationally
Voice Principle	All spoken terms was in a human voice rather than a machine voice	Most of the spoken terms was in a human voice rather than a machine voice	Some of the spoken words was in a human voice rather than a machine voice	All the spoken terms were in a machine voice.

Appendix A (continued)

Pre-training (Design-based)	Navigation was intuitive and learning tools were user friendly-No tutorial sessions needed	Navigation was somewhat intuitive and learning tools were somewhat user friendly	Navigation and learning tools were user friendly- Tutorial sessions were needed	Tutorial sessions were necessary
Personalization	All material was presented conversationally rather than formally	Most of the material was presented conversationally rather than formally	Some of the material was presented conversationally	All material was presented formally rather than conversationally
Voice Principle	All spoken terms was in a human voice rather than a machine voice	Most of the spoken terms was in a human voice rather than a machine voice	Some of the spoken words was in a human voice rather than a machine voice	All the spoken terms were in a machine voice.

Appendix B: Demographic Survey

What is your age?

☐ 18-22 years old

☐ 23-27 years old

☐ 28-35 years old

What class standing are you at Midway University?

☐ Freshman

☐ Sophomore

☐ Junior

☐ Senior

How often do you play Video Games?

☐ Once a day

☐ Once a week

☐ Once a month

☐ Once a year

☐ Never

Have you experienced Virtual Reality with a head mounted display?

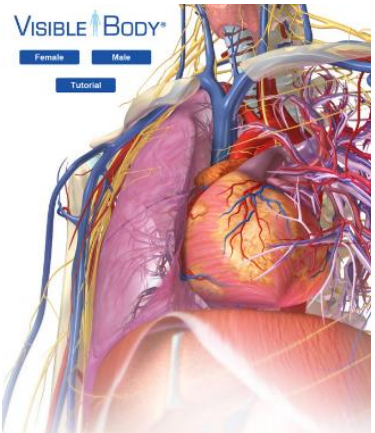
1 – Never

2 – Almost never

3 – Occasionally/Sometimes

4 – Almost every time

5 – Every time



Have you studied Human Anatomy through three-dimensional (3D) digital models?

1 – Never

2 – Almost never

3 – Occasionally/Sometimes

4 – Almost every time

5 – Always

Appendix C: Testing Instrument Pre-Post Test

1. Draw the mitral valve and show 4 components on your diagram (4 points)

    a. Mitral annulus
    b. Mitral leaflets
    c. Chordae tendineae
    d. Papillary muscles

Mitral Stenosis (MS)

2. What is Mitral Stenosis (MS)? (1 point)

3. List 2 causes of MS? (2 points)

4. List 3 symptoms that a patient with MS might experience (3 points)

5. List 3 complications that MS can lead (3 points)

6. List 2 medicine treatments that a patient with mitral stenosis can be prescribed (2 points)

Mitral Regurgitation (MR)

7. What is Mitral Regurgitation (MR)? (1 point)

8. List 3 causes of MR (3 points)

9. List 3 symptoms that a patient with MR might experience (3 points)

10. List 3 complications that MR can lead (3 points)

11. List 2 medicine treatments that a patient with MR can be prescribed (2 points)

Clinical Reasoning

12. A 68-year-old woman is scheduled to undergo mitral valve replacement for severe mitral stenosis and mitral regurgitation. Although the diagnosis was made during childhood, she did not have any symptoms until 4 years ago. Recently, she noticed increased symptoms. During the initial interview with the nice lady, as a nurse what would you most likely learn that the client's childhood health history? (3 points)

____

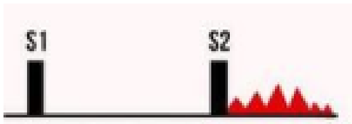
13. A 70-year-old woman is admitted to a local hospital emergency department with acute chronic heart failure for the third time in the past year. She complains of increased swelling of her legs. This was preceded by palpitations lasting a few minutes and occurring several times daily. She had been diagnosed with mitral valve prolapse as a teenager.

