St. Cloud State University

# theRepository at St. Cloud State

Culminating Projects in Higher Education Administration

Department of Educational Leadership and Higher Education

# Teaching Methods Matter: A Comparison of Learning Outcomes and Persistence in STEM between Traditional Lectures and Active Learning Using Undergraduate Learning Assistants in Introductory Chemistry Courses

Jodi Laudenbach
jrlaudenbach@go.stcloudstate.edu

Follow this and additional works at: https://repository.stcloudstate.edu/hied_etds

**Teaching Methods Matter: A Comparison of Learning Outcomes and Persistence in STEM between Traditional Lectures and Active Learning Using Undergraduate Learning Assistants in Introductory Chemistry Courses**

by

Jodi Laudenbach

A Dissertation

Submitted to the Graduate Faculty of

St. Cloud State University

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Education in

Higher Education Administration

December, 2020

Dissertation Committee:
Rachel Friedensen, Chairperson
Melissa Hanzsek-Brill
Jennifer Jones
Roseann Wolak

**Abstract**

Student retention in STEM majors is low. The literature is clear: poor teaching contributes to students' decisions to leave STEM. From this I wondered if the teaching method made a difference in their choice. This study followed a quantitative, quasi-experimental research design. I compared two teaching methods, a traditional lecture (TRAD) and active learning using the Learning Assistant Program (LAP) to determine if there was a difference in student learning outcomes and persistence in STEM for students enrolled in an introductory chemistry course at a mid-sized regional comprehensive public university (RCPU). My results showed that there was no statistically significant difference between the two groups based on student performance on the American Chemical Society Final Exam and the percentage of students who enrolled in a subsequent STEM course. However, I found a statistically significant difference between the two groups when comparing Total Points Earned, and the DFW rates. LAP students achieved higher performance and a 2:1 overall pass ratio compared to TRAD students. The LAP teaching method positively influenced women and students of color with higher performance in overall grades achieved and course completion rates. The active learning teaching method that used the Learning Assistant Program improved student performance and persistence in the introductory chemistry courses and was particularly effective for women and students of color.

**Acknowledgements**

Many individuals are deserving of my heartfelt thanks and appreciation for the support they provided me throughout this process.

To start with my family, my best champion was my husband, Dave. It was Dave who supported me though my doctoral journey both financially and emotionally and through the day to day rigor of completing my coursework and my dissertation. Along with his valued support, I must acknowledge the support from my daughters, Michaela and Catherine, who kept me moving forward in the process. My parents, Harlan and Violet Jensen and my sister, Dawn Regnier, all contributed to my success. For my Mother's stead-fast encouragement, my Father's endless enthusiasm for reading my drafts, and my sister's help with proofreading, I am truly grateful for their support to accomplish this most challenging part of my education journey.

To Dr. David Wren, a very special individual, who has been a true inspiration dedicating countless hours coaching and mentoring me through the dissertation writing process. His guidance and direction helped me formulate my thoughts and pushed me in new directions. To him, I dedicate this significant accomplishment.

For my advisor, Dr. Rachel Friedensen, I extend my appreciation and gratitude for the professional guidance, unwavering support, and personal encouragement to assist me to finish the process and grow both personally and professionally.

Dr. Roseann Wolak is also deserving of recognition for her continued support and motivation to be my best and complete this momentous milestone. I cherish the personal and professional relationship we have developed.

A thank you to all the SCSU members, the Higher Education Administration faculty members, and my committee members who provided me with their professional guidance and support.

Finally, for the perseverance, dedication, and tireless support from all the truly amazing people willing to help me through the doctoral program and dissertation writing process, I thank you. Even with all the support and guidance, the responsibility for this study was mine alone and I accept any shortcomings held within.

Jodi Laudenbach

**Table of Contents**

**List of Tables**

# **List of Figure**

Figure                                                                                                                     Page

**Chapter 1: Introduction**

Knowledge of science, technology, engineering, and mathematics (STEM) plays an important role in the United States economy and overall strength of our society (President's Council of Advisors on Science & Technology, 2012). Rated first in science and engineering, the United States has a long-established history of investment in research and science education (National Science Board, 2018c). A strong foundation in science and science education fosters economic growth and continued developments that build a safe, healthy, and well-educated society prepared for the 21st century (National Science Board, 2018c). Maintaining excellence in science is critical for the health and welfare of the nation (National Science Board, 2018c).

Despite the strong historical foundation in STEM, the United States (U.S.) has faced challenges when working to maintain excellence in STEM fields. Belser, Shillingford, Daire, Prescod, and Dagley (2018) explained how the U.S. lacked an adequate number of workers to keep up with the demand for a trained science, technology, engineering, and mathematics workforce. The lower numbers of STEM workers can be attributed to an overall reduction of undergraduate students declaring