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Evaluating the Effects of a Flipped Classroom Compared to a Traditional Classroom on Retention of Information and Course Engagement in a Radiation Safety Course

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Evaluating the Effects of a Flipped Classroom Compared to a Traditional Classroom on
Retention of Information and Course Engagement in a Radiation Safety Course

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of
Philosophy at Virginia Commonwealth University.

by

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Abstract

EVALUATING THE EFFECTS OF A FLIPPED CLASSROOM COMPARED TO A TRADITIONAL CLASSROOM ON RETENTION OF INFORMATION AND COURSE ENGAGEMENT IN A RADIATION SAFETY COURSE

By Stephanie Anne McHugh, MBA

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

Virginia Commonwealth University, 2018

Major Director: Timmerie Cohen, PhD, Clinical Coordinator-Radiation Therapy, Department of Radiation Sciences

The purpose of this study was to compare the flipped and traditional classroom pedagogies in relation to retention, critical thinking skills, and student engagement as measured by the multiple choice and short answer questions on the final exams, course evaluations, and CUCEI scores. Radiologic technologists, nuclear medicine technologists, and radiation therapists play vital roles in both diagnostic and therapeutic applications in patient care. Employers today are seeking graduates who know more, are better able to apply this knowledge, and solve more challenging problems (McLean, et al., 2016). This quasi-experimental study aimed to compare the flipped and traditional classroom pedagogies at increasing retention and critical thinking skills, as measured by final exams, and student engagement, as measured by course evaluations. The model was delivered and assessed for 61 radiation science students at Virginia Commonwealth University's College of Health Professions Radiation Science program. Based

on numerical results for the final exam and College and University Classroom Environment Inventory (CUCEI), no significant difference in critical thinking skills, retention, or student engagement was observed between the flipped and traditional pedagogies for radiation science students. For the purpose of this study, pedagogy referred to the application of a method of teaching, the flipped or traditional classroom, in relation to constructs of the Cognitive Learning Theory (CLT). For this study retention is defined as the amount of information that a student can retain for the length of a semester, 15 weeks. Critical thinking is defined as the students' successful ability to take several concepts and put them together to make an analysis of a given situation. Student engagement for this study was defined as the level of attention and interest for the material being taught. Further analysis of the results indicated that the demographics (gender, age, years in college, and race) did not affect preference for flipped or traditional pedagogy. Statistically significant results on the CUCEI subcategories of satisfaction and innovation indicate that students found the flipped classroom more enjoyable and innovative than the traditional classroom. These results support professor exploration of different teaching pedagogies that they are comfortable with. Further studies are needed to ensure model validity and generalizability of findings.

Keywords: flipped classroom, pedagogy, cognitive learning theory, retention, engagement, critical thinking

Chapter 1 – Introduction

Overview

Educators strive to both instill knowledge within their students and for them to retain that knowledge throughout their careers. While retaining information is of primary importance, enjoying the experience of learning is also important. Retention and student engagement with the class are especially important for students in the allied health fields, as they will one day play a vital role in the delivery of health care. Radiologic sciences (Radiologic Technology, Nuclear Medicine, and Radiation Therapy) are vital to the delivery of therapeutic radiation in health care. Radiologic imaging and Nuclear Medicine allow for the diagnosis of maladies and disease, and help physicians monitor and diagnosis physiologic disorders. Radiation therapy is a common treatment modality for cancer and requires a high degree of precision. With such important roles in both diagnostic and therapeutic applications, it is crucial that students in the radiologic sciences are properly prepared for their future careers. See Table 1 for a breakdown of the radiologic science modalities.

The American Registry of Radiologic Technologists (ARRT) offers a certification exam that can gauge learned content. However, it is not perfect at gauging how prepared students of the radiologic sciences are for future careers. The radiologic sciences would benefit from exploring educational methods that connect content and the workplace.

Table 1

The Radiologic Science Professions Tools And Purposes Explanation

Profession	Diagnostic/Treatment tool	Primary purpose
Diagnostic Radiology		
	MRI	Detailed soft tissue and organ analysis.
	CT	Create cross-sectional images of bones, blood vessels and soft tissue.
	Diagnostic X-ray	Detect abnormalities in the body, especially for bones.
	Ultrasound	Diagnosis problems with soft tissue and organ without radiation.
	Mammography	To detect breast abnormalities.
	Fluoroscopy	Diagnosis of alimentary canal issues through live imaging.
Nuclear Medicine		
	Bone Scans	Diagnosis and track diseases of the bone.
	Cardiac Imaging	Assess the overall health and function of the heart and related vessels.
	PET Scan	With the aid of radioactive tracers, determines the functionality of tissue and organs.
Radiation Therapy		
	Medical Dosimetry	Personnel that determines the proper amount of radiation to use during radiation therapy treatments.
	Brachytherapy	Uses the direct placement of radioactive implants into the cancerous tumor.
	High (external beam) Radiation Doses	Treatment of cancers.

This seminal study explored if changing the way radiation science professionals educate their students affects student engagement, retention of the material taught, and critical thinking skills. According to Clark (2014), the most common method of delivering content in radiation science courses is the traditional lecture style. For this study, the traditional lecture style served as the control group while the intervention was the flipped classroom (experimental group). Flipped and traditional classroom teaching methods were studied during the Spring Radiation Safety course. The traditional classroom was defined as a teaching pedagogy that primarily uses class time to deliver content and assigns homework to supplement the material.

Flipped classrooms allow more flexibility to change lesson plans (Butzler, 2014; Simpson & Richards, 2015), accommodate new technologies, techniques, and safety requirements just as the student will experience once employed. Flipped classrooms also give students the opportunity to practice, apply, and analyze, thus helping to develop critical thinking, retention, and application abilities (O’Flaherty & Phillips, 2015; O’Connor, et al., 2016; McLean, Attardi, Faden & Goldszmidt, 2016; Rotellar & Cain, 2016; Koo, et al., 2016).

The purpose of this study was to compare the flipped and traditional classroom pedagogies in relation to retention, critical thinking skills, and student engagement as measured by the multiple choice and short answer questions on the final exams, course evaluations, and CUCEI scores. This study compared class evaluations, final exam multiple choice and short answer questions between the 2016 and 2017 classes at Virginia Commonwealth University (VCU). Class evaluations were used to determine if students were more satisfied with their instruction in the flipped classroom than the traditional classroom, with the same course content. Retention and critical thinking skills were analyzed using the final exam multiple choice and short answer questions to determine if the flipped classroom was more effective at improving

these skills than the traditional classroom. This was done to explore potential impacts of changing teaching styles in radiologic technology schools. The findings did not support that students in the flipped classroom were better able to think critically, improve retention, or had increased student engagement. These results indicate that teaching styles do not have an impact on these skills in the studied radiation safety class.

The Cognitive Learning Theory (CLT) was used as the theoretical underpinnings of this study. The tenets of CLT are 1) how students acquire information, 2) the way the brain processes that information, and 3) how engaged the students perform during the process (Brandt, 1996; Yilmaz, 2011; Kay & Kibble, 2016; Aliakbari, Parvin, Heidari, & Haghani, 2016; Moore, Leamon, Cox, & Servis, 2002; Williamson, Gunderman, Cohen, & Frank, 2014; Khalil & Elkhider, 2016; McGilly, 1994). The independent variable was teaching pedagogy. The flipped classroom was the experimental environment and the traditional pedagogy was the control environment. Creating an environment that is conducive to most learning styles is critical in CLT and the flipped classroom. The dependent variables were: retention of information, critical thinking skills, and student engagement. Retention of information and critical thinking skills measure how the brain process information. The final exam multiple choice and short answer questions measured the dependent variables of retention of information and critical thinking skills, respectively. Student engagement measured the level at which the students were engaged during class. The College and University Classroom Environment Inventory (CUCEI) and course evaluations were used to measure the dependent variable student engagement. For this study, brain processing referred to the processes by which the brain acquires, interprets, and stores information. How the brain processes information determines retention, and the connections that students make to previous material determine how well they can apply it. Student engagement,

which could lead to increased satisfaction, is critical in CLT. Student engagement for this study was defined as the level of attention and interest for the material being taught.

Problem Statement

The suspected inability of students to retain what they are learning in class and their ability to apply it in their future careers should be examined and corrected if necessary (Smith, 2014; McLaughlin, et al., 2014; Sharma, Lau, Doherty, & Harbutt, 2014; McGilly, 1994). According to Bloom's Taxonomy, there are six domains in the hierarchy of thought processes, beginning with the lowest process, remembering, followed by understanding, applying, analyzing, evaluating, and culminating with creating (Morton & Colbert-Getz, 2016; Short, 2014; Kahlil and Elkhider, 2016). The traditional lecture style, based on the behavioral theory, focuses on the two lowest domains, remembering and understanding. These levels of thinking involve skills such as: know, identify, recall, memorize, restate, locate, explain, and review (Hessler, 2016). However, in order for students to excel in their future careers they need to utilize the higher domains of apply, analyze, evaluate, and create. The higher order domains involve thinking skills related to: demonstrate, organize, compare, contrast, deduce, infer, design, and invent. The flipped classroom, based on cognitive or constructivist learning theories, provides time for these higher order domains to become the focus of class by allowing students to complete the lecture material at home (O'Flaherty & Phillips, 2015; Mortensen & Nicholson, 2015; Gilboy, Heinerichs, & Pazzaglia, 2015). The purpose of this study was to compare the flipped and traditional classroom pedagogies in relation to retention, critical thinking skills, and student engagement as measured by the multiple choice and short answer questions on the final exams, course evaluations, and CUCEI scores. For the purpose of this study, pedagogy referred to the application of a method of teaching, the flipped or traditional classroom, in relation to constructs of the Cognitive Learning Theory (CLT). This study evaluated the CLT constructs,

environment, and how the brain processes information, by measuring student retention and critical thinking along with student engagement as measured by course evaluations.

The flipped classroom is so named because it flips around that which is traditionally completed as homework with that which is traditionally accomplished in the classroom. Lecture material is explored via videos or readings outside of class while in-class time is spent completing activities relevant to those assignments done outside the classroom (O’Flaherty & Phillips, 2015; O’Connor, et al., 2016; McLean, et al., 2016; Rotellar & Cain, 2016; Koo, et al., 2016). The pre-recorded video lecture material can be undertaken in a variety of ways; it is most commonly assigned as either reading or watching a pre-recorded lecture followed by a short quiz based on what students watched (Felder, 2012; Gilboy, et al., 2015; Baepler, Walker, & Driessen, 2014). In class, time is spent doing hands-on, thought-provoking application activities that engage students with what was assigned as homework (Roach, 2014; Hao, 2016; Rotellar & Cain, 2016) to deepen students’ understanding of the information and clarify any questions that they may have had from the readings or videos (Butzler, 2014; Clark, 2014). This platform may give professors more time to spend with their students, engaging them in the critical thinking and problem solving skills needed for careers in Radiation Science (Smith, 2014; Gilboy, et al., 2015; Sharma, et al., 2015; Huang & Hong, 2015).

The flipped classroom technique is in contrast to the traditional lecture style by which students receive the majority of the course content through lecture provided in a face-to-face format (Chen, 2016; Hessler, 2016; Gillispie, 2016; Mattis, 2015; Clark, 2014; Liebert, Mazer, Bereknyei Merrell, Lin, & Lau, 2016; Hao, 2016). Lecture typically consists of students taking notes as a professor dictates the lesson either with or without a visual aid (Liebert, Mazer, et al., 2016; Hessler, 2016; Schultz, Duffield, Rasmussen & Wageman, 2014). Students leave the

traditional classroom setting with a range of homework assignments consisting of assigned reading and answering corresponding questions, writing a paper, or doing worksheets (O'Connor, et al., 2016; Schultz, et al., 2014; Hessler, 2016). The common purpose of these assignments is typically to provide a review of the information that was presented in class (Hessler, 2016; Schultz, et al., 2014). A potential problem with this scenario is that these types of assignments do not require the critical thinking and problem solving skills (Clark, 2014; Felder, 2012; O'Connor, et al., 2016) students need to excel.

Purpose Statement

The purpose of this study was to compare the flipped and traditional classroom pedagogies in relation to retention, critical thinking skills, and student engagement as measured by the multiple choice and short answer questions on the final exams, course evaluations, and CUCEI scores. Final exam multiple choice scores measured student retention and final exam short answer questions measured critical thinking skills. For both the control and experimental group, the final exam consisted of multiple choice and real-life scenario, short answer, questions that required the students to recall information from multiple lessons. The study also compared flipped and traditional classroom pedagogies student engagement ratings, as measured by course evaluations. Engagement scores were determined using end of the semester course evaluations and College and University Classroom Environment Inventory (CUCEI) that students completed.

The research questions which the seminal study addressed were:

1. Does a change in teaching pedagogy in a Radiation Safety course make a difference in retention of information, critical thinking, and student engagement?
2. Do age, gender, years in college, and race impact how students view the flipped classroom?

Theoretical Framework

There are three main learning theories: behaviorism, cognitivism, and constructivism. Each theory examines different ways that students learn. These competing frameworks shape different teaching pedagogies. Behaviorism explores how students respond to different stimuli in order to give an expected response (Williamson, et al., 2014). How the brain processes the information is not important; the outcome of a correct or incorrect answer and what stimuli produced the proper response is the goal in behaviorism (Yilmaz, 2011; Brandt, 1996; Williamson, et al., 2014). Under the basic tenets of constructivism, in order for students to gain information, they need to reconstruct the information in a way that makes sense to them in relation to what they already know (Gilboy, et al., 2015). In this theory of learning, students may all receive the same information, but may understand it differently (Koeing, 2010). Cognitivism focuses on how well students process and organize the new material with what they already know, predicting the behavior of students (Nalliah & Idris, 2014). The constructs of this theory describe how people retain information and are able to access it and connect it to new things during the learning process (Pinker, 2009).

The flipped classroom pedagogy utilizes cognitive learning theory, while the traditional classroom pedagogy is based on behaviorism. In the classroom, behaviorism leads to a professor-centered approach that focuses on observable behaviors and performance but does not take into consideration how the brain processes the information (Brandt, 1996; Williamson, et al., 2014). Meanwhile, cognitivism manifests itself as a student-centered approach whose primary focus is how the brain processes information and how students use that information (McGilly, 1994). Cognitivism also emphasizes the learning environment and utilizes that to improve student focus, which can in turn can help students master independent problem solving (McGilly, 1994; Brandt,

1996). Of the three main learning theories (behaviorism, cognitivism, and constructivism) the most recent is constructivism, a branch of cognitivism. While the two share many similarities, the defining difference in the classroom is that cognitivism is guided by the professor and constructivism is self-guided learning by the student (Ertmer & Newby, 2013). For this study, the flipped classroom will follow the professor-guided method.

The research question and corresponding variables are connected with CLT. The independent variable, pedagogy, had two groups: flipped and traditional classrooms. The flipped classroom served as the alternative environment to the traditional classroom. The dependent variable retention was measured by the difference in multiple choice scores. The second dependent variable critical thinking skills were measured by the difference in the short answer scores on the final exam. The third dependent variable, student engagement, was measured through course evaluations.

Significance of Study

Research reflects that students' ability to concentrate and focus begins to fade after approximately ten to fifteen minutes (Das & Sarkar, 2015; Gilboy, et al., 2015; Smith, 2014). With the flipped classroom, the professor aims to actively engage students during class with a variety of activities that relate to the previous homework assignment. Delivering lecture content via videos or readings allows for more class time to be devoted to these various activities. One activity is article analysis; this gives students the opportunity to determine how to connect to what is happening in the class and the workplace. Another is research to see how radiation safety equipment has changed over the years and why those changes have been implemented. Projects are also used to demonstrate that students understand how to utilize radiation safety principles in different situations. Using case studies can help examine faulty practices accompanied by an

analysis of what should change (Das & Sarkar, 2015; Tune, Sturek, & Basile, 2013; Strayer, 2012). By keeping students engaged, they not only learn the information, but also retain it more proficiently than if they had been taught using primarily lecture, as in a traditional class (Mattis, 2015; Tune, et al., 2013; Smith, 2014). When students are more engaged during class they can focus for longer periods of time allowing for increased retention (Mattis, 2015; Tune, et al., 2013). According to Gilboy, Heinerichs, and Pazzaglia (2015), students only retain about twenty percent of the information taught in traditional lecture style (McLaughlin, et al., 2014). The traditional lecture style does not involve critical thinking, complex reasoning skills, or effective retention of information that is important for students in future courses and careers (Belfi, Bartolotta, Giambone, Davi, & Min, 2015; Felder, 2012). To measure critical thinking and complex reasoning skills in this study, both formative and summative assessments were used throughout the course. Questions on the final exam required students to apply their cumulative knowledge from the course using critical thinking and complex reasoning skills to answer questions properly. Grading of essay questions used a rubric for each question to limit bias and subjective scoring; this also increased interrater reliability. For this study retention is defined as the amount of information that a student can retain for the length of a semester, 15 weeks. Critical thinking is defined as the students' successful ability to take several concepts and put them together to make an analysis of a given situation.