Based on her complains and symptoms what would be your initial diagnosis related to her mitral valve? (3 points)

____

14. Which one describes the heart sound that a patient diagnosed with mitral stenosis? (1 point)

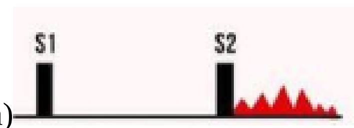
a) 

b) 

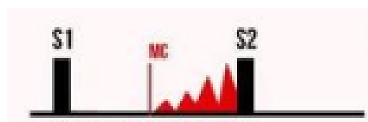
c) 

d) 

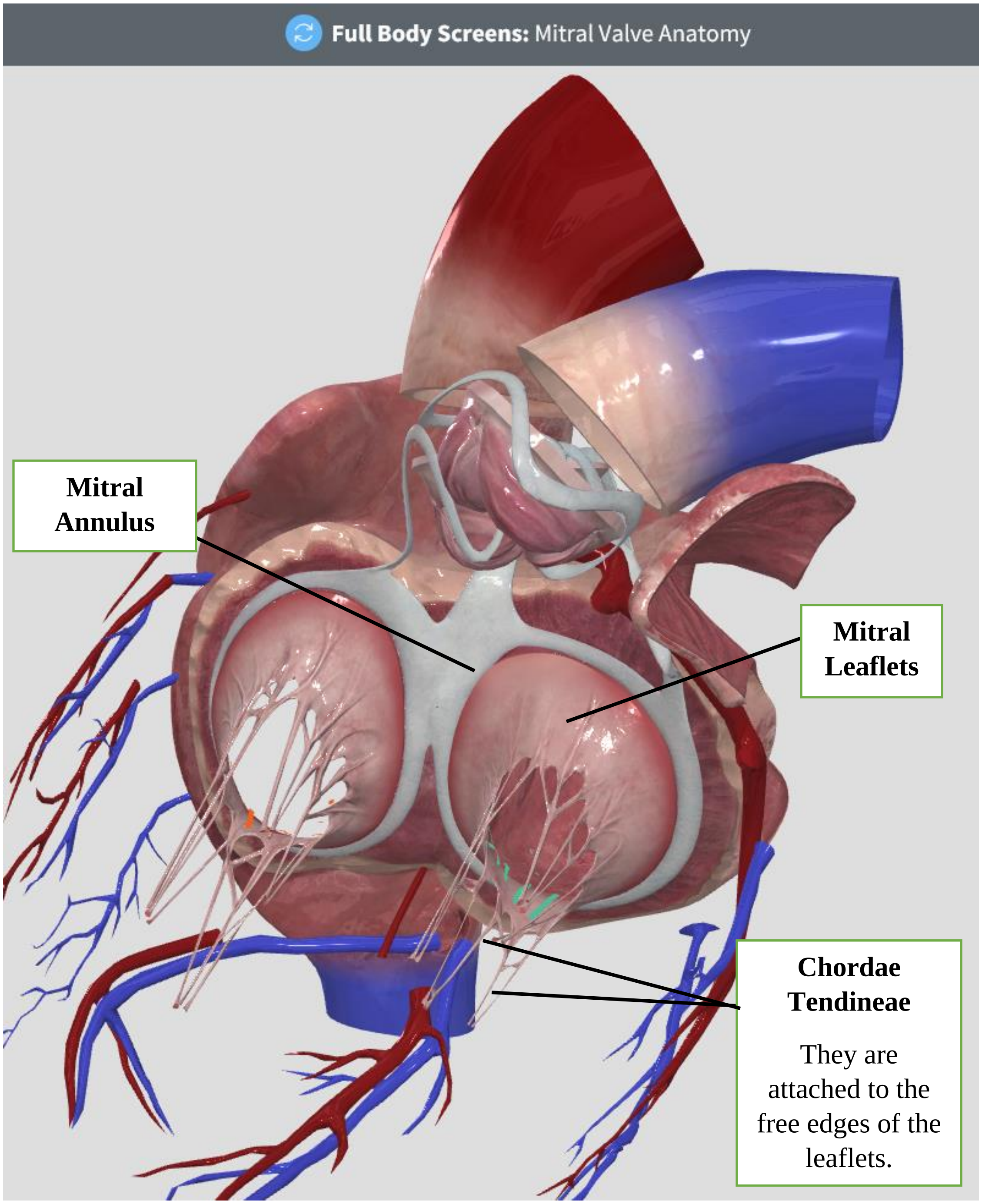
15. Which one describes the heart sound that a patient diagnosed with mitral regurgitation? (1 point)