Using the flipped classroom, professors are better able to assist those who are struggling with a concept, give students more one-on-one attention, and encourage students to be in charge of their learning (Simpson & Richards, 2015; Tune, et al., 2013; Das & Sarkar, 2015). Students need to be responsible and finish assigned readings and videos at home. Completion of the assigned work is checked for to help provide extrinsic motivation for completion; however, a

large part of the motivation need for a flipped classroom is intrinsic. Students need to show this same motivation in class by asking for clarification when they do not understand a part of the lesson. By students asking questions about what they are struggling with, the professor can personalize the lessons for that session. In situations where students can learn the basic content more efficiently, they are also able to develop better critical thinking and problem solving skills. With the flipped classroom, professors may develop lesson plans that fit the various learning styles of those in class. When a professor can easily adapt lesson plans by adjusting the activities done in class to meet student needs, students are able to improve their learning (Tune, et al., 2013; Mattis, 2015).

Having the ability to adjust the delivery mechanism efficiently in a field that is as rapidly changing as radiologic technology is invaluable (Baepler, et al., 2014; Roach, 2014). Using the flipped classroom helps professors in radiation science programs to adapt their curriculums with minimal amounts of time or effort quickly, *after* the initial design (Baepler, et al., 2014; Roach, 2014). Safety and patient electronic record regulations change often; adapting an activity that reflects these changes takes less time than preparing new slides or lecture material (Fulton, 2012; Tune, et al., 2013). Having students complete an activity regarding the changes in equipment or electronic medical records will help the students retain the information more than had they just been told about the changes in equipment or electronic medical record requirements.

Summary of Data Sources

A primary data source was used to test the hypotheses proposed for this study. The subjects for this study were all students in the College of Health Professions Radiation Science program at VCU required to take Radiation Safety; these students are primarily first year students in their respective disciplines. Both the Spring 2016 and 2017 sections had identical

content and assessment tools. The subjects for the control group consisted of those students enrolled during the Spring 2016 course, and the experimental group was formed from those enrolled in the Spring 2017 course. Statistical significance of the findings were evaluated by assessing the scores from the 2016 and 2017 classes on the multiple choice and short answer questions of the final exams and course evaluations as measured by the CUCI. Despite this seminal study being conducted at a single institution with a single professor, this research still has the potential to provide an initial assessment for radiation science and apply to other radiologic technology programs (Munson & Pierce, 2015; McLean, et al., 2016). The radiation safety course was chosen as the course to study for its importance in all of the radiation science fields. Since radiation therapy, diagnostic radiology, and nuclear medicine require the use of radiation to obtain the needed imagery it is vital that students understand the importance of radiation safety for both themselves and their future patients. The importance of radiation safety in a variety of disciplines helps make these findings more generalizable. This framework of Radiation Science students in the United States of America in the state of Virginia has yet to be used in a published flipped classroom study. Other healthcare professions (radiology assistants, physician assistants, and physicians), including other allied health professions (nursing, pharmacy, dental hygienists), have successfully implemented the flipped classroom pedagogy (Hantla, 2014; Liebert, Lin, Mazer, Bereknyei, & Lau, 2016; Thai, De Wever & Valcke, 2017). The threats to reliability and validity will be discussed in Chapter 3 – Methods.

Organization of the Study

This seminal study was conducted to gain a deeper understanding of how pedagogy plays a role in retention, critical thinking, and student engagement. Upon determining the two pedagogies to be compared, traditional and flipped classrooms, the curriculum of the radiation

safety course was analyzed. Objectives were defined and compared to the chapters being covered in the class. Alterations to the course content were made, before the start of the 2016 spring semester, to align more closely with the defined objectives. After clearly identifying the content to be covered, the activities for the flipped classroom were developed and new lecture material was prepared for the traditional classroom. Once the classes were prepared, a survey was sought to identify changes in student engagement.

The CUCEI, a student engagement survey, has validation data available for two samples and includes information about each scale's internal consistency (Cronbach's alpha reliability) and discriminant validity (mean correlation of a scale with the other six scales). The first sample consisted of 372 people in 30 college and university classes (Fraser, Treagust, & Dennis, 1986). The second sample consisted of 742 students in 62 classes (Fraser, Williamson, & Tobin, 1987). The alpha coefficients for different CUCEI scales ranged from 0.70 to 0.90 for the first sample. The corresponding ranges for the second sample were 0.70 to 0.87 (Fraser, 1998; Fraser et al., 1986; Strayer, 2012). Overall, each of the seven categories (personalization, involvement, student cohesiveness, satisfaction, task orientation, innovation, and individualization) has its own mean ranging from 4.83-3.21 and a standard deviation of 1-41 (Strayer, 2012). According to Fisher and Parkinson (1998), these values suggest that each CUCEI scale displays satisfactory internal consistency. The discriminant validity ranged from 0.34 to 0.47, for the first sample, and from 0.23 to 0.49 for the second. This indicates satisfactory discriminant validity and suggests that the CUCEI measures distinct, although somewhat overlapping aspects, of the learning environment (Fraser, 1998; Fraser et al., 1986). Due to the needs of the study and the close fit of the CUCEI, no other surveys were considered. As a result, the CUCEI was determined to be the best fit for this seminal study. The CUCEI was slightly altered to account for questions that

already appeared in the course evaluations for VCU, per VCU policy. The added questions were not scored as a part of the engagement measure. The cognitive learning theory was found to be the best fit not only for the study, but also with the CUCEI. A checklist was adapted to determine that the flipped classroom was following pre-determined qualifications for flipped classrooms.

In order to assess retention and critical thinking the final exam was chosen as the evaluation tool. Final exams are commonly used to assess the knowledge learned throughout the course (Van der Vleuten, 2000). Multiple choice questions make it a good tool for determining retention and short answer questions requiring students to incorporate several concepts can determine the critical thinking capabilities of students. The final exam that was used had been given over multiple years and aligned with the objectives of the course. Content validity of the final exam was achieved with the alignment of the course objectives (Wass, Van der Vleuten, Shatzer, & Jones, 2001). In a study conducted by Wass, Van der Vleuten, Shatzer, & Jones (2001) the reliability of multiple choice exams was approximately 0.92 and short answer exams was approximately 0.82. The use of the exam over multiple years also attributed to determining that the final exam was reliable (Van der Vleuten, 2000).

After compiling all the evaluations and ensuring that the content was properly prepared, implementation of traditional classroom began with the Spring 2016 radiation safety course. The flipped classroom was then implemented in the Spring 2017 radiation safety course.

This introductory chapter covered the significant aims of this study, followed by the purpose, in addition to a brief introduction of the theoretical framework. The chapter concludes with the significance of the study and a summary of data sources. A literature review and a methods chapter follow. Chapter 2 summarizes the current literature addressing flipped classrooms and presents a discussion of studies from kindergarten through college related to the

flipped classroom. Chapter 2 also explores the history of learning theories and how CLT applies to the flipped classroom. Finally, Chapter 2 calls attention to gaps in the literature as well. The methods chapter, Chapter 3, includes a detailed description of the specific study components, including research design, population and sample information, interventions, instruments, data collection procedures, and data analysis. Chapter 4 gives a detailed analysis of the results of the study in relationship to the hypotheses. An interpretation of the results and their significance for radiation sciences also appears in Chapter 4. Chapter 5 explores the relevance of the findings and a comparison of the findings to similar studies. The limitations and future directions to take with the study are also discussed.

Summary

Evaluating different teaching methods could help address the gap between what Radiation Safety content students are retaining and what they are being taught in the classroom. Critical thinking and problem solving skills are necessary for students not only to excel in school, but in a clinical setting as well. While the traditional classroom presents the required information that students need to gain, it lacks the higher cognitive domains to develop the critical thinking and problem solving skills that employers are looking for in employees (Ertmer & Newby, 2013; Felder, 2012; McGilly, 1994).

The purpose of this study was to compare the flipped and traditional classroom pedagogies in relation to retention, critical thinking skills, and student engagement as measured by the multiple choice and short answer questions on the final exams, course evaluations, and CUCEI scores. The flipped classroom model utilizes constructs of the CLT while the traditional lecture classroom is based on constructs of behavioral learning theory. The use of the flipped classroom in other allied health professions (nursing, pharmacy, dental hygienists), has been

studied (Hantla, 2014; Liebert, Lin, Mazer, Bereknyei, & Lau, 2016; Thai, De Wever & Valcke, 2017). The flipped classroom in radiation sciences has yet to be explored in a published study.

Chapter 2 - Literature Review

Overview

The proposed study aimed to compare the flipped and traditional classroom pedagogies at increasing retention and critical thinking skills, as measured by final exams, and student engagement, as measured by course evaluations. This study used the cognitive learning theory constructs to support the flipped classroom pedagogy.

The research questions which the seminal study addressed were:

1. Does a change in teaching pedagogy in a Radiation Safety course make a difference in retention of information, critical thinking, and student engagement?
2. Do age, gender, years in college, and race impact how students view the flipped classroom?

Chapter 1 called attention to the importance of critical thinking and problem solving skills for students not only in the classroom, but for life as well. To address these issues, flipped classroom pedagogy was tested against traditional classroom pedagogy. This determined if, based on the multiple choice and short answer questions final exam scores, students in a flipped classroom were better able to think critically and retain more information compared to those in the traditional classroom. Problems on the final exam assessed students' abilities to use critical thinking and problem solving skills based on the information taught throughout the semester. Student engagement was also explored based on end of the semester course surveys.

Chapter 1 also gave a brief overview of cognitive learning theory (CLT), the theoretical framework which the study used. Chapter 1 concluded with a discussion of the data source of undergraduate students enrolled in Radiation Safety through the College of Health Professions Radiation Science program at Virginia Commonwealth University and defined a reference population to consider as a source of the study sample.

Chapter 2 gives a detailed literature review of the three different learning theories: behaviorism, cognitivism, and constructivism. A portion of this chapter is dedicated to rationale behind why this study used cognitivism, specifically CLT. A history of CLT and the flipped classroom is covered. The relationship between the constructs of CLT and the flipped classroom follows. The chapter ends with a discussion on the gaps in knowledge in the flipped classroom and how this study proposes to fill those gaps.

Introduction

Learning theories and pedagogy. The three main learning theories are behaviorism, cognitivism, and constructivism. Flipped classrooms based on constructivism are normally self-paced: students work at their own pace, completing all requirements prior to the end of the allocated timeframe. This study used cognitivism, which means the professor guided the whole class through each lesson.

The cognitive learning theory's constructs support the flipped classroom as an effective teaching method aiming to meet the needs of students regardless of their learning style. By doing so, the flipped classroom gives the opportunity for several different sense memories, memories created from one of the five senses (taste, touch, hearing, smell, and sight), to form. Its flexibility to adjust lesson plans allows lessons to align with the most recent technology. This grants students the opportunity to learn in the type of environment that they find most conducive. The

environment of the flipped classroom allows students to maximize the amount of information they can retain by creating flexibility in where class can be conducted, according to CLT.

The flipped classroom was first developed in 1991 by Mazur, who was teaching high school at the time. To maximize his students' capacity to learn, he began recording his lectures and realized the benefits. He implemented this best practice for all his students. Bergmann and Sams (2012) perfected the flipped classroom and developed it into its current form. With documented success of the flipped classroom in secondary education, professors in higher education explored this new pedagogy. It became especially well-suited for those in health care fields where application and critical thinking skills are crucial to student success (Lage, Platt, & Treglia, 2000 and Frederickson, Reed, & Clifford, 2005).

Theories Related to Learning

Three of the most influential theories which focus on how humans learn are the behavioral, constructivist, and cognitive theories (Williamson, et al., 2014). Each theory examines how learners acquire information and the environment in which they acquire it. Learning theories then help to explain how these different aspects affect the learner, each with different perspectives and processes. By understanding these different theories, professors can develop a deeper understanding of the various teaching pedagogies and adapt to fit their students' needs to increase student engagement.

Evolution of Learning Theories

Behaviorism is the oldest of the three learning theories and is commonly associated with B.F. Skinner (Nalliah & Idris, 2014; Kay & Kibble, 2015). It explores how students respond to different stimuli in order to give an expected response (Williamson, et al., 2014). According to the theory of behaviorism, how the brain processes information is not important; the outcome of

a correct or incorrect answer and what stimuli produced the proper response is the goal (Yilmaz, 2011; Brandt, 1996; Williamson, et al., 2014). The “experimenter” strives to reinforce those actions that produce a proper response from a stimulus. Teaching based on this theory enhances recall, defining terms or processes, and memorizing any procedure that has little to no variation; these cognitive processes are found at the lowest levels of Bloom’s taxonomy (Ertmer & Newby, 2013). By the 1950’s, psychologists and educators became frustrated with the limitations of behaviorism and its lack of consideration for how the brain processes information. The understanding of complex cognitive processes became more important, and psychologists and educators were determining the role that complex cognitive processing would take in education. The emphasis shifted to how the students acquire information and what they already know, leading to the development of cognitivism (Ertmer & Newby, 2013; Grider, 1993).

While the idea of cognitivism can be traced to Plato’s time, the development of what it has become today is credited to Tolman, Wundt, Piaget, Bartlett, Lewin, and Gestalt (Grider, 1993). According to Brandt (1996), the main objective of each class is to concentrate on how the mind processes information to allow students to learn using the best practices available; cognitivism considers values, ethics, politics, emotions, and social implications. Cognitivism is a student-centered approach that emphasizes and examines the best practices to engage students in their environment, the classroom, and how to master independent problem solving (McGilly, 1994; Brandt, 1996; Williamson, et al., 2014). Twenty years later in the 1970’s, psychologists began to delve more deeply into cognitivism. Psychologists and educators explored how learners gained and internalized knowledge. Social interactions determined this internalization and knowledge acquisition (Butzler, 2014). Interest in how learners gain and internalize knowledge led to the theory that humans construct their own meaning behind what they learn instead of

simply acquiring it (Ertmer & Newby, 2013). Because of these deviations from cognitivism, the branch of constructivism was conceived.

The developers of constructivism include Dewey, Piaget, and Vygotsky (Butzler, 2014; Felder, 2012). Constructivism asserts that the mind is constructed from its own reality and is not waiting to be discovered as it is with cognitivism (Felder, 2012). As a branch of cognitivism, there are similarities between the two theories: both are student-centered approaches to learning and focus, in part, on how the learner processes information (Ertmer & Newby, 2013). The defining difference between the two is that cognitivism is guided by the professor and constructivism is self-guided learning by the student (Ertmer & Newby, 2013; Butzler, 2014).

Behavioral theories. The main focus of the behaviorist learning theory, the basis of traditional classrooms (the control group in this study), is on how the learners change their behavior based on different stimuli (Brandt, 1996). Behaviorism asserts that students internalize a learned behavior, one they are able to produce in response to the proper response without receiving a reward (Koeing, 2010). The behavioral theories do not take into account how the brain processes information (Pinker, 2009) as the constructivist and cognitive theories do. In the past, professors have commonly used behaviorist learning theory in conjunction with the lecture style of teaching and testing (Brandt, 1996). Recall of information is the primary concern for tests in these classrooms; how students could apply this information is not examined (Khalil & Elkhider, 2015; Williamson, et al., 2014).

Constructivist theories. The constructivist theory “tends to view learning in connection with a community of practice and knowledge as an integral part of the context in which learning develops” (Williamson, et al., 2014). Constructivists view knowledge as information that a person gains through education. In order for students to gain information, they need to

reconstruct the information in a way that makes sense to them in relation to what they already know (Gilboy, et al., 2015). Consequently, students may all receive the same information, but may understand it differently (Koeing, 2010).

While constructivism has been used as a theory in some flipped classrooms, these tend to be mastery flipped classrooms. In the mastery flipped classroom, a professor creates all the content, typically online, and students work through the information at their own pace. Students cannot proceed to the next unit until they have reached a satisfactory score on the previous unit test. Because of the professor-guided pace of the radiation safety class used in this study, cognitivism was determined to be a better fit for this study.

Cognitive theories. Tolman is often considered the originator of cognitive theory. He conducted an experiment on rats which determined that they would memorize a maze because of their own motivation instead of simply responding to stimuli; the rats had purpose and direction in memorizing the maze, even when a reward was withheld (Grider, 1993). While Piaget is not considered the originator, he is one of the largest contributors to this theory. Piaget developed schemas to explain how students put information together. He explained that students' abilities to process and organize the new material would combined with what they already knew to determine the behavior of students (Nalliah & Idris, 2014). The constructs of this theory explain how people retain information and are able to access it and connect it to new things during the learning process (Pinker, 2009). This concept makes CLT different from behaviorism and constructivism.

Cognitive learning theory applied. The cognitive learning theory focuses on relating new content to a student's prior knowledge and learning ability. It also takes into account how students best learn and create an environment that encourages this. According to Yilmaz (2011),

one of the main premises of CLT is how the brain processes information based on previous knowledge and how to incorporate that into the new material being taught. By creating a positive learning environment and connecting current content to previous content, retention, critical thinking, and student engagement can be increased. Cognitive learning theory encourages students to guide their own learning in relation to behavioral, environmental, and personal cognition factors, as shown in Figure 1 (Yilmaz, 2011). Behavior is defined as the way students approach learning and the way they act. Environment refers to the decorations and arrangement in the classroom, distractions caused by other students, and outside noise. Finally, personal cognition factors focus on the students' previous knowledge of the topic and how engaged they are in the activity (Schunk, 1989).

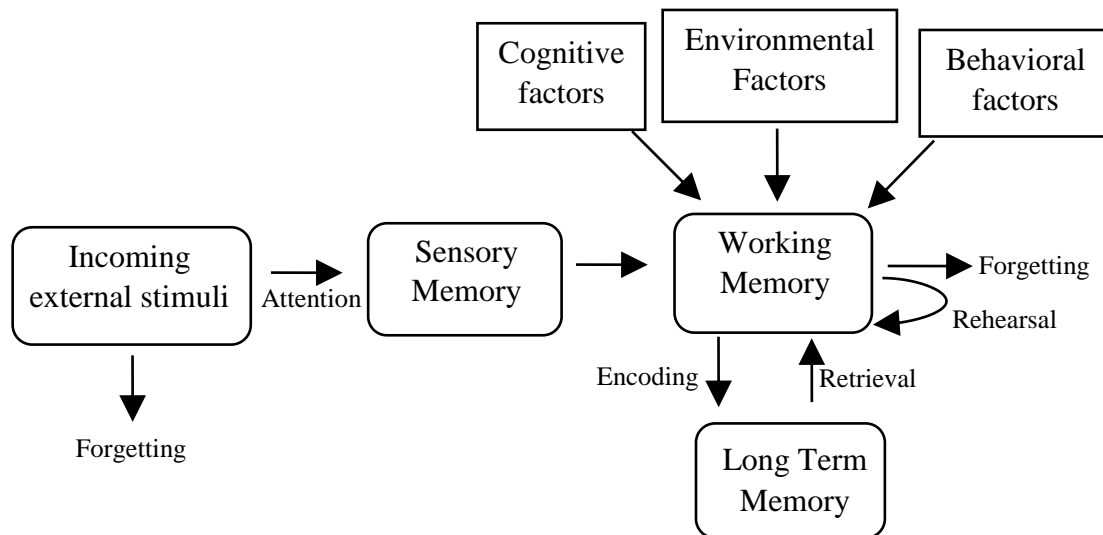


Figure 1

Cognitive Learning Theory

While the flipped classroom can be achieved by utilizing either the methods of cognitivism or constructivism, the classroom for this study was flipped using cognitivism to allow for a more professor-guided process. In the university setting, especially in healthcare, it is important to have the professor available to assist the students with the most critical skills, such

as Radiation Safety. The cognitive learning theory within the flipped classroom allows students to process information in a manner that best suits them while developing critical thinking skills in an environment where help is available when needed. The cognitive learning theory focuses on the connection between previously learned and new information to help deepen connections and increase the retention of information.

The College and University Classroom Environment Inventory (CUCEI) has seven scales: personalization, involvement, student cohesiveness, satisfaction, task orientation, innovation, and individualization (Strayer, 2007; Strayer, 2012; Fraser, et al., 1986). The cognitive learning theories focus on relating information to what each student knows, and making connections between new and old information relates to the personalization and individualization scales within the CUCEI (Strayer, 2012). Creating an environment that allows students to make connections corresponds with the satisfaction and task orientation scales. While cognitive learning theory does not directly relate to the involvement, student cohesiveness, and innovation by creating the environment and personalization of lessons central to the CLT, these scales can be achieved. These three scales are also the cornerstone of the flipped classroom, used to increase critical thinking and problem solving skills (Strayer, 2007; Strayer, 2012; Fraser, et al., 1986).

Development of the Flipped Classroom

In 1991, Mazur was the first high school teacher to report on the use of the flipped classroom by using the aforementioned techniques in his physics class, although humanities classes have been using similar methods for much longer. During 2001, two major studies were published concerning the flipped classroom (Lage, et al., 2001; Strayer, 2007). In 2006, Bergmann and Sams (2012) thrust flipped classrooms to the forefront of pedagogy and are often

cited as the ones who popularized the technique. In all of these studies, lecture content was made available online utilizing various delivery methods: using a voice recording over a PowerPoint presentation, recording lectures and making them available online, or distributing lecture notes, and hosting an online discussion board (Schultz, et al., 2014).

Students miss class for various reasons or may be in attendance but inattentive. It is difficult and nearly impossible to find time to reteach all of these students (Bergmann & Sams, 2012). To address this concern, Bergmann and Sams (2012) decided to record their lectures via screen capture technology; this allows a narrator to record a voice on a PowerPoint presentation. They would then post their videos on their websites for students to view. Students were able to view the lectures after missing class, use them to study before an exam, or to help with the understanding of difficult concepts. Bergmann and Sams (2012) collected data on student views of the online lecture material and made CD's of the lectures for those who did not have reliable internet at home. Specifics of the data was not reported: it was only noted that it made a measurably improved difference in students' test scores and their ability to stay informed of current class topics even when absent. After Bergmann and Sams (2012) saw the success students were having, they put all their record videos online for students to view anytime outside of class. Class time was spent doing activities that reinforced the concepts of the videos. Once other professors saw the positive impact that these methods were having, they began implementing this method, the flipped classroom, as well. The idea of switching lecture content and homework was innovative and had a large impact on secondary and higher education.

While the method is innovative, the flipped classroom makes a number of assumptions about students. One of these assumptions is that students complete the assigned videos or readings before class starts. Though both the traditional and flipped pedagogies may benefit

some learning styles they may not fit all learning styles; with diversity in classrooms increasing, it is also difficult to know the impact on learners that speak English as a second language (ESL).

Importance in secondary education. Millennials, those born between 1982 and 2002, tend to learn differently than baby boomers and those born before them; they are usually more involved in technology and are more likely to find difficulty focusing on one thing at a time (Simpson & Richards, 2015; Gillispie, 2016). With regular advancements in technology, lessons often need to be adjusted quickly to adapt (Strayer, 2012). By using the flipped classroom, professors can use several different live interactive activities to assess the student's knowledge base and adapt that day's lesson to what the students need for each class (Fulton, 2012). Students are learning not only the subject material, but how to use technology in a positive, productive manner (Huang & Hong, 2015).

Utilizing the flipped classroom allows students to receive important content, even when not in attendance. When students return, they are on track with the rest of the class, and make-up work is limited (Herreid & Schiller, 2013). Those students who are in class are able to receive more one-on-one personalized attention, with class size having little to no effect, when compared to a traditional class. Students receive help understanding the material and its applicability instead of learning only the facts (Huang & Hong, 2015). Students with higher academic aptitude may require less time to learn facts, concepts, and ideas than those who are not as academically focused (Heacox, 2012). With the flipped classroom, professors adjust lessons to meet students' individual needs to challenge them all (Chen, 2016). Professors are able to teach more personalized lessons not only to those at various learning levels but also in a variety of class sizes. With class sizes continuing to grow, reaching a wider array of students is of increasing importance (Norcini, Leapman, Patel, & Bonaminio, 2007; Harris, 2007).

Importance in higher education. Employers today are seeking graduates who know more, are better able to apply this knowledge, and solve more challenging problems (McLean, et al., 2016). Technology in the workplace is rapidly changing as new programs are introduced and technology becomes more ingrained into daily tasks. It is difficult to keep pace with such rapid technological advances (Felder, 2012; Hessler, 2016).

The majority of classes students take are traditional lecture-based courses; the primary use of class time is lecturing with the main focus being the dissemination of information. This environment does not promote the critical thinking and problem solving skills that students need in future classes and careers (Belfi, et al., 2015). The design of the flipped classroom allows for the possibility of acquiring both the desired skills and knowledge in one setting (Hessler, 2016; Felder, 2012; Gillispie, 2016; Herreid & Schiller, 2013).

Utilizing the flipped classroom, the professor may assign students to small groups to work on different tasks, including case studies and projects, to apply the skills learned for the topic. The professor moves around the room, assists students, and asks thought-provoking questions to encourage a deeper understanding of the topic (Koo, et al., 2016). These tasks prompt students to explore, analyze, and discuss real world situations for a better understanding of the clinical practice that they are about to enter (Rotellar & Cain, 2016). These activities make it easier for the professor to connect the class material to topics already covered in other courses (Strayer, 2012; Mattis, 2015). Students engage more deeply in their learning when they are able to see the relevance and interconnectedness of their courses (McLean et al., 2016).

Some faculty have been reluctant to adopt the flipped classroom because of the *initial* time necessary to develop content for the course (Liebert, Lin, et al., 2016; O'Flaherty & Phillips, 2015). It takes approximately 120 percent more time to set up a flipped classroom the

first time it is used in comparison to a traditional classroom. However, exploring non-traditional teaching methods is important in order to help increase retention of information and develop the needed critical thinking and problem solving skills that employers are demanding.

Gaps in Knowledge

No consensus currently exists on the structure of a flipped classroom. However, literature indicates in order to constitute a flipped classroom traditional lecture material needs to be completed outside the classroom, via readings or videos. Activities that engage students in concepts viewed before class are done during class time (Rose, et al., 2016; Gillispie, 2016; Liebert, Mazer, et al., 2016; Liebert, Lin, et al., 2016; O’Flaherty & Phillips, 2015; Herreid & Schiller, 2013). These activities should focus on developing students’ critical thinking and problem solving skills relevant to real word situations that can occur in the workplace (Gillispie, 2016; O’Flaherty & Phillips, 2015; Schultz, et al., 2014; Munson & Pierce, 2015). While much is known about flipped classrooms, little is known about the effectiveness of flipped classrooms in the radiologic sciences. No published data exists on the flipped classroom in radiologic technology, nuclear medicine, or radiation therapy, or on the radiation safety class required for graduation. This study aimed to fill this gap by designing a flipped classroom for a radiation safety course and comparing findings between flipped and traditional classroom.

Previous studies of health professions and allied health education have included some constructs from CLT, such as cognitive factors and behavioral factors (McGilly, 1994; Mattis, 2014; Strayer, 2012). The studies that used these constructs did not look at how the environment influenced or played a role in how effectively information is processed. A large number of studies assessed if students were more satisfied during flipped classrooms, leading to more engaged students (Gilboy, et al., 2015; Rose, et al., 2016; Hao, 2016; Koo, et al., 2016).

However, no literature examined how students being more engaged can lead to a deeper understanding of the material and better application skills according to CLT. This study aimed to fill this gap by analyzing student engagement in relation to test scores. While some studies of the flipped classroom used cognitive aspects or different cognitive theories, none of these published studies used CLT to support the constructs of the flipped classroom. This study aimed to fill this gap by using CLT to see how outcomes change, via test scores and course survey scores, to improve retention and engagement.

Exam and Survey Tools

Methods to assess retention of course content have been widely studied using formative and summative assessments throughout the semester. In order to obtain a true assessment of students' retention and critical thinking skills, both the control and experimental groups used a final exam that included short answer questions based on real life scenarios that cover multiple content areas. Similar to studies done by Baepler, Walker and Driessen (2014), Tune, Sturek, and Basile (2013), and Mortensen and Nicholson (2015), this study used standard multiple choice questions in conjunction with real life scenario essay questions to thoroughly examine students' abilities to retain information and use critical thinking skills.

The final exam that was used had been given over multiple years and aligned with the objectives of the course. Content validity of the final exam was achieved with the alignment of the course objectives (Wass, Van der Vleuten, Shatzer, & Jones, 2001). In a study conducted by Wass, Van der Vleuten, Shatzer, & Jones (2001) the reliability of multiple choice exams was approximately 0.92 and short answer exams was approximately 0.82. The use of the exam over multiple years also attributed to determining that the final exam was reliable (Van der Vleuten, 2000).

In order to measure student engagement for this study, the College and University Classroom Environment Inventory (CUCEI) was used. Other studies on flipped classrooms have utilized this assessment to determine student engagement; specifically the categories of involvement, satisfaction, and task orientation (Butzler, 2014; Strayer, 2012). The seven items being tested on the CUCEI (personalization, involvement, student cohesiveness, satisfaction, task orientation, innovation, and individualization) are closely related to the goals of the flipped classroom. The CUCEI and CLT are related because both assess the classroom environment's effect on student engagement. Many publications attest to the validity and reliability of the CUCEI (Fraser, et al., 1986; Fraser, 1998; Strayer, 2012).

Two of the more important early uses of the CUCEI instrument were conducted by Ingersoll and Lawson (Farris, 2014). In a descriptive study by Ingersoll results showed significant correlations between the talk styles of support and feedback and the CUCEI scales of involvement, innovation, and individualization (Ingersoll, 1991). A 1988 study by Lawson he sought to identify the relationship between the teacher's communication style and classroom context. Assertiveness, responsibility, and versatility, three domains of teacher communication style, were determined to have a relationship with the seven scales on CUCEI (Farris, 2014).

More recent studies using the CUCEI instrument in the classroom learning environment include those done by Wanless (2012), Hizer (2010), and Goyak (2009). Wanless (2012) used the CUCEI to determine students' perception of the psychosocial environment in a strictly online class versus a blended type. Results showed that the blended group perceived more innovation, individualization, and student cohesiveness than the online classroom (104). Hizer (2010) used the CUCEI in relation to Supplemental Instruction (SI) in science classrooms. For the Hizer (2010) study, supplemental instruction consisted of offering material and/or study strategies for

those courses with lower retention and grades (4). Results showed increases in the CUCEI scales of personalization, cooperation, student cohesiveness, and innovation. Goyak (2009) studied the effects on a higher education classroom that traditional lecture has versus cooperative learning techniques. For the Goyak (2009) study, cooperative learning techniques consisted of working in small groups to maximize personal learning (4). There were two focuses: student perceptions of classroom environment and student critical thinking skills. Results showed that in the cooperative learning group had a strong positive correlation with CUCEI scales of equity, cooperation, and innovation.

Summary

In Chapter One the purpose, significance, and gaps in literature were presented. This study aimed to measure if there was a difference between the flipped and traditional classrooms in relation to retaining information, as measured by final exam scores. It also assessed if a difference existed between traditional and flipped classrooms in regards to student engagement, as measured by course evaluations. The study design based on current gaps in literature and the study aim was included.

In Chapter Two the three different learning theories – behaviorism, cognitivism, and constructivism – were related to different teaching pedagogies. How and why the study was going to be using the constructs of CLT in relation to the flipped classroom was also explored. The histories of both CLT and flipped classrooms were analyzed. The relationships between the constructs and of cognitive learning theory (CLT) and the flipped classroom were compared. Gaps in knowledge were addressed with an emphasis on the effectiveness of the flipped classroom in alleviating critical thinking and problems solving issues; both issues with new

employees, as identified by employers, in other healthcare professions (Felder, 2012; Ertmer & Newby, 2013).

Chapter 3 presents a review of the research design. A detailed description of participant inclusion and exclusion criteria will be covered. The method for statistical evaluation and why it was appropriate will also be discussed. The variables will be identified. The validity and reliability of the final exams, and CUCEI will be reviewed in relation to Bloom's taxonomy in conjunction with CLT.

Chapter Four details cohort inclusion and exclusion criteria. Demographic information for the College and University Environment Instrument (CUCEI) was analyzed for both cohorts and the study over all. The validity of the course is covered in statistical detail in reference to the flipped classroom checklist. A detailed statistical explanation of the results by exam and survey type for both sections of the Radiation Safety course was done. How these results were analyzed and the meaning of these results concluded the chapter.

Chapter Five will give an overview of the highlights of the study. A summary of the findings was given and their interpretation was reported. The context of the findings in relation to Cognitive Learning Theory (CLT) was also covered. Limitations of the study will be outlined and discussed and the future direction for similar studies will conclude the chapter.

Chapter 3 – Methodology

Overview

In Chapter One the purpose, significance, and gaps in literature were presented. This study aimed to measure if there was a difference between the flipped and traditional classrooms in relation to retaining information, as measured by final exam scores. It also assessed if a difference existed between traditional and flipped classrooms in regards to student engagement, as measured by course evaluations. The study design based on current gaps in literature and the study aim was included.

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Chapter three will cover how the study will assess the ability of the flipped classroom to improve retention of information, critical thinking, and student engagement in comparison with the traditional classroom in the student population at Virginia Commonwealth University. The research design and implementation of the flipped classroom used constructs related to the

cognitive learning theory. This chapter discusses the design of the study while explaining the study's research, rationale, and appropriateness. Details of the participant criteria are also included with importance placed on sample type, size, location of participants, and sampling procedures. An overview of the statistical evaluation procedures will be given along with the statistical tests that were used. The flipped classroom intervention in this study is described in detail, giving special attention to the structure, design, and implementation. Identification of the dependent, independent and control variables along with how each was measured is gone over. The instruments used to assess the outcomes of this study are described in terms of appropriateness for the study and the validity and reliability of the CUCEI. Following the assessment there will be an in-depth explanation of how the Primary Investigator (PI) administered both exams and the CUCEI.