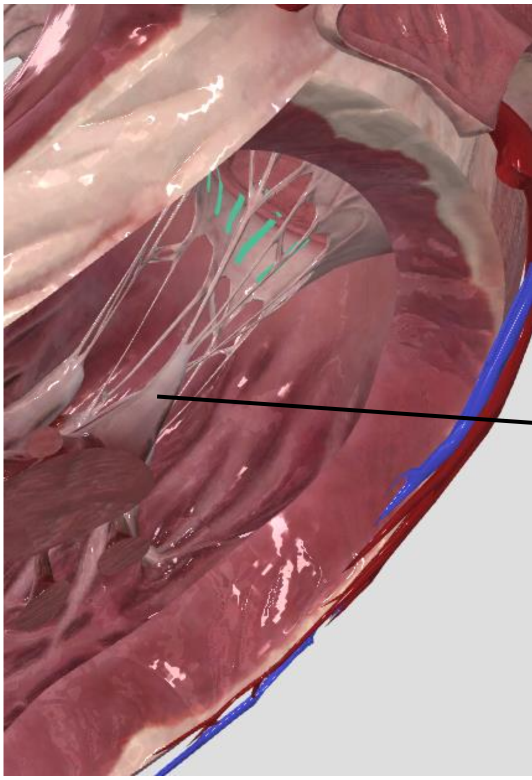
a) 

c) 

d) 

Appendix D: Reading Notes for Control Group


Full Body Screens: Mitral Valve Anatomy
Mitral Annulus
Mitral Leaflets
Chordae Tendineae
They are attached to the free edges of the leaflets.



Papillary Muscles

They are arising from the ventricular walls and joining with the chordae tendineae. During ventricular contraction, any blood moving backwards towards the atrium pulls the leaflets closed, increasing the tension in the papillary muscles and the chordae tendineae.

Now you will read two dialogues on case studies describing two mitral valvular diseases: Mitral Valve Stenosis and Regurgitation.

Case Study: Mitral Stenosis

Angela Nurse**:** Hello, I am Angela. I am a cardiac nurse at Frankfort Medical center. Two days ago, Mrs. Smith was admitted to our hospital with several complaints including chest pain, irregular heartbeats, difficulty in breathing and feeling fatigued. I immediately listened to her heart and found there is a diastolic opening snap (OS) that corresponds to the opening of the mitral valve, followed by decrescendo murmur.

Heart Sound of Mitral Stenosis

Although the signs clearly have shown Mitral stenosis, I wanted to do further tests to make the right diagnosis and assessment. Upon the 3D echocardiogram, she has a severe mitral stenosis. Now, Mary, my colleague, is with her explaining her health conditions.

Mary Nurse: Good Morning, Mrs. Smith, how are you feeling this morning?

Mrs. Smith*:* The medications that I took yesterday seemed to help me with the chest pain. What is happening?

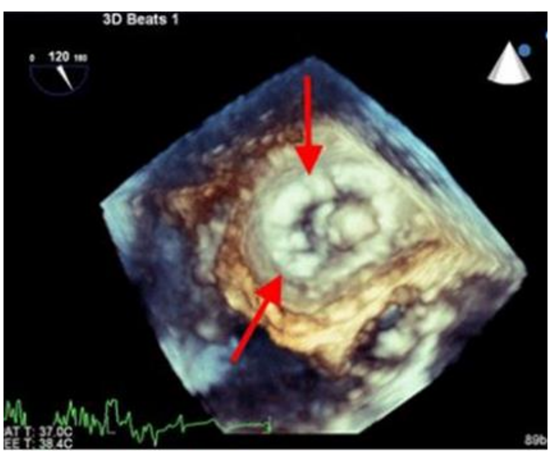
Mary Nurse: Mrs. Smith, one of the valves is narrowing. This abnormal valve doesn't open properly, blocking blood flow into the main pumping chamber of your left chamber. We call it Mitral valve stenosis. This condition makes you tired and short of breath, among other problems such as chest pain. One of the pills that you have taken is a diuretic or so called 'water pill.'

Mrs. Smith: Water pill?

Mary Nurse*:* Yes, they are for reducing the amount of blood and other fluids that accumulate in your lungs. And also you have other complaints such as irregular heartbeats. In this case, you are taking beta blockers, and these help your heart beat more slowly and with less force, thereby reducing your blood pressure. You are also taking an anticoagulation drug to prevent a possible blood clot.

Mrs. Smith*:* As I said, I have been feeling a little bit better with the drugs. When can I be discharged then?