Research Design

The research questions posed for this study were:

1. Does a change in teaching pedagogy in a Radiation Safety course make a difference in retention of information, critical thinking, and student engagement?
2. Do the covariates – age, gender, years in college, and race – impact how students view the flipped classroom?

In relation to the first research questions this study addressed the following null hypotheses:

H01: There will be no statistical difference between the multiple choice final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H02: There will be no statistical difference between the short answer questions on the final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H03: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses.,

In relation to the second research questions this study addressed the following null hypothesis:

H04: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

H05: There will be no statistical difference in the CUCEI subscales of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

For this seminal study, the pedagogy, flipped or traditional classroom, was assessed in relation to the environment construct of the Cognitive Learning Theory (CLT). This study also evaluated the CLT constructs, behavior (H03) and how the brain processes information (H01 and H02), by measuring student retention (H01) and critical thinking (H02) along with student engagement as measured by course engagement surveys (H03, H04, and H05).

A mixed methods quasi-experimental design was used to assess the differences between a traditional classroom and a flipped classroom. Below is a diagram of the proposed study design:

Traditional classroom: O_1 QUAN + QUAL

Flipped classroom: X O_1 QUAN + QUAL

O_1 denotes the observation and collection of test scores and course evaluations. The course evaluations contained both Likert scale and open-ended questions. X indicates the intervention, the flipped classroom.

Data Collection Procedures

The observation consisted of the final exam which was given to all students enrolled in the Radiation Safety course at Virginia Commonwealth University (VCU) during the Spring 2016 semester, serving as the nonequivalent control group. This was also replicated for the Spring 2017 semester, the experimental group. The course evaluations were also a part of the observation and were given at the end of the semester to the same groups of students. Both the final exam and course evaluations were distributed via paper copies. The flipped classroom served as the intervention for the study. The curriculum for the Radiation Safety class was re-designed before the Spring 2016 Radiation Safety class. This allowed the content, i.e: the topics to be covered, to be the same for both the Spring 2016 and 2017 courses. The Spring 2017 flipped classroom also implemented the entirety of the curriculum, activities, pre-recorded lecture material, and post-video questions. The course professor administered course evaluations following the final exam of both semesters. Participants who were enrolled in the class were also enrolled in the study. All students who enrolled in the course completed the coursework and final exam. Only those who completed the course, final exam, and the course evaluation were included in the statistical analysis.

The population for the Radiation Safety course is composed of students in the College of Health Professions Radiation Science program. There are three radiation science programs at VCU: radiography, nuclear medicine technology, and radiation therapy. The Radiation Safety course includes students from all three disciplines, as it is a mandatory class for all students under the radiation science heading. Students typically take the course during their first year in their respective disciplines at VCU during the Spring semester.

On the first day of class for both the control and experimental group, the Spring 2016 semester class and the Spring 2017 semester class respectively the course instructor, gave students a syllabus and an overview of the course goals, format, content and grading. For the students in the 2017 Spring semester flipped classroom, the course professor provided demonstrations to show the students where to find their homework, the pre-recorded video lectures and end-of-video questions. Examples of each type of activity were reviewed with students to increase their comfort level with the activities. The course professor was removed entirely from the grading process and a teacher's assistant took over these responsibilities of the course. The course professor was also removed from the grade book in its entirety so she could not see students' grades as well as to maintain confidentiality.

The implementation portion of this study was designed to be completed during the 15 week semester. The final exam was designed to be completed in the allotted two hour and 50 minute time slot for final exams according to VCU policy. The College and University Classroom Environment Inventory (CUCEI) was modified to delete questions that were duplicates on the pre-existing course evaluation form, and demographic questions were added as well. The survey was designed to take approximately 20-30 minutes to complete. During the 15 week Spring 2016 Radiation Safety course the course professor used the traditional classroom model while teaching. During the 15 week Spring 2017 Radiation Safety, she taught using the flipped classroom model. At the conclusion of both courses, students were given the final exam and course evaluation. The course professor delivered the lecture content face-to-face during class time in the traditional classroom and assigned pre-recorded videos of the lecture content as homework in the flipped classroom. She assigned end-of-chapter questions in the traditional classroom as homework and students completed activities in-class for the flipped classroom. The

table below emphasizes these similarities and differences in the flipped classroom. A summary of these differences can be seen in Table 2.

Table 2

Flipped And Traditional Classroom Similarities And Differences

Similarities	Differences
Content - the topics to be covered	Lecture content <ul style="list-style-type: none"> ● Traditional - face to face ● Flipped - pre-recorded videos
Final exams	Class time <ul style="list-style-type: none"> ● Traditional - lecture focused ● Flipped - Application and problems solving activities
Course evaluations	Outside of class <ul style="list-style-type: none"> ● Traditional - End of chapter questions ● Flipped - View pre-recorded lectures and take corresponding quizzes
Professor	
Classroom environment <ul style="list-style-type: none"> ● Moveable desks ● Open floor plan (i.e. no columns, stairs, outlets on each wall) ● At least one outlet on each wall ● White board and projector screen opposite the entry door. 	
Class length each week <ul style="list-style-type: none"> ● 1 hour and 40 minutes – in-class ● Approximately 1 hour out of class 	
Day and time of class <ul style="list-style-type: none"> ● Tuesday’s from 2:00-3:40pm 	

Validity of Research Design

This study used a quasi-experimental design that was limited in time as only a post-test was given to both cohorts. Quasi-experimental studies are susceptible to threats of internal validity. History, maturation, mortality, testing, and instrumentation are common threats to this

design type and were considered during this study's development with the design, implementation, and assessment of the flipped classroom considered to help minimize as many threats as possible. In order to minimize history threats, a control group was selected from a comparable group of participants. To decrease maturation threats, content covered in the traditional safety class was reviewed to ensure minimal overlap between classes. Mortality and selection threats were addressed by collecting demographic data on students to determine if these variables affected the results. The length of all testing instruments was assessed to determine how long they would take to complete. Instrumentation threats were minimized by choosing surveys and assessments, other than the final exam, that met the needs of the study and were able to be completed in less than 30 minutes. To ensure that the flipped classroom fit the proper criteria to be qualified as a flipped classroom a checklist was used. The flipped classroom checklist observations were not scheduled and occurred randomly without the course professor being informed ahead of time to avoid introducing confirmation bias.

To confirm that each instrument measured the designated construct correctly the following items were addressed: hypothesis guessing, researcher expectancies and bias, construct definition, and treatment interactions. In order to avoid hypothesis guessing students were not made aware that they were part of the study; this was done with IRB approval.

Researcher expectancies and bias were addressed by removing the researchers from data collection and grading. Data was also coded so that researchers would not be able to identify students. Construct definitions were reviewed by four different committee members to make certain that definitions were precise and understandable. Since students were not aware they were a part of the study this also decreased the possibility of interactions between the flipped and traditional pedagogy students.

Beyond the control of study design were extraneous factors like prior experience, student's fatigue, attitude towards the course and topic, and regression because of testing error. These extraneous factors can affect retention, critical thinking skills, and student engagement. Sampling of the population was done using purposive sampling. This type of sampling is based on the characteristics of the identified population and study criteria. Additionally, the use of a purposeful sample from a single institution introduces threats to the external validity of the study. External validity, in relation to student engagement, can also be susceptible to influence from interactions between the control and experimental groups, interactions between the experimental group and the intervention, and interactions between the setting and the intervention. Three Radiation Science majors were included in the study, data was broken down by age, and a detailed description of the methods is included to decrease external validity threats to generalizability.

Threats to statistical conclusion validity were also taken into account when analyzing results and determining relationships. This study was susceptible to low statistical power and restriction of range threats. Low statistical power threats may have caused it to appear that there was no relationship between teaching pedagogy and critical thinking, retention, and student engagement. Due to the time restraint of the study only a post-test was given to one comparison group. With limited data for the comparison group, flipped classroom, the relationship between the variables could have been diminished. Both of these effects were acknowledged and as a result, caution was used in interpreting the results and replication is recommended.

Population and Sample

Participant criteria. Purposive sampling was used for this study. The target population for this study included all students in the College of Health Professions Radiation Science

program at VCU required to take Radiation Safety; these students are primarily first year students in their respective disciplines. On average, approximately forty students enroll in the Radiation Safety course each Spring. Depending on the number of students enrolled in each of the three programs under the Radiation Science heading, there can be a different number of Radiation Therapy, Nuclear Medicine Technology, and Radiography students in a class. Because of the availability of students and the strict entry requirements, a purposeful sample of the students registered for the course for each semester was the study sample. With an already small sample, 33 students for Spring 2016 and 30 students for Spring 2017, consecutive sampling and any probability sampling would have only decreased the sample size and as a result increased the probability of incorrect statistical outcome due to type II errors.

The number of participants was dependent upon the number of first year students in their respective disciplines and students taking the course. The Institutional Review Board (IRB) deemed that consent was not needed from students due to the nature of the study. Students were allowed to participate regardless of their year in school. Students were eliminated if they failed to take the final exam at the designated time or the CUCEI and the final exam in its entirety. Because the entire Spring 2017 class used the flipped classroom pedagogy, all students enrolled in the course completed the observations and interventions. The Co-Investigator (CI), removed data from students not included in the study prior to statistical analysis. The Primary Investigator (PI), was the course instructor. The CI also served as the contact for students regarding study participation. Students that withdraw from the class at any time during the semester were not included in the data analysis. There was no bearing on the student's grade according to their participation in the study or the CUCEI. A teacher's assistant graded the final exams using a

rubric; the PI and CI assessed the CUCEI using a Likert scale and did thematic content analysis of open-ended questions.

Statistical evaluation. Increase in a student's retention of information and their critical thinking skills relevant to clinical practice was measured by the multiple choice and short answer questions final exam scores. Retention of information was assessed on the multiple choice section of the final exam and critical thinking was assessed with the short answer questions of the final exam. The CUCEI scores reflected if students were more engaged during class. The difference between the average multiple choice and short answer questions final exam scores in the Spring 2016 and 2017 Radiation Safety course cohorts were used to determine if there was a statistically significant mean difference in retention of information and critical thinking skills. Assessing the difference in the scores on the CUCEI between the Spring 2016 and 2017 Radiation Safety course cohorts indicated if there was a statistically significant mean difference in student engagement. The CUCEI consisted of 54 questions based on a four point Likert scale and one open-ended question.

The statistical technique for these null hypotheses presented below

H01: There will be no statistical difference between the multiple choice final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H02: There will be no statistical difference between the short answer questions on the final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

MANOVA was used to compare the centroids formed by the best linear combination of exam and short answer questions scores for the final exam analysis with the traditional and flipped classroom pedagogies. Despite a lack of statistical significance in the MANOVA comparison ANOVA was used for a follow up test for both retention and critical thinking skills.

H03: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses, with or without covariates.

ANOVA was performed for both the overall CUCEI scores and the subscales.

For the nulls associated with the second research question were

H04: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

H05: There will be no statistical difference in the CUCEI subscales of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

ANCOVA and MANCOVA were run to determine if the covariates – age, gender, race, years in college – had an effect on the CUCEI as well.

With a sample size of 30 students for both the Spring 2016 and 2017 semesters an effect size of .65 would also be a result, describing a medium to low effect. According to powerandsample.com, with an alpha of .05 in order to determine if there was a significant change, the power needs to be set at 0.5 with a beta of 0.8. With participation from 61 students in the study the power, according to powerandsamplesize.com, was 0.68; indicating there was not enough power in the study to distinguish between random occurrence of results and actual significance.

Intervention

The intervention in this study was the flipped classroom. Students in a flipped classroom, in a broad sense, viewed lecture material at home through the use of videos or podcasts; class

time was used to complete activities that promote problem solving and critical thinking skills to deepen a student's understanding of the material (Belfi, et al., 2015).

One of the foundational constructs of the Cognitive Learning Theory is the learning environment. Both the flipped classroom and the cognitive learning theory emphasize the importance of creating an environment that enhances and stimulates learning (O'Connor, et al., 2016; Hao, 2016; Yilmaz, 2011; Brandt, 1996; Ertmer & Newby, 1993; Grider, 1993). By creating an environment that stimulates learning, the learner is more engaged in the activity (O'Flaherty & Philips, 2015; Butzler, 2014; McLean, et al., 2016; Rotellar & Cain, 2016). When learners are more engaged they tend to be both more satisfied with the class and retain more information (McLaughlin, et al., 2014; Gilboy, et al., 2015; Rose, et al., 2016).

Developing critical thinking and problem solving skills are two of the main goals of the Cognitive Learning Theory (Khalil & Elkhider, 2016; Aliakbari, et al., 2016; McGilly, 1994; Brandt, 1996). With the flipped classroom pedagogy, professors have more time to develop and implement activities during class that foster these skills (Hessler, 2016; Rotellar & Cain, 2016; O'Flaherty & Phillips, 2015; Munson & Pierce, 2015; Dominguez, et al., 2015; Simpson & Richards, 2015; Das & Sarkar, 2015; McLaughlin, et al., 2014; Gilboy, et al., 2015; Smith, 2014). This is essential as employers are noticing a decrease in critical thinking and problems solving skills from new graduates as they enter the workplace (Ertmer & Newby, 2013; Felder, 2012; McGilly, 1994). By using the flipped classroom, which encourages higher order thinking skills such as critical thinking and problem solving, students are also more likely to retain this information.

The cognitive learning theory's primary focus is on how the brain processes information in order to retain information (Williamson, et al., 2014). Cognitive Learning Theory

conceptualizes information processing in three stages: sensory register, short-term memory, and long-term memory (Kay & Kibble, 2016). The information is then stored in long term memory in schemas (Yilmaz, 2011; Ertmer & Newby, 1993). According to Yilmaz (2011), these schemas are similar to organized index cards, each containing a specific piece of information. When students are able to retrieve the schemas and apply them to a variety of situations, the students are said to have learned the concept (Ertmer & Newby, 1993; Brandt, 1996; Kay & Kibble, 2016). The flipped classroom pedagogy aims to increase retention of information by designing activities that allow students to make several connections to both new and previously learned; thus, they are able to increase the number of connections made to each schema (Ertmer & Newby, 1993; Brandt, 1996; Khalil & Elkhider, 2016). Recalling information more frequently in this way allows for better storage in the long term memory (Kay & Kibble, 2016; Grider, 1993).

For this study, the flipped classroom consisted of pre-recorded lectures from the traditional lecture style class that students were to view at home before coming to class. The CI created lecture videos that contained major points or objectives for that class period. Each hour and 40 minute class started with a short (10-20 minutes) question-and-answer session to ensure that students understood the video content. At this point, the class proceeded in either one of the two ways demonstrated in Figure 2:

1. The question and answer session required more time than anticipated, or
2. Discussion took the allotted amount of time and the activity planned for class occurred.

If the question and answer session required more time than the professor anticipated, she did not assign that class period's activity as homework.

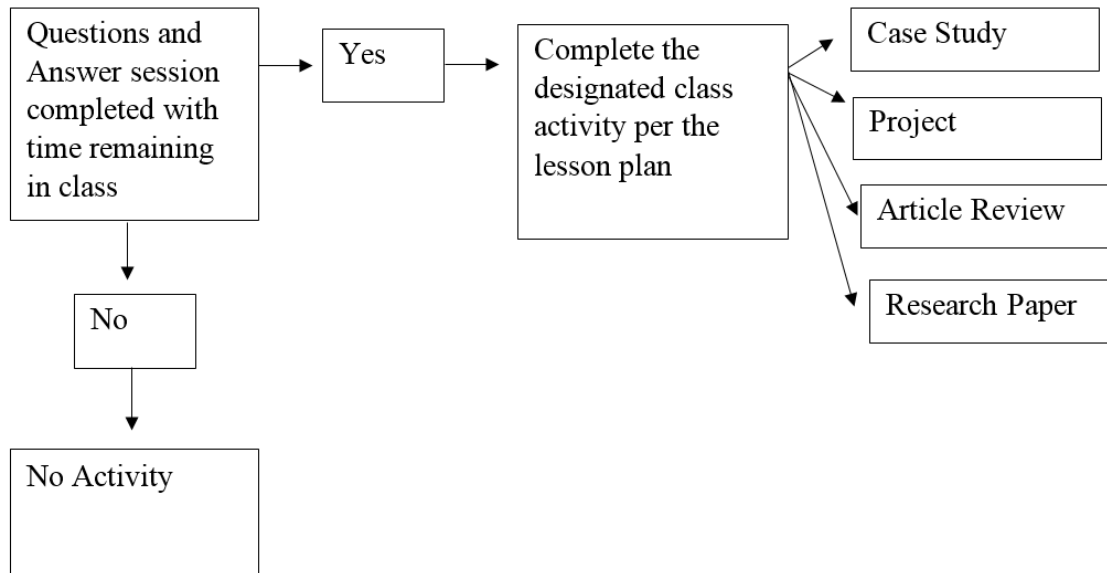


Figure 2 - Flowchart Of Flipped Classroom Intervention

Instead, the professor anticipated what needed to be done during the next session to determine if the activity should be moved to the following session or not completed. If the question and answer session proceeded as the professor anticipated, students completed one of four different activities as outlined in Table 3, depending on which lesson they were completing.

As shown in Table 3, students performed the same activity for a minimum of two consecutive class sessions to ensure that they understood how to do the activity and knew what was expected of them. During lesson 1, students received an introduction to the class; lessons 4, 8, and 12 were the lessons during which students took tests. After the introduction of all the types of activities, the activities were varied by class period.

Because of the variety of ways a professor can implement a flipped classroom, comparison between flipped classrooms can be difficult. Studies often lack the proper amount of detail to allow others to replicate the study. This study aimed to provide sufficient detail to facilitate other researchers to replicate the content and activities of a flipped classroom easily.

Table 3

Flipped Classroom Activities, Lesson Number, And Key Concept Covered

<u>Activity</u>	<u>Lesson</u>	<u>Key concept</u>
Case Study	5	X-ray quality
	6	X-ray interactions with matter, radiographic quality control
	15	Cardinal principles of radiation protection, effective dose
Project	11	Molecular and Cellular Radiobiology
	13 & 14	Early and late effects of Radiation
Research paper	7	Performance assessment standards, digital display device quality control
	10	Fundamental principles of Radiobiology
Article Review	2	Sources of ionizing radiation, basic radiation protection, radioactivity, types of ionizing radiation
	3	Photons, inverse square law, electron target interactions, x-ray emission spectrum, factors affecting the x-ray emission spectrum
	9	Human Biology
	16	Designing for radiation protection

While content and activities may be easy to replicate the central components of the flipped classroom, replication of the professor may prove difficult due to varying comfort levels with the flipped classroom and skill sets. Having the same professor teach both the traditional and flipped classroom sections helped to increase continuity.

However, in the event another instructor is used to teach another section, each would have been sent to a training session about flipped classrooms. They would have also been required to prepare and work through lesson plans together to help develop best practices. Ensuring continuity through having a single professor or professors with equivalent training increases intervention fidelity.

Both the flipped and traditional classes were one hour and 40 minutes in length and met once a week for 15 weeks. While the flipped class had to watch videos at home, the traditional class had to answer end-of-chapter questions; each activity took approximately an hour each week. The classroom used for both classes was the same. The floor plan was open with no stadium seating, stairs, or other obstructions in the room. The white board and projector screen were opposite of the door. Each wall had at least two outlets making power sources available to at least eight people if needed. The seating was that of a single desk per student that could easily be moved around the room to facilitate small group activities or large class discussions without difficulty.

Variables and Instruments

Pedagogy. To ensure the fidelity of the flipped classroom, a checklist was devised to ensure all necessary components were occurring. The flipped classroom checklist, modified from The University of Utah, included only the sections related to observations that could be made during class. The sections on evaluating the video content and learning objectives were omitted due to feasibility of evaluation and the time required to assess both of these plus the lesson. It was also modified from a Likert scale to a Yes/No format. Due to multiple faculty members evaluating the flipped classroom, changing from a subjective Likert scale to an objective Yes/No format increased the validity of results. The modified checklist contains 19 questions within three major categories: instructor-student and student-student interaction, teaching technology, and lesson plan. Instructor-student and student-student interaction questions related to the relationship the professor had with students and how they fostered engagement. Teaching technology questions determined how technology was used in the classroom and the way the professor ended class. Questions in the lesson plan category related to how the professor started

class, used class time, encouraged preparation, and engagement in higher level thinking skills. Two observers used the checklist to ensure interrater reliability was increased. See Appendix A for the complete checklist.

Critical thinking and retention. Final exams are a common way to determine how much knowledge a student has retained over the course of a semester. In a study conducted by Wass, Van der Vleuten, Shatzer, & Jones (2001) the reliability of multiple choice exams was approximately 0.92 and short answer exams was approximately 0.82. Content for the final exam has been developed and continuously used by faculty for the past three years, serving the equivalent of an expert panel. There have also been consistent results of the final exam scores amongst the previous radiation safety courses. The same final exam was given the previous three years with consistent results. The consistent results indicate that the final exam was reliable since each class over the past three years achieved similar results. Validity was also confirmed when results were similar indicating that content retention was assessed. Exam and survey results provided the quantitative data. See Appendix B for sample questions from the final exam.

Student engagement. Qualitative and quantitative data are often collected through surveys because of their reliability and ease of administration. Using a survey, such as the CUCEI, with proven validity and reliability from a similar study will save time in determining the reliability and validity of a new survey. The alpha coefficients for each of the seven different CUCEI scales ranged from 0.70 to 0.90 (Fraser, 1998; Fraser et al., 1986; Strayer, 2012). The discriminant validity ranged from 0.23 to 0.49, This indicates satisfactory discriminant validity and suggests that the CUCEI measures distinct, although somewhat overlapping aspects, of the learning environment (Fraser, 1998; Fraser et al., 1986).

The College and University Classroom Environment Inventory (CUCEI) was developed specifically with higher education in mind to provide a tool to measure classroom environment (Fraser, 1993; Fraser, et al., 1986, Fraser, 1991). The CUCEI, a 49-item self-report measure, is based on Moos’s three dimensions of classroom environment, Relationship Dimension, Personal Development Dimension, and System Maintenance and Change Dimension (Williams, 1995). The final version of the CUCEI contains seven 7-item scales as seen in Table 4. Each item has four responses (strongly agree, agree, disagree, strongly disagree), and polarity is reversed for approximately half of the items (Fisher & Parkinson, 1998). See Appendix C for the CUCEI in its entirety.

Table 4

CUCEI 7-Item Scale Descriptions

Item Name	Description
Personalization	The opportunities individual students have to interact with the instructor and the concern for students’ personal welfare.
Involvement	How much students participate actively and attentively in class discussions and activities.
Student cohesiveness	Extent to which students know, help, and are friendly toward each other.
Satisfaction	How much students enjoy their classes.
Task orientation	Extent to which class activities are clear and well organized.
Innovation	How often new and different teaching and learning activities are used.
Individualization	Extent to which students are allowed to make decisions and are treated differently.

Adapted from “Improving Nursing Education Classroom Environments,” by Fisher and Parkinson, 1998, *Research Briefs*, 37, 232-236. Copyright by “Journal of Nursing Education”.

This survey evaluates student perceptions of seven psychosocial dimensions of the classroom environment (Strayer, 2012). According to Clark, Norman, & Besterfield-Sacre (2014) previously flipped classroom research suggests several dimensions in the CUCEI are particularly relevant including: involvement, student cohesiveness, satisfaction, personalization,

and innovation. The dimensions previously found to be significantly different between flipped vs. traditional classrooms were task orientation, innovation, and involvement, with the latter two receiving higher scores in the flipped classroom (Strayer, 2012).

Following the CUCEI Likert scale, open-ended questions on they were added to allow for collection of quantitative data. The PI and CI analyzed the written responses for common themes. Below are sample Likert scale questions from the CUCEI on a student's perception of the flipped classroom.

- The pace of the course met my needs.
- The course was well organized.
- Course requirements were clear from the beginning.
- Scheduled class time was used efficiently.
- Adequate time for questions was provided.

The independent variable was pedagogical technique, which is the flipped classroom or traditional lecture style classroom. The dependent variables were retention of information, critical thinking, and student engagement. Covariates included: age, gender, years in college, and race. A summary of the instruments and the corresponding variables can be seen in Table 5.

Summary

In Chapter One the purpose, significance, and gaps in literature were presented. This study aimed to measure if there was a difference between the flipped and traditional classrooms in relation to retaining information, as measured by final exam scores. It also assessed if a difference existed between traditional and flipped classrooms in regards to student engagement, as measured by course evaluations. The study design based on current gaps in literature and the study aim was included.

Table 5

Variables: Identification, Descriptions, And Measurement

Variable Type	CLT Construct	Variable	Description	Measure	Data Type
Independent variable	Environment	Pedagogy	The method used to disseminate information.	Categorical	Categorical
Dependent Variable	Behavior	Student engagement	How attentive the student is during the lesson.	CUCEI	Continuous
Dependent Variable	Cognitive	Retention of Information	The amount of information that students are able to remember over the course of the semester.	Multiple choice score of Final Exam	Continuous
Dependent Variable	Cognitive	Critical thinking skills	Ability to apply information to a variety of situations	Open-ended questions score of Final Exam	Continuous
Covariates	N/A	Age	How old a person is numerically rounded to the nearest whole number	Age in years	Continuous
Covariates	N/A	Gender	Male or Female	Male =1 Female =2	Dichotomous
Covariates	N/A	Years in College	Number of years a student has spent in higher education.	Number of years in whole numbers	Continuous
Covariates	N/A	Race	The race that a student identifies most closely with.	White =1 Black =2 Hispanic =3 Asian =4 Middle Eastern = 5	Categorical

In Chapter Two the traditional and flipped classrooms were compared to the three different learning theories: behaviorism, cognitivism, and constructivism, along with a detailed explanation of each theory. The purpose for using the constructs of CLT in relations to the flipped classroom was also explored.

Chapter Three addressed the research questions and described the study's quasi-experimental design. The intervention was the use of the flipped classroom. The Radiation Safety class at Virginia Commonwealth University (VCU) served as the class used for the intervention. The course professor taught both the Spring 2016 and 2017 Radiation class. She taught the control group, students of the Spring 2016 class, using the traditional lecture style. For the experimental group, the Spring 2017 class, she used the flipped classroom. Radiation Safety is a mandatory class for any major that is included in Clinical Radiation Sciences, which leads to a diverse student population and low dropout rate. Each class consisted of approximately 40 students and was an hour and 40 minutes long. The same classroom was used for both classes: the class was an open space classroom with individual desks that could easily be moved. A comparison of the results between a flipped and traditional classroom used a MANOVA with a chi-square for the final exam and an ANOVA for the CUCEI.

Chapter Four details cohort inclusion and exclusion criteria. Demographic information for the College and University Environment Instrument (CUCEI) was analyzed for both cohorts and the study over all. The validity of the course is covered in statistical detail in reference to the flipped classroom checklist. A detailed statistical explanation of the results by exam and survey type for both sections of the Radiation Safety course was done. How these results were analyzed and the meaning of these results concluded the chapter.

Chapter Five will give an overview of the highlights of the study. It will also summarize the findings and interpret the results. The context of the findings in relation to Cognitive Learning Theory (CLT) will also be covered. Limitations of the study will be outlined and discussed and the future direction for similar studies will conclude the chapter.

Chapter 4 – Results

Overview

The proposed study compares student retention and critical thinking skills of the flipped and traditional classroom pedagogies. Retention and critical thinking skills are measured by final exams and also student engagement as measured by course evaluations. This study addressed the following null hypotheses:

H01: There will be no statistical difference between the multiple choice final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H02: There will be no statistical difference between the short answer questions on the final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H03: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses.,

H04: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

H05: There will be no statistical difference in the CUCEI subscales of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

If results fail to reject the null hypothesis, the study would add to the current body of evidence of how different teaching pedagogies impact retention of information and student engagement. Change in pedagogy could provide a way to assist in bridging the gap between

the retention of information while studying at accredited institutions and the level needed by entry level professionals in the work environment (Felder, 2012; Ertmer & Newby, 2013).

Introduction

This chapter will describe the outcomes of this project in relation to the proposed hypothesis and stated aims. This section includes information pertaining to participant demographics, enrollment, and previous flipped classroom experience. It describes the measures of the flipped classroom, the measures validity and analysis. This chapter also measures the implementation and delivery of the flipped classroom to Radiation Science students in terms of course completion and class evaluations (CUCEI), the cognitive and behavior constructs, respectively. This chapter details the flipped classroom assessment process and summarizes the final exam and CUCEI usage and outcomes. The final exam, multiple choice and short answer, and CUCEI scores will be used to evaluate the proposed hypotheses for this study. Throughout the study, potential threats to validity and inherent biases were also considered.

Study Population and Demographics

Study population. For the Spring 2016 traditional classroom course, VCU enrolled 35 students in the Radiation Safety course in the Radiation Sciences program: Radiography had the largest group of enrollees with 12, Radiation Therapy had 14, and Nuclear Medicine had nine. The distribution of college experience in the course was eight with two years, 12 students with three years, six students with four years, and five students with five or more years. For the Spring 2017 flipped classroom course, 30 students were enrolled in the Radiation Safety course in the Radiation Sciences program. The distribution of the students was comparable to that of the Spring 2016. The largest group was Radiography with 13, Radiation Therapy had 10, and Nuclear Medicine had seven. Of these 30 students, the college experience distribution was also

similar. Eight had two years of college experience, 13 had three years, four had four years, and five had five or more years. All 65 students were included in the study having met the requirements set forth for the study and approved by the Institutional Review Board (IRB). A breakdown of the traditional 2016 and flipped 2017 cohorts by discipline and years in college are shown in Tables 6 and 7.

Table 6

2016 vs 2017 Cohort Enrollment By Major In Radiation Science Program

Cohort	2016	2017	Total
Radiography	12 (34.29%)	13 (43.33%)	25 (38.46%)
Radiation Therapy	14 (40%)	10 (33.33%)	24 (36.92%)
Nuclear Medicine	9 (25.71%)	7 (23.34%)	16 (24.62%)
Total Discipline	35 (100%)	30 (100%)	65 (100%)

Table 7

2016 vs 2017 Cohort Enrollment By Years In College

Cohort	2016	2017	Total
2 or less	8 (22.86%)	8 (26.67%)	16 (24.62%)
Three years	12 (34.29%)	13 (43.33%)	25 (38.46%)
Four years	6 (17.14%)	4 (13.33%)	10 (15.38%)
Five or more years	5 (14.29%)	5 (16.67%)	10 (15.38%)
Total College	35 (100%)	30 (100%)	65 (100%)

A chi square (134.535, df=128, and p=0.329) for Table 6 to determine if discipline had an effect on cohorts showed no statistical difference. A second chi square (4.531, df = 6, and p=0.605) was done for Table 7 to determine if years of experience had an effect on cohorts also

showed no statistical difference. The lack of statistical significance in this test indicates that the disciplines and years in college were uniform between the two cohorts; increasing generalizability.

Demographic information. Data was missing for four students on age, gender, years in college, and race. Two students did not complete the demographic portion of the CUCEI and two dropped the course before the CUCEI was given. Therefore, overall percentage data for age, gender, years in college, and race was evaluated using 61 of the 65 participants, see Table 8.

Gender. The majority of the students enrolled in the study were female students (84%) and in their third year of college when taking this course. The 2016 cohort consisted of 87% females and the 2017 cohort consisted of 80% females. Males comprised 13% of the 2016 cohort and 20% of the 2017 cohort. While there were slightly fewer females in the 2017 cohort, this difference was not significant, which allowed gender to be a comparable variable between the two cohorts. The lack of statistically significant results means that there was no difference in male and female results on the flipped classroom versus the traditional classroom.

Race. The majority of students in the study (60.66%) reported their race as White. Those students identifying as White in 2016 made up 65% of the cohort and in 2017 made up 56% of the cohort. The second highest race group reported was Black (21.31%). Twenty three percent of the students in the 2016 cohort identified as Black compared to 20% of the 2017 cohort. The Hispanic group followed (8.2%), with 6% for the 2016 cohort and 10% of the 2017 cohort. Next was the Asian group (6.56%), with 6% of the 2016 cohort and 7% for the 2017 cohort. The lowest reported race group was Middle Eastern (3.28%). Only students in the 2017 cohort identified as Middle Eastern and they made up 7% of the students. The largest difference between cohorts was in those that identified as White and Middle Eastern.

Table 8

2016 vs 2017 Demographic Data And Analysis

Cohort	2016	2017	Total	Chi-square, df, and p-values
Gender				42, 32, 0.111
Female	27	24	51	
Male	4	6	10	
Race				134.535, 128, 0.329
White	20	17	37	
Black	7	6	13	
Hispanic	2	3	5	
Asian	2	2	4	
Middle Eastern	0	2	2	
College experience				209.263, 192, 0.187
Two years	8	8	16	
Three years	12	13	25	
Four years	6	4	10	
Five or more years	5	5	10	
Age				198.746, 192, 0.354
19	3	2	5	
20	6	12	18	
21	9	4	13	
22	3	4	7	
23	2	3	5	
24	3	0	3	
25 or older	5	5	10	

However, these differences were not significant allowing race to be compared between cohorts. Race was non-significant in pedagogy preference.

Age. The age of participants ranged from 19 to 48. The mode age reported was 20 years, while the median value was 21 years. The average age was calculated to be 22.8 years with a

standard deviation of 5.266. The reported ages were divided into one-year intervals for ages 19-24 and those that were 25 or older were grouped together. Based on these groupings, the majority of responding students fell into the 20 (29.5%) and 21(21.3%) year categories, the typical age for students in their first year of their respective disciplines. There was some discrepancy in the size of each age group between cohorts; however, it was determined that age was still a comparable variable for the study. While age was a comparable variable, a review of the results of the CUCEI indicated that age did not play a role in determining their preference of pedagogy.