Mary Nurse**:** I am afraid your valve condition will not go away with these medicines. These medicines are just to mitigate the symptoms that are caused by your narrowing valve. A normal valve area is between 4-6 centimeters. Yours is 2.5.



Mrs. Smith: Well my valve looks like a fish mouth. Funny!

Mary Nurse*:* Actually it is a pretty accurate analogy. We also call it fish mouth-mitral stenosis. Did you have strep infections when you were a child, Mrs. Smith?

Mrs. Smith: No, why?

Mary Nurse: One of the common causes of your condition is related to rheumatic fever during childhood. In your case, the main cause can be calcium deposits that have built up. Your mitral valve sits on a kind of ring and this ring is typically flexible. However, as we get older, due to the calcium accumulation on this ring, it becomes less flexible. It is okay, you are in good hands.

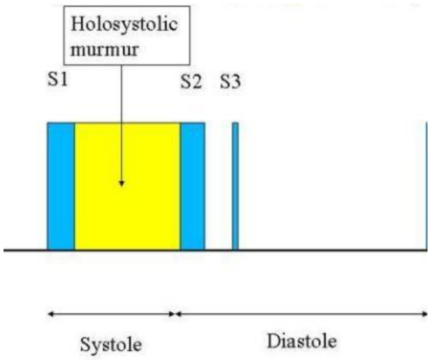
Nurse Angela: As you listened to Mrs. Smith's case, you should be able to describe symptoms, causes and medical management of mitral stenosis. Let's wrap up her health situation. Mrs. Smith is 76, and due to her age, her mitral valve stenosis is due to mitral annulus calcification. The pathophysiology is thought to be an absence of normal annular dilatation during diastole, resulting in functional mitral stenosis. Another cause of mitral stenosis is rheumatic fever developed in childhood. Common symptoms include fatigue, dyspnea, atrial fibrillation, chest pain and pulmonary edema. Diuretics are prescribed to treat the symptoms of pulmonary edema. If atrial fibrillation has developed, a beta blocker, a calcium channel blocker or digoxin may be used to improve diastolic left ventricle filling. Chronic anticoagulation therapy to prevent a blood clot is recommended for patients with mitral stenosis. I recently talked to Mrs. Smith and found her rather uncomfortable—she is worrying about the replacement of her valve. But what if we don't?

A narrowed mitral valve can have serious complications if it is left untreated. It interferes with blood flow. This can cause pressure to build in her lungs, leading to fluid accumulation. The fluid buildup strains the right side of her heart, leading to right heart failure. When blood and fluid back up into your lungs, it can cause a condition known as pulmonary edema. The pressure buildup of mitral valve stenosis also results in enlargement of her heart's upper left atrium. The stretching and enlargement of your heart's left atrium may lead to atrial fibrillation.

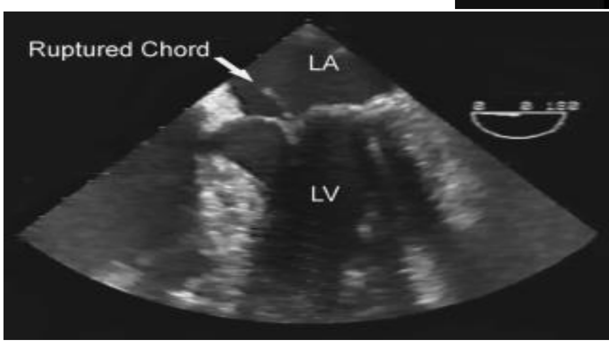
Case Study: Mitral Regurgitation

Nurse Angela: Hello again. In this case study, we will learn one of the common heart valve diseases and its symptoms, causes, medical treatment and complications. This is

Mr. Harmon. He is feeling extremely fatigued. He was admitted to our emergency room yesterday with difficulty in breathing, having swollen ankles and feeling fatigued and lightheaded. I heard a holosystolic murmur. Beginning at the first heart sound and continuing through the second heart sound.



We also examined his 3D echocardiogram of his mitral valve. According to the test result as you see, Mr. Harmon is having mitral regurgitation or mitral insufficient. Now I am on my way to talk to him.



Nurse Angela: Good afternoon Mr. Harmon. How are you feeling?

Mr. Harmon: Feeling tired as if I worked out in the field for hours. What is happening?