Case elimination. All 65 students enrolled in the 2016 (35) and 2017 (30) cohorts participated in the study, as the IRB deemed that consent was not needed. In order to be considered in the study, students needed to complete the final exam on the designated date and time. Those that needed to take the exam on a different day were not given the CUCEI and had incomplete data sets. Two of the 35 students from the 2016 cohort did not complete both the final exam and the CUCEI. All data collected from these two students was removed prior to data analysis, leaving a total of 63 students. Additionally, two other students chose to drop the course during the 2016 semester and no data was able to be collected on them. These two students did not complete the course and therefore did not complete all the traditional classroom material nor take the CUCEI or final exam. Due to incomplete datasets, these two students were excluded from data analysis. Therefore, as shown in Figure 3, a total of 61 Radiation Science students completed the course, the CUCEI, and met the requirements: 31 in the 2016 cohort and 30 in the 2017 cohort. The two cohorts were approximately the same size making the samples more comparable and increasing the clarity of the effect of pedagogy on the results.

Skew and kurtosis was evaluated for outliers in the distribution of each of the DVs.

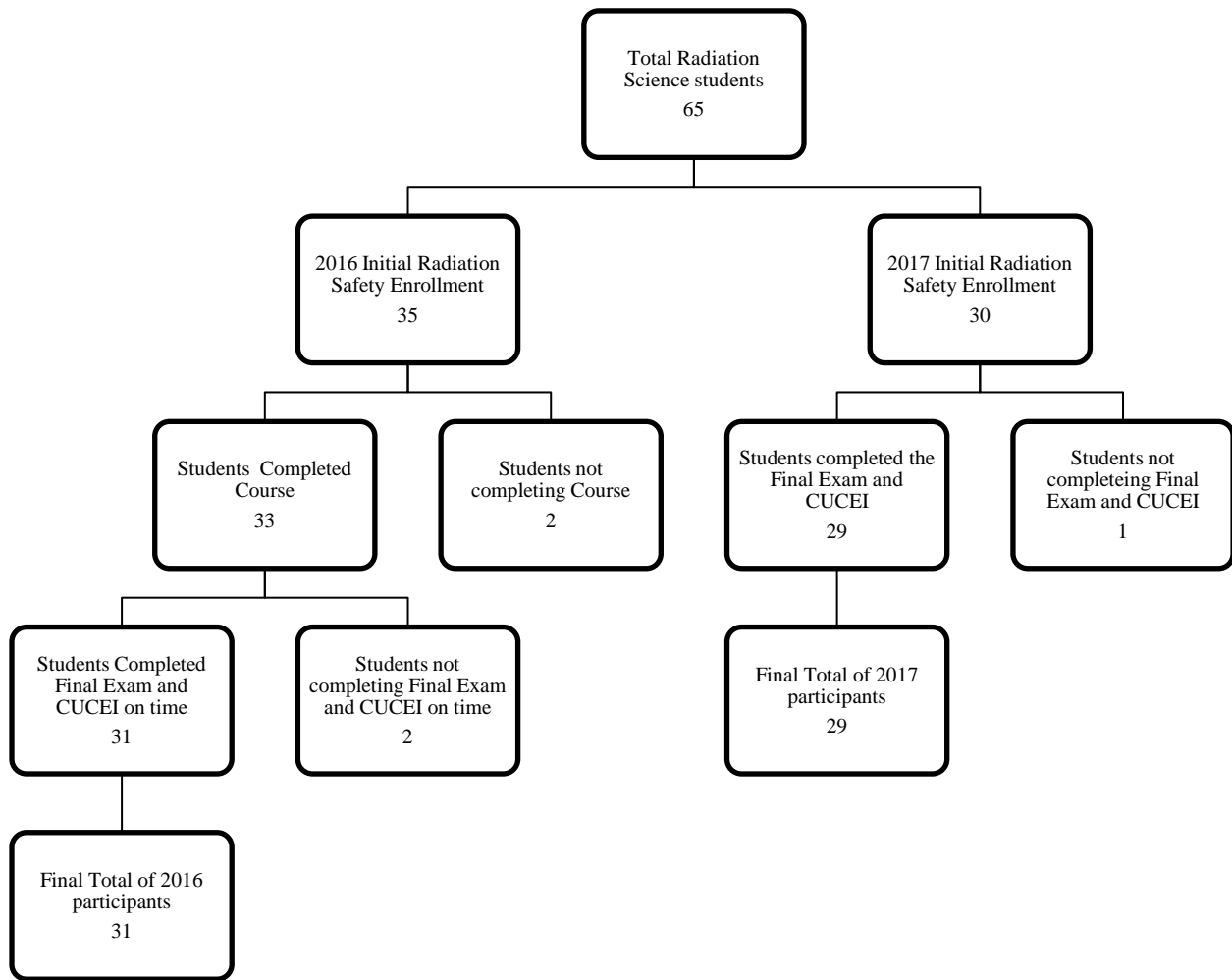


Figure 3

Students Included In Data Analysis

Skewness and kurtosis results suggest distributions of the DVs were not statistically significant different from a normal distribution. This was evaluated by computing standard skew and kurtosis scores for each pedagogy group for each DV where a z score equivalent measure of skew and kurtosis was 3 or greater: see Table 9.

Table 9

Preliminary Data Results

	Skewness	Kurtosis	N
Exam 1:	-0.932	1.013	63
Exam 2:	-1.196	1.223	63
CUCEI:	-0.424	-0.823	61

Course Validity

Faculty evaluation. Two faculty members from the VCU Radiation Science program were asked to review the implementation of the flipped classroom, using the evaluation form in Appendix A. Faculty members were chosen randomly based on availability. If faculty members were teaching during the same time, they would not be able to observe the Radiation Safety class. Faculty members also needed to teach in one of the three majors under the Radiation Science program that require the Radiation Safety course for graduation. This evaluation was used to assess the validity, also known as fidelity, of the flipped classroom. All invited faculty members participated and submitted the evaluation document by the date requested and completed all sections and questions.

Once the faculty members were selected, they chose a date to observe. The date of observation was not revealed to the instructor. In order to assess the authenticity of the flipped classroom, the observer used a modified checklist form based on the University of Utah Flipped Classroom Observation short form. The form consisted of two main categories: Lesson Plan and Instructor-Student & Student-Student Interactions. The subcategories that were assessed within

the Lesson Plan category are: Warm-up/Review, Practice Phase of Lesson, Teaching Technology, and Wrap-up. There are no subcategories for Instructor-Student & Student-Student Interactions.

In order for satisfactory presence of each of the subcategories for Lesson Plan a certain number of criteria must be met. There are four criteria for Warm-up/Review, seven for Practice Phase of Lesson, one for Teaching Technology, and two for Wrap-up. The Instructor-Student & Student-Student Interactions category has five criteria that must be met. Those categories and subcategories with more criteria are more important in the implementation of the flipped classroom than those with fewer. A breakdown of categories, subcategories, and criteria can be seen in Figure 4. If any of the criteria are not met in any of the subcategories or categories, then the classroom does not meet the flipped classroom requirements. Both evaluators agreed that each criterion had been met in all categories and subcategories. Due to the satisfactory completion of all categories, the flipped classroom was determined to be valid and have fidelity. Agreement by both evaluators shows inter-rater reliability of the groups of the IV.

Course Results

Final exam. The final exam was administered during the designated time of finals week at VCU for both the 2016 and 2017 cohorts. There were two parts to the final exam: multiple choice and free response or short answer. The content for the Radiation Safety course was modified prior to the start of the Spring 2016 course. This was done to ensure only the necessary content was covered. The final exam was analyzed after the content change to ensure that the exam contained only the information included in the new content. Analysis was performed comparing the 2016 and 2017 results on the two parts separately; overall exam scores were not analyzed.

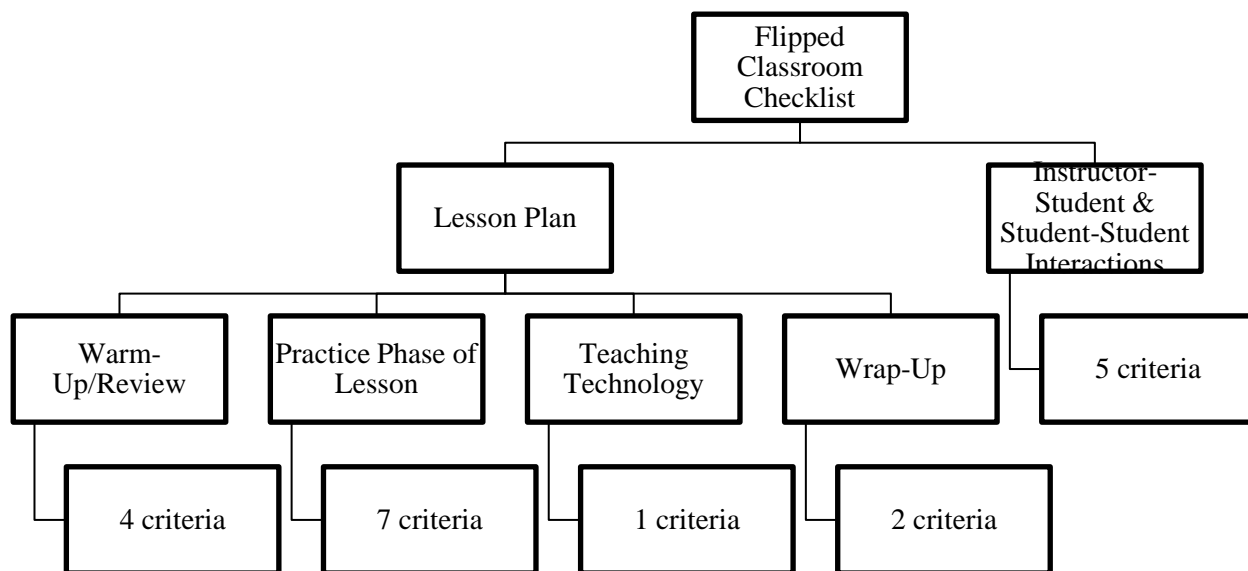


Figure 4

Breakdown Of Flipped Classroom Checklist

Analysis of the overall exam scores would not delineate between retention and critical thinking skills. The intervention, the Flipped Classroom, was implemented starting in week one of Spring 2017 and concluded in week 15 of Spring 2017. All grading was done by a teacher's assistant within the Radiation Science department.

Analysis of the first research question, does a change in teaching pedagogy in a Radiation Safety course make a difference in retention of information, critical thinking, and student engagement, was done using MANOVA with follow-up simple F tests and oneway ANOVA. Final exam results between the 2016 and 2017 cohorts were analyzed to test the first hypothesis for each research question posed for this study. Null hypothesis one for this study was: there will be no statistical difference between the multiple choice and short answer final exam scores in the Spring 2016 and Spring 2017 Radiation Safety courses. Multiple choice scores were compared to determine how retention was affected and short answer questions were compared to determine if

critical thinking skills had been affected. Both retention and critical thinking skills relate to the cognitive construct of CLT.

The change in score for both the multiple choice and short answer questions between the 2016 and 2017 cohorts was evaluated using MANOVA to find the centroids formed by the best linear combination of EXAM1 and EXAM2. Separate oneway analysis for EXAM1 and EXAM2 were done as follow-up tests. These tests helped to determine if the null hypothesis should be accepted or rejected. Null hypothesis one states that there will be no statistical difference between the multiple choice final exam scores, retention, (EXAM1) in the traditional and flipped pedagogies used in the Radiation Safety courses. For this analysis, significance was determined using an alpha of 0.05 and a power of 0.58. This study did not produce a significant change in student performance to multiple choice questions between the 2016 and 2017 cohorts.

Null hypothesis two states that there will be no statistical difference between the short answer questions, critical thinking skills, (EXAM2) on the final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses. This study did not produce a significant change in short answer questions between the 2016 and 2017 cohorts. Results of the MANOVA can be seen in Table 10.

Table 10

MANOVA Summary Results

Test name	Value	Exact F	Hypoth. DF	Error DF	Significance of F
Pillais	0.01005	0.30464	2.00	60.00	0.739
Hotellings	0.01015	0.30464	2.00	60.00	0.739
Wilks	0.98995	0.30464	2.00	60.00	0.739
Roys	0.01005				

The average multiple choice and short answer question scores for the 2016 cohort were 85.9/100 and 8.28/10, respectively. For the 2017 cohort, the average multiple choice and short answer

question scores were 86.14/100 and 8.48/10, respectively. The standard deviation for the 2016 and 2017 multiple choice scores were 6.51 and 7.11, respectively. For the 2016 and 2017 short answer questions, the standard deviations were 1.64 and 1.84, respectively. The p-value, based on Bartlett-Box F with 1/11091 degrees of freedom, for the multiple choice was determined to be 0.610 and for the short answer was 0.668. A Bonferroni correction was performed on the p-values due to follow up testing. Additional output results on the Wilk's lambda test provided a value of 0.98995 and a significance of F value of 0.739. Based on these results, null hypotheses one and two were accepted, indicating that there was no significant difference in exam or short answer scores between the 2016 traditional classroom and the 2017 flipped classroom. EXAM1 and EXAM2 were determined to be equally important indicating a step-down analysis was not needed. See Tables 11 and 12 for further follow-up analysis.

Table 11

Verification Of Homogeneity Of Groups For EXAM 1 (Multiple Choice)

	Mean	Standard Deviation	P-value	Univariate F	Degrees of Freedom
2016	85.9	6.51			
2017	86.1	7.11			
Total – 2016 and 2017	86.3	6.14	0.610	0.5534	1/61

Table 12

Verification Of Homogeneity Of Groups For EXAM 2 (Short Answer)

	Mean	Standard Deviation	P-value	Univariate F	Degrees of Freedom
2016	8.28	8.48			
2017	8.48	1.84			
Total – 2016 and 2017	8.43	1.67	0.668	0.2598	1/61

CUCEI. The overall College and University Course Environment Inventory (CUCEI) scores ranged from 0 to 212 depending on how the student scored each answer. The answer for each question was based on a four point Likert scale: Strongly Agree, Agree, Disagree, and

Strongly Disagree. These statements were converted to numerical scores for interpretation. A scale from one to four, whole numbers, was used for the numerical interpretation starting with a four representing Strongly Agree to a one representing Strongly Disagree. The following questions were negatively worded and therefore scored inversely: 1, 22, 23, 25, 29, 33, 38, 40, 41, 42, 43, 50, 51, and 53. Using a CUCEI scoring sheet, the CI identified the questions in the modified CUCEI made for this course and manually went through and inverted the scores. The CI went through the scores twice and had a third party go through the scores twice as well to ensure they were properly inverted.

The CUCEI numerical scores were used to evaluate null hypothesis three proposed for this study. The hypothesis stated that there will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses. The change in scores from the 2016 to 2017 cohorts was evaluated using an ANOVA to determine whether flipped classrooms changed course engagement scores compared to traditional classrooms. For this analysis, significance was determined by using an alpha of 0.05 and a power of 0.58. This study did not produce significant changes between the 2016 traditional and 2017 flipped classrooms. The average 2016 traditional classroom score was 149.32 with a standard deviation of 15.78. The average 2017 flipped classroom score was 154.27 with a standard deviation of 14.28. Using an ANOVA, the p-value was determined to be .089 and the F statistic was 3.001 with 1/59 degrees of freedom. See Table 13 for a summary of the CUCEI ANOVA summary results.

Based on these results, the null hypothesis was accepted, indicating that there was no significant difference in student engagement scores for Radiation Science students before and after the flipped classroom intervention.

Table 13

CUCEI ANOVA Summary Results

	Sum of Squares	df	Mean square	F	Significance
Between groups	681.947	1	681.947	3.001	0.089
Within groups	13180.636	58	227.252		
Total	13862.583	59			

Covariates – demographics – were analyzed to determine if there was an effect between the 2016 and 2017 cohorts on the CUCEI; none of them showed significance. Table 14 displays the overall CUCEI change results and descriptive statistics for this data set.

Table 14

Changes Between 2016 And 2017 CUCEI Scores

	CUCEI	
	2016	2017
Mean	149.32	154.27
Standard Deviation	15.78	14.28

The quartile data indicates that the range for the 2016 CUCEI was 129-182 and 131-184 for 2017. Twenty-five percent of the scores fell below 138 for 2016 and 146.5 for 2017. The median for 2016 was 143 and for 2017 it was 153. The data also indicated 75% of the scores for 2016 were below 162 and for 2017 they were below 165.

Category evaluation. Students’ overall scores for the CUCEI were divided into seven categories based on the different criteria needed to qualify as a flipped classroom. This was done to address the second research question: do age, gender, years in college, and race impact how students view the flipped classroom. The question number that is associated with each category is shown in Table 15.

Table 15

Question And Category Assignment

Category	Personalization	Involvement	Students Cohesiveness	Satisfaction	Task Orientation	Innovation	Individualization
Question number	21, 26, 32, 36, 40, 44	16, 22, 27, 33, 37, 45, 50	23, 28, 38, 41, 43, 51	24,29, 34, 42, 47, 52	2, 3, 4, 9, 11, 30	31, 35, 39, 43, 48, 53	1, 25,54

The fourth null hypothesis stated that there will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates. The scores for each category were averaged to give an overall interpretation of the results. The categories involvement, students cohesiveness, satisfaction, task orientation, innovation, and individualization all showed positive changes in scores between the 2016 and 2017 cohorts. Personalization was the only category to show a negative change in score between the 2016 and 2017 cohorts. The category results for the CUCEI are shown in Table 16.

Table 16

Changes Between 2016 And 2017 CUCEI Scores And Category Result Averages

Category	Personalization	Involvement	Students Cohesiveness	Satisfaction	Task Orientation	Innovation	Individualization
2016 Average	3.37788	3.44701	3.26344	3.14516	3.67204	2.88172	2.65591
2017 Average	3.31429	3.63333	3.66111	3.39444	3.98889	3.06667	2.73333
Overall Average	3.34609	3.54017	3.462275	3.2698	3.83047	2.97420	2.69462
Change in Score	-0.06359	0.18632	0.39767	0.24928	0.31685	0.18495	0.07742

When an ANOVA was done on the individual categories, satisfaction and innovation showed significant results. These results indicate that the flipped classroom pedagogy, compared to the traditional pedagogy, had a positive influence on student’s enjoyment; students also felt

that new and different teaching and learning activities were used more frequently. The categories showing no significant results were: individualization, task orientation, student cohesiveness, involvement, and personalization. However, both student cohesiveness and involvement approached significance, as shown in Table 17.

Table 17

ANOVA Results By Category With P, F And df Values

Category	Personalization	Involvement	Students Cohesiveness	Satisfaction	Task Orientation	Innovation	Individualization
P-value	0.483	0.053	0.052	0.025*	0.262	0.004*	0.760
F stat	0.493	3.772	3.808	5.100	1.260	8.475	0.094
df effect/ df total	1/60	1/60	1/60	1/60	1/60	1/60	1/60

* Indicates results that have significance.

Effects of demographics. The fifth null hypothesis stated that there will be no statistical difference in the CUCEI subscales of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates. After initial analysis, student overall scores for the CUCEI were analyzed based on the following demographics: gender, age, years in college, and race. Demographic analysis was done to determine if there was a correlation between individual demographics and student engagement.

An ANCOVA was run to determine if any of the demographics had a significant effect on the CUCEI results. While pedagogy did have some effect on the demographic statistics, it was not significant. Demographics, in order of most to least impactful are: gender, age, race and years in college. The impact of demographics was shown to not be significant on the CUCEI scores; therefore, the demographics chosen do not play a major role in determining student engagement in the classroom.

Summary

In Chapter One the purpose, significance, and gaps in literature were presented. This study aimed to measure if there was a difference between the flipped and traditional classrooms in relation to retaining information, as measured by final exam scores. It also assessed if a difference existed between traditional and flipped classrooms in regards to student engagement, as measured by course evaluations. The study design based on current gaps in literature and the study aim was included.

In Chapter Two the traditional and flipped classrooms were compared to the three different learning theories: behaviorism, cognitivism, and constructivism, along with a detailed explanation of each theory. The purpose for using the constructs of CLT in relations to the flipped classroom was also explored.

Chapter 3 presents a review of the research design. A detailed description of participant inclusion and exclusion criteria will be covered. The method for statistical evaluation and why it was appropriate will also be discussed. The variables will be identified. The validity and reliability of the final exams, and CUCEI will be reviewed in relation to Bloom's taxonomy in conjunction with CLT.

Results discussed in Chapter Four indicated that the null hypotheses were to be accepted. MANOVA results for the multiple choice and short answer scores were not significant. The ANOVA results for the overall CUCEI scores and the categories involvement and student cohesiveness neared significance. The categories of innovation and satisfaction on the CUCEI were the only ones to show significant results. Demographics (age, gender, race, and years in college) were analyzed using ANCOVA and did not produce significant results. While the

overall results did not show significance, there were overall increases in scores for both parts of the final exam and the CUCEI.

Chapter Five will give an overview of the highlights of the study. A summary of the findings is given and how the results were interpreted is also covered. The context of the findings in relation to Cognitive Learning Theory (CLT) is also covered. Limitations of the study will be outlined and discussed and the future direction for similar studies concludes the chapter.

Chapter 5 – Discussion

Overview

This study assessed how the flipped classroom affects academic performance in comparison to a traditional classroom. The three constructs of Cognitive Learning Theory (CLT), environment, behavior, and cognitive, were used to design the flipped classroom. The purpose of this study was to investigate the difference in multiple choice and short answer final exam and CUCEI scores for Radiation Science students before and after the flipped classroom intervention. Final exam scores were used as a measure of students' retention capabilities and CUCEI scores assessed student engagement within the classroom. The researcher chose final exam and CUCEI scores based on the environment and cognitive constructs of CLT to see how they affect learning outcomes.

The study compared the flipped and traditional classroom pedagogies on three dimensions: retention and critical thinking skills as measured by final exams, and student engagement, as measured by course evaluations. There were five hypotheses addressed in this study in relation to the aforementioned aim. The null hypotheses for this study were:

H01: There will be no statistical difference between the multiple choice final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H02: There will be no statistical difference between the short answer questions on the final exam scores in the traditional and flipped pedagogies used in the Radiation Safety courses.

H03: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses.,

H04: There will be no statistical difference between the course engagement survey scores of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

H05: There will be no statistical difference in the CUCEI subscales of the traditional and flipped pedagogies used in the Radiation Safety courses after adjusting for covariates.

Improvement of student engagement and retention, due to pedagogy changes, could assist in alleviating weaknesses in critical thinking and problem solving skills of new employees in healthcare professions, as identified by employers (Felder, 2012; Ertmer & Newby, 2013). If changes in pedagogy show significant results, this would identify one potential way to bridge the gap between what abilities students are graduating with and what is expected of them upon hire.

Summary of Findings

The aim of this study was addressed through the design, implementation, and assessment of flipped and traditional classroom on retention and student engagement scores. The researcher conducted a mixed methods quasi-experimental design using two groups: one group received a traditional pedagogy, and the second group received a flipped pedagogy. A convenience sample of students in the Radiation Science program at Virginia Commonwealth University was used. The study results did not show a significant difference between the scores achieved on the Final Exam and CUCEI for the traditional cohort in 2016 and the flipped cohort in 2017. Therefore, the null hypotheses were rejected in favor of the alternative hypotheses.

Based on previous studies (Strayer, 2012; Clark, et al., 2014; Fisher & Parkinson, 1998; Butzler, 2014), using the CUCEI in the Radiation Safety class at VCU was appropriate to achieve statistically significant results. Studies (Strayer, 2012; Clark, et al., 2014; Fisher & Parkinson, 1998; Butzler, 2014) have shown that small non-laboratory lecture-based classes with a sample size for each cohort of approximately 30 are a good fit for the CUCEI. Although the overall change results used to evaluate the hypotheses showed no significant difference in student retention or engagement before and after the flipped classroom intervention, further investigation of relationships between demographics and CUCEI scores should be completed.

An ANCOVA model including gender, age, years in college, and race compared to pedagogy were not significant in predicting the CUCEI scores. Evaluating the interaction with these variables and the outcome variable did not provide additional insight as to what population would benefit the most from the flipped classroom pedagogy that might have contributed to the overall study results. The small sample size in the different categories did not provide enough power to provide significant results. Although this study was designed to evaluate retention and student engagement, results of the categories and demographics were examined to ascertain additional information about the model design and assessment instruments utilized.

Interpretation of Findings

The model which was designed, implemented, and assessed for this study failed to show a significant improvement in retention or student engagement for the students included in the study. MANOVA results for the Final Exam showed an increase in scores from the 2016 cohort to the 2017 cohort; however, the results were not significant. Results for the ANOVA done on CUCEI scores showed a strong correlation between student engagement and pedagogy. Even though the correlation was strong, it was not significant. While the overall CUCEI scores did not

prove significant, analysis of individual categories of the CUCEI showed that satisfaction and innovation produced significant results. The significant results of satisfaction and innovation indicate that students enjoyed class more and found that there were a wider variety of teaching and learning activities used in the flipped classroom compared to the traditional classroom pedagogy. These results along with the lack of negative change in final exam scores between cohorts indicate that professors should explore alternative teaching pedagogies. Exploration of alternative teaching pedagogies should be of those that the professor feels comfortable with. Having professors use a teaching pedagogy that they are comfortable with could allow them to better convey content to students. The researcher compared demographics based on age, gender, years in college, and race to CUCEI scores to determine if there were any predictive relationships. Results showed there was no correlation between any of the demographics and CUCEI scores.

Context of Findings

The flipped and traditional classrooms both contained the same content, learning objectives, themes, and concepts; however, only the flipped classroom used the projects, case studies, article reviews, and research paper activities. Units for both cohorts illustrated the connection between the themes and concepts with the learning objectives and a course overview was given to assist in guiding students through the course. For the flipped classroom, the professor asked students to watch pre-recorded lectures at home and do a variety of activities in-class that reinforced the content viewed the night before. These activities included article reviews, case studies, projects, and research assignments. Students applied concepts from the homework to the activity for the class period with the help of the professor and electronic

resources as references. The duration of the Radiation Safety course was a single 15 week semester.

The researcher developed content and activities for the Radiation Safety course in this study which incorporated the constructs of Cognitive Learning Theory (CLT), environment and how the brain processes information. The students completed the CUCEI at the end of the Radiation Safety course and after the final exam. There was a decrease in scores reflective of individualization between the traditional and flipped classrooms. With individualization defined as the extent to which students are allowed to make decisions and are treated differently. Based on, these results, there is a need for more individualization within the flipped classroom model. The faculty within the Radiation Science department found that the flipped classroom designed for this study contained all parts (Warm-up/Review, Practice phase, and Wrap-up) deemed necessary by the modified checklist from The University of Utah. This assisted in determining that the flipped classroom was different than the traditional classroom for the Radiation Safety course. Studies found in the literature utilizing CLT did not empirically evaluate student engagement or retention, but provided some insight into successful model design and implementation.

A study from the Pennsylvania College of Technology (Penn College) shares some similarities with the flipped classroom pedagogy and observations made about the affect on CUCEI, and final exam scores (Butzler, 2014). The Penn College course studied the effects of motivation among non-science majors using CUCEI scores. There were some differences in the use of the learning theories, this seminal study on the Radiation Safety course used cognitivism and Penn College used constructivism, and their associated constructs. Although students from the Penn College study provided positive responses to the content and flipped classroom

pedagogy, faculty observations were not made to determine if the flipped classroom met the necessary requirements (Butzler, 2014). While content of the two courses differs, if both are authentic flipped classrooms, the presentation of the material should be done in a similar fashion.

Additional studies found in the literature shared some overlap with constructs related to CLT and those utilized in this study but were not designed using this theory (Strayer, 2012; Williams, 1995; Butzler, 2014; Mattis, 2015; McLaughlin, et al., 2014; Gilboy, et al., 2015). These studies showed some success with incorporation of a similar design and implementation strategies. A study in the area of Nutrition compared the flipped and traditional classroom pedagogies using the constructivist theory. Though there were no retention assessments, this method was reported to have positive results for graded case studies and engagement levels among students in the nutrition discipline (Gilboy, et al., 2015). A study in the area of Anatomy used the flipped classroom pedagogy to evaluate the effect of pedagogy over traditional lecture pedagogy on analysis and retention. The Morton and Colbert-Getz (2016) study showed that although the flipped classroom pedagogy improved analysis results and increased retention scores, it was not significantly compared to the traditional classroom pedagogy.

The literature search produced studies indicating both positive and negative results between the flipped and traditional classroom pedagogies for improving retention (Baepler, et al., 2014; Tune, et al., 2013; Mortensen & Nicholson, 2015). In a study conducted by Butzler (2014), student engagement surveys for an Environmental Science elective were influenced by different instructors, the elective nature of the course, and insufficient sample size. However, none of these studies were in the Radiation Sciences nor did they use the CUCEI.

The design and structure of this Radiation Safety course corresponded with much of the literature regarding retention and student engagement in relation to constructs similar to CLT.

This suggests that the flipped classroom may have utility in yielding positive results for retention and student engagement. Based on student and faculty evaluations, the flipped classroom design meets the necessary requirements to be classified as such. According to Hantla (2014), the previous experience of the professor with the flipped classroom can influence the success of the course. However, conducting research to determine what other professors have done for similar classes and using evaluation forms to determine if the flipped classroom meets necessary requirements can also assist professors new to flipping (Hantla, 2014). Hantla (2014), also noted that trial and error played a significant role in determining what worked for each professor and their students.

The researcher evaluated the hypotheses using final exam and CUCEI scores. For this seminal study on the Radiation Safety course, no significant difference was observed between the 2016 traditional classroom and 2017 flipped classroom for these indicators. Further analysis using ANCOVA of the CUCEI scores and collected demographics showed no significance. A study conducted by Farris (2014) examined the effects of demographics on CUCEI scores. Farris (2014) found that prior degree and class rank, equivalent to years in college for this study, had a negative effect on flipped classroom perceptions. The other demographics, including, race, gender, and age, did not show an effect on the CUCEI scores in Farris's study (2014). Since Farris's (2014) study examined the nursing program as a whole and not just one specific class, the difficulty and type of content was not emphasized. Since such a variety of types of classes were included, the findings are able to be generalized to a various other classes. Results for the CUCEI were similar to what was found in this study. Demographics though, showed significant impact on CUCEI scores in Farris's study (2014) whereas this study of the Radiation Safety course did not. The findings of these two studies are not contradictory however.

Limitations

There are a number of limitations associated with the mixed methods quasi-experimental design using a purposeful sample from a single institution used for this study. Potential threats to the internal validity include history, maturation, mortality, testing, and instrumentation. External validity can also be susceptible to influence from interactions between the control and experimental groups, interactions between the experimental group and the intervention, and interactions between the setting and the intervention. The researcher decreased the volume of content before the implementation of the traditional classroom to decrease maturation threats. The researcher also collected demographic data to control for mortality and selection threats. Length of time to complete both the final exam and CUCEI was assessed to decrease instrumentation threats. The common internal and external validity threats were considered in the study design, implementation, and assessment. Extraneous variables were also considered.

It was not possible to eliminate the effects of history and maturation in this study. In order to try to minimize the effect of history, course objectives for all courses relevant to radiation safety were examined. Any overlap found between courses was eliminated or changed to reflect an emphasis on the importance of the objective in radiation safety. However, learning from other courses and outside experiences will always be a factor. These experiences vary for all students and were not controlled for or measured in regards to this study. The material was condensed to focus on radiation safety topics to help control maturation. Additionally, the intervention was limited to a single semester. However, student fatigue regarding the subject may still have been a factor as the semester progressed. This aspect was not specifically tracked for this study. An assumption was also made on the compliance of students in reference to watching the assigned video lectures. While the course professor, the course instructor, made the

videos available to students, data was able to be collected on if students had watched the videos; however, only the last date the student viewed the video was available. The number of times the student may have watched the video was not available.

The study minimized mortality with the mandatory nature of the radiation safety course. It is a prerequisite for courses students need the following semester; this leads to a dropout rate of only one or two students each semester. The effects of mortality were further reduced by not including data from students that did not complete both the final exam and CUCEI in the statistical analysis. Therefore, the final exam and CUCEI data used for hypotheses testing was composed of results from the same group of students.

The study parameters helped to control for instrumentation bias. The delivery of the final exam and CUCEI occurred in a consistent manner, utilizing the same paper testing forms with constant room conditions and scheduling for both cohorts. To avoid bias through changes in the testing instrument, both the 2016 and 2017 cohort used the same test for the final exam and CUCEI. Someone other than the instructor graded the tests to avoid introducing any confirmation bias.

Another limitation of this study relates to the external validity. This study was only conducted at a single institution using a purposeful sample of students; therefore, the results are not generalizable to other radiation science programs. Three concerns with external validity for this study are interactions between the control and experimental groups, interactions between the experimental group and the intervention, and interactions between the setting and the intervention. Although the student population at VCU is diverse in age and race and is balanced in gender, this population may not be representative of student body populations seen at other institutions. Although the VCU education setting and curriculum meet accreditation

requirements, they will vary to some extent in terms of student course load and rigor in comparison to other institutions.

There are some implied assumptions that form the foundation of the flipped classroom that present limitations to the study. One of these assumptions is that students will prepare ahead of class. In order for the students to get the most out of a class they need to watch the designated videos before arriving to class. If the students have not watched the videos they will not be prepared to participate in the designated class activity. Another assumption is that traditional pedagogy only involves lecture. However, there may be instance when discussions occur, short in-class activities happen, or other student-professor interactions transpire. When these interactions happen between the students and professor the difference in student engagement between the two pedagogies becomes null. Lastly, the assumption that improved learning was a result of the flipped classroom and not due to other reasons. While pedagogy could play a role in how students learn it is also important to look at other influences. The professor's personality and their ability to create relationships with students could also cause students to perform better in class. Students may also enjoy the change of delivery from standard lecture leading them to become more engaged, even if it was not flipped classroom pedagogy. If these implied assumptions were not recognized the results could incorrectly assigned to the flipped classroom pedagogy.