Nurse Angela: Here are inflow valves and outflow valves that serve a similar function to valves in the cylinders of a car — or a water pump on the filter in a pool. Very simply, only two things can go wrong with a valve. It won't open easily or becomes clogged or it won't close appropriately (regurgitation). In you case your valve doesn't close as it should which allows blood to partially flow backwards towards the lungs and leads to a form of heart failure.

Mr. Harmon: Ohh… that is why I am feeling so tired?

Nurse Angela: Yes, your heart is not working as efficiently as it should. This results from less blood being pumped forward and requiring a higher "workload" on the heart. That is why you feel tired. Also your heart becomes "overloaded" because it is receiving the usual load of circulating blood from the lungs plus the blood that leaked back into the lungs. This can result in permanent damage to the heart. You told me that you are having trouble breathing. Well the back-up of blood into your lungs can cause them to get soggy like a wet sponge. We call this pulmonary edema or congestive heart failure. It makes it hard for your lungs to exchange oxygen and carbon dioxide and therefore you are having difficulty in breathing.

Mr. Harmon: Oh my... so why is my valve not closing properly?

Nurse Angela: When I read your information, I found out that you served in the Army and you were a paratrooper. Let me take you to those years when you were paratrooper. Our valve resembles a parachute. The valve flaps are the parachute, the parachute cords are the chordae tendineae and you, as a paratrooper, are the papillary muscle. In your situation one of your parachute cords is damaged and not working.

Mr. Harmon: It is a serious problem.

Nurse Angela: Yes, I am afraid so. Right now you are taking some medicines. But I am here to talk to you about your heart surgery and its procedure…

Nurse Angela: Mr. Harmon's case is more serious and needs surgical intervention soon. Let's wrap up what Mitral regurgitation is, its causes and medical management. In mitral valve regurgitation, the valve doesn't close tightly, causing blood to leak backward into the left atrium. If it is acute, as in Mr. Harmon's case, it usually occurs with a spontaneous chordae tendineae rupture causing a sudden volume overload on an unprepared left ventricle and left atrium. Increased left ventricular filling pressures, combined with the transfer of blood from the left ventricle to the left atrium during systole, results in increased left atrial pressures. This increased pressure is transmitted to the lungs resulting in acute pulmonary edema and dyspnea.

There are other causes that lead to mitral regurgitation. The most common one is Mitral valve prolapse. In this condition, the mitral valve's leaflets bulge back into the left atrium during the heart's contraction. Rheumatic fever, Mitral Annular Calcification, degeneration of mitral leaf and left ventricle dilatation are other chronic mitral regurgitation causes. As you listened, Mr. Harmon came to the emergency room feeling extremely fatigued and having difficulty breathing. Other symptoms are heart palpitation, swollen ankles and pulmonary edema.

Now he is being given intravenous diuretics to relieve pulmonary edema; vasodilators to reduce the resistance to forward flow; and warfarin to prevent blood clots. His surgery will be scheduled next week. What if he did not have the surgery? Severe mitral valve regurgitation places an extra strain on his heart because, with blood pumping backward, there is less blood going forward with each beat. The left ventricle gets bigger and, if untreated, weakens. This can cause heart failure. Also, pressure builds in his lungs, which we call pulmonary hypertension.

Lastly, the stretching and enlargement of his heart's left atrium may also lead to this heart rhythm irregularity which we call atrial fibrillation. This can cause blood clots, which can break loose from his heart and travel to other parts of his body, causing serious problems, such as a stroke if a clot blocks a blood vessel in his brain. That is why we prescribed him warfarin.

This is the end of this learning session. Thank you for joining me. Hope to see you again.

Appendix E: Cognitive Load Rating Scale

Cognitive Load Rating Scale

How difficult was the learning human heart anatomical structure for you?

1 not at all	2 just a little bit	3 somewhat	4 pretty much	5 very	6 extremely

How difficult was it to learn with the material?

1 not at all	2 just a little bit	3 somewhat	4 pretty much	5 very	6 extremely

How much did you concentrate during learning?

1 not at all	2 just a little bit	3 somewhat	4 pretty much	5 very	6 extremely

Overall-- In studying the human heart I invested…..

1. Very, very low mental effort
2. Very low mental effort
3. Low mental effort
4. Rather low mental effort
5. Neither low nor high mental effort
6. Rather high mental effort
7. High mental effort
8. Very high mental effort
9. Very, very high mental effort