There are several extraneous variables that may have impacted results of both pedagogies that were not examined, see Table 18. The flipped classroom may benefit some learning styles more than others. Those who are primarily auditory learners learn best by listening and may prefer a traditional lecture style class. The strength of intrinsic motivation that students have may impact how involved they are in the class.

Table 18

Student Related Extraneous Factors

Extraneous Factor	Explanation
Learning Style	A student’s unique approach to learning according to their strengths and weaknesses.
Extrinsic Motivation	Behavior that is driven by outside rewards, such as grades.
Intrinsic Motivation	The activity brings about the behavior because the activity is enjoyed.
Prior Academic performance	Students grade point average in other classes, in particular those in Radiation Sciences.
Outside responsibilities	These include things like: jobs, marital status, and if they have any children.
Organization Skills	Ability to use ones time, resources, and energy to accomplish the desired task.

Since the Radiation Safety course is a mandatory course, intrinsic motivation is likely lower than with a class of the student’s choosing. For those who would not have chosen the class, a lack of interest in the content or thinking the course is not relevant to their career may have a negative influence on their intrinsic motivation. Students with a lower GPA at the start of the course may have improved their GPA due to the Radiation Safety flipped classroom, which would demonstrate a higher impact of the flipped classroom than what was determined. The number of outside responsibilities may impact how much time students spent preparing for a class. As completion of the at home material is essential to success in the flipped classroom, organizational skills could have impacted scores. Students who struggle with organization may have found it more difficult to complete the lectures and therefore also been less engaged in class.

There were also extraneous variables relating to the professor that were not measured in this study, see Table 19.

Table 19

Professor Related Extraneous Factors

Extraneous Factor	Explanation
Past experience with the flipped classroom	Professors that have previously taught using the flipped classroom pedagogy, taken training courses on it, or been a part of a flipped classroom.
Course load	The number of classes a professor teaches each semester.
Class schedule	The frequency of each class, the day and time that each course is offered that the professor teaches.
Prior experience in education	Degrees in education, professional development in education, and/or teaching experience in primary or secondary education.

Professors with prior flipped classroom experience are more comfortable with the flow of the class and its implementation. Since a large part of determining what works for each professor and their students is trial and error (Hantla, 2014), a professor with less experience faces a larger learning curve than one with more experience. This lack of experience could affect how students feel about the flipped classroom. Flipped classrooms take longer to prepare initially due to the number of activities and pre-recorded lectures that need to be done. Due to the increased time requirement upfront, professors with heavier course loads may find it more difficult to properly prepare or implement the flipped classroom compared to those with lighter loads. Course load could also be directly related to a professor’s class schedule. Having back-to-back classes can make it more difficult to properly prepare for different classes, especially if they are all flipped. Time between classes could allow a professor to become more comfortable with what is going to be done in class that day and prepare necessary materials. Professors with prior educational experience, specifically those with degrees in the field of education, could influence how a professor views and understands a flipped classroom. Having prior experience in education could

make the lesson planning and development of activities easier. Understanding the foundation of the flipped classroom and other teaching theories could also help guide a professor in preparing their flipped classroom. All of these could impact how a student views the flipped classroom and their reception of it.

Finally, extraneous factors about course content and class setting that were not assessed in this study include interest in the content, the mandatory nature of course, and the physical space. Student interest in the content can influence how engaged they are during the class. With classes that have more structured and mandatory content, there is less flexibility in what the class can cover making it more difficult to gain students attention and engage them. When courses are mandatory, students may be less interested in taking the class and more interested in getting through the content to continue on to higher level classes that they may prefer to take; this also makes it more difficult to engage them.

The physical space where the class takes place could also impact how students perceive a flipped classroom. Classrooms that have various levels, fixed seats, poles, or other obstacles make it difficult or impossible to arrange students into groups comfortably for long periods of time. Larger classrooms also make it more likely that students will disengage as they can sit further back, making it harder for a professor to engage them. Due to the frequent use of technology in flipped classrooms, a lack of power outlets or inconveniently placed outlets may affect how students participate in class. Class size may influence how students view a flipped classroom if this leads to crowded table space and an overall lack of resources. The day of the week and hour the class was held may have also influenced the students focus on class material.

The results based on MANOVA, ANOVA, and ANCOVA models, final exam scores and faculty evaluations have limited validity. Due to a smaller than expected class size the proper

alpha was not reached; this means that results could be contributed to chance and not the flipped classroom pedagogy. The ANCOVA results referenced in this study were based on self-reported demographic characteristics affecting the reliability of the results in this area. Two faculty members completed the faculty evaluations, both of which work at VCU; again this could affect the reliability of the results. Results from these instruments are discussed, along with their implications; however, no conclusions about the results can be drawn without further analysis.

Future Directions

Although this study resulted in no significant change in retention and student engagement for radiation science students after the implementation of the flipped classroom, it serves as a starting point for future studies. A number of gaps exist in the literature related to pedagogy effectiveness and the radiation science professions. Although this study attempted to fill a number of these gaps, more work needs to be done in order to fully evaluate this topic and construct a method for improving retention and student engagement in this population. It will also be important to ensure all assessment tools are valid and reliable.

To minimize additional validity threats, the study could be repeated using more than one cohort for both the traditional and flipped classrooms. It may not be possible to conduct a true experimental analysis with a randomized sample; however, increasing the number of cohorts for both pedagogies and extending this study to multiple institutions has the potential to increase the sample size and statistical power. Additionally, adding more institutions will likely result in more generalizable findings. A large, diverse sample of multiple sections of the same class would also assist in confirming or contradicting the relationships observed between the demographic data, such as age, gender, race, and years in college in relation to the CUCEI scores.

For a more thorough result analysis, there are several other assessments that could allow for a more complete picture of how the flipped and traditional pedagogies compare. To determine how extraneous variables affect students, the following surveys or data could be conducted: learning style test, motivation survey, collection of GPA data, and surveys on outside responsibilities and organization skills. Using these surveys or collecting the aforementioned data can help determine if some of the extraneous variables played a role in how the students viewed or participated in the flipped classroom. Gathering data on student interest in the content, the impact of the mandatory nature of the class on motivation and interest, and how the physical classroom space impacted their learning would give researchers a better idea how the environment impacted results. While most of this new data would be self-reported and bias would be introduced because of this, it would help provide further analysis of the results to give a more complete picture of how pedagogy impacts academic performance.

Examining the role of the professor would also provide a more complete understanding of the relationship between pedagogy and retention. A survey for professors on their prior experience with the flipped classroom, their comfort level with the flipped classroom, course load, class schedule, and educational experience would also allow researchers to determine what, if any, impact those professors had on the results. Determining if training or other professional development opportunities were available to learn about using different pedagogies could help figure out why more professors aren't using different pedagogies. Also, longitudinal studies over multiple years could show how the professor adapts and changes to using non-traditional pedagogies. Most of this data would not have to be self-report and could be done via observations; alternatively, collecting this data from the universities would decrease the possibility of bias.

Professors should use the teaching pedagogy that they are the most comfortable with to best convey content to students. Since final exam scores did not decrease between traditional and flipped classrooms alternative teaching pedagogies could be explored without negatively affecting student learning. There were also statistically significant increases in satisfaction, how much students enjoy their classes, and innovation, how often new and different teaching and learning activities are used. These results further support the exploration of alternative teaching pedagogies that professors feel comfortable with.

While the data did not reject the null hypothesis, this seminal study offers many ways in which pedagogy, retention, critical thinking, and engagement can be examined in future studies. Ensuring that students are properly prepared for the workforce is one of the primary jobs of educators. Using some of the concepts and suggestions for future directions from this study can help make certain that students are learning as much as they can from their courses.

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Appendix A

Modified University of Utah Flipped Classroom Checklist

Date:

Instructor Name:

Class Name &/or Number:

of Students:

FACE-TO-FACE APPLICATION

LESSON PLAN		
Warm-up/Review		
Beginning of Class: <ul style="list-style-type: none"> • Class starts on time • Lets students know class is starting 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Lesson outline given at beginning of class, verbally & visually (e.g., on board, slide, or handout)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Elaborates upon prior courses, lessons, assignments, &/or readings	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Warm-up/ introductory question, example, activity, etc. to topic	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Practice Phase of Lesson		
Effective use of time: <ul style="list-style-type: none"> • Adequate time provided for completion of activities • Promptly moves on as students complete activity 	<input type="checkbox"/> Yes	<input type="checkbox"/> No

<p>Encourages preparation:</p> <ul style="list-style-type: none"> • Provides incentive for students coming to class prepared (e.g., written piece completed before class, short quiz, activity utilizing content from video lecture) • Refrains from repeating content covered in video lecture 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<p>Draws upon student experience &/or current events</p>	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<p>Teaching techniques:</p> <ul style="list-style-type: none"> • Uses variety of teaching techniques (e.g., discussion, demonstration, small group work, etc.) • Changes teaching technique every 15 to 20 minutes • Students do whatever they can do without instructor (i.e., instructor only does what students cannot do) 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<p>Appropriate activity selection:</p> <ul style="list-style-type: none"> • Activity supports success with learning objective(s) • Activity appropriate for level of students (e.g., not too simplistic or advanced) • Activity provides application component (e.g., students can connect theory to practice) • Ends with activity debrief (i.e., takes a moment to make sure students have made connection between activity & course concept) 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<p>Lesson engages higher level cognitive abilities (e.g., analyzing, evaluating, creating)</p>	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<p><i>(for classes longer than 80 minutes)</i> Provides appropriate breaks</p>	<input type="checkbox"/> Yes	<input type="checkbox"/> No

Teaching Technology		
<ul style="list-style-type: none"> • Uses best visual medium for material & classroom • Visual aids complement, illustrate, or explain material • Visuals uncluttered (e.g., appropriate amount of text per slide, whiteboard content clear & organized) • Pacing of visuals appropriate 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Wrap-up		
Finishes with overview of what was covered	<input type="checkbox"/> Yes	<input type="checkbox"/> No
End of Class: <ul style="list-style-type: none"> • Class ends on time • Closes lesson appropriately (e.g., bidding farewell: “Have a nice weekend”, “See you on Thursday”; preview or reminders for next steps, such as flipped section/ module students should proceed with) 	<input type="checkbox"/> Yes	<input type="checkbox"/> No

INSTRUCTOR-STUDENT & STUDENT-STUDENT INTERACTION		
Checks or is aware when students are lost, hurried, etc. (e.g., asks content comprehension questions, monitors during group work)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Questioning Style: <ul style="list-style-type: none"> • Asks one question at a time • Questions are clear • Provides ample wait time (10 secs) for student answers before repeating, responding, or moving on 	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Instructor Response to Questions/Comments: <ul style="list-style-type: none"> • Aware of raised hands • Answers question that was asked • Verifies question answered to student’s satisfaction • In light of incorrect response, remains respectful, not immediately negative; turns into teachable moment • Reacts appropriately if doesn’t know answer (e.g., writes down to respond 	<input type="checkbox"/> Yes	<input type="checkbox"/> No

later or asks rest of class to attempt response)		
Student Engagement: More than just a few students ask questions/participate in discussion	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Fostering Participation: <ul style="list-style-type: none"> • Asks variety of question types (e.g., factual, application, opinion, critical) • Builds off student answers/comments • Encourages dialogue/discussion/student-student interaction 	<input type="checkbox"/> Yes	<input type="checkbox"/> No

Appendix B

Final Exam Sample Questions

Sample multiple choice

What differentiates x-rays from alpha and beta radiation?

- a. X-rays are more penetrating
- b. X-rays have no mass
- c. X-rays have no charge
- d. All of the above are correct
- e. None of the above are correct

You are 18 inches away from an x-ray unit. The output at this distance is 540 mR/hour when the unit is on. You move to a position 5 feet from the unit and behind a wall that has an effective shielding capacity equal to 1 HVL of lead. You are exposed for 45 minutes while behind this wall. What total integrated exposure will you receive?

- a. 18 mR
- b. 61 mR
- c. 675 mR
- d. 2,250 mR
- e. 2,625 mR

A radiation producing source needs 75mm of lead to reduce its intensity by 50%. How many millimeters of lead are needed to reduce its intensity to less than .05%?

- a. 300mm
- b. 350mm
- c. 450mm
- d. 525mm

You are being exposed at a rate of 60 mR/hour at 6 inches. What is the exposure if you increase your distance to 3 feet for 20 minutes?

- a. 10 mR
- b. 0.6 mR
- c. 6.2 mR
- d. 8.4 mR

Which of the following statements is true regarding the pregnant radiographer?

- a. If the radiographer becomes pregnant, her supervisor may fire her.
- b. The dose equivalent limit for the fetus is .5 rem during the gestation period.
- c. Dose limits for the fetus only apply to individuals who do not declared their pregnancy to their supervisor.
- d. Employees should work in fluoroscopy while they're pregnant.

Sample essay

How would you stress the ALARA principle to your employees?

You have to do an abdomen x-ray on a 3-year-old girl. The parent wants you to explain to them how you would limit the girl's exposure. What would you say to them?

Appendix C

College and University Classroom Environment Inventory (CUCEI)

Directions

The purpose of this questionnaire is to find out your opinions about the class you are attending right now. This questionnaire is designed for use in gathering opinions about small classes at universities or colleges (sometimes referred to as seminars or tutorials). It is not suitable for the rating of lectures or laboratory classes. This form of the questionnaire assesses your opinion about what this class is actually like.

Indicate your opinion about each questionnaire statement by choosing:

SA if you **STRONGLY AGREE** that it describes what this class is actually like.

A if you **AGREE** that it describes what this class is actually like.

D if you **DISAGREE** that it describes what this class is actually like.

SD if you **STRONGLY DISAGREE** that it describes what this class is actually like.

1. The pace of the course met my needs.
2. The course was well organized.
3. Course requirements were clear from the beginning.
4. Scheduled class time was used efficiently.
5. Adequate time for questions was provided.
6. Instructor seemed interested in teaching this course.
7. Instructor responded to my questions with clarity.
8. Difficult concepts were explained in a helpful way.
9. Assignments contributed to my learning.
10. Assignments were consistent with course objectives.
11. Expectations on class-related work were clear to me.
12. Lectures were consistent with the subject matter in the course outline.
13. Help was available to me outside class if I had questions.
14. I learned fundamental principles and theories.
15. I was given the opportunity to adequately demonstrate what I learned.
16. Exams covered material on which I expected to be tested.

17. Exams reflected objectives of course content.
18. Grading criteria were clearly defined.
19. Grades were an impartial assessment of my performance.
20. The instructor considers students' feelings.
21. The instructor talks rather than listens.
22. The class is made up of individuals who don't know each other well.
23. The students look forward to coming to classes.
24. All students in the class are expected to do the same work, in the same way and in the same time.
25. The instructor talks individually with students.
26. Students put effort into what they do in classes.
27. Each student knows the other members of the class by their first names.
28. Students are dissatisfied with what is done in the class.
29. Getting a certain amount of work done is important in this class.
30. New and different ways of teaching are seldom used in this class.
31. The instructor goes out of his/her way to help students.
32. Students "clockwatch" in this class.
33. After the class, the students have a sense of satisfaction.
34. The instructor thinks up innovative activities for students to do.
35. The instructor helps each student who is having trouble with the work.
36. Students in this class pay attention to what others are saying.
37. Students don't have much chance to get to know each other in this class.
38. Teaching approaches in this class are characterized by innovation and variety.
39. The instructor seldom moves around the classroom to talk with students.
40. It takes a long time to get to know everybody by his/her first name in this class.
41. Classes are boring.
42. The seating in this class is arranged in the same way each week.
43. The instructor isn't interested in students' problems.
44. There are opportunities for students to express opinions in this class.
45. Students in this class get to know each other well.
46. Students enjoy going to this class
47. The instructor often thinks of unusual class activities.
48. The instructor is unfriendly and inconsiderate towards students.
49. The instructor dominates class discussions.
50. Students in this class aren't very interested in getting to know other students.
51. Classes are interesting.
52. Students seem to do the same type of activities every class.
53. It is the instructor who decides what will be done in our class.

Written Response question:

54. Please provide additional comments regarding aspects of the course you thought worked well and those that could be improved. Any suggestions for how this course could be improved are greatly appreciated.

Vita

Stephanie Anne McHugh was born on the 5th of January 1987 in Shawano, Wisconsin. She graduated with a Bachelors of Science in Radiologic Technology in 2009, and a Masters in Business Administration-Health Care Administration in 2013 both from Concordia University Wisconsin. Previously she had worked as a Radiology Assistant at Froedert Memorial Lutheran Hospital from 2008-2009. Stephanie subsequently taught at Globe University of La Crosse from 2010-2013. She is currently teaching at Escuela Americana San Salvador in El Salvador and has been since 2013.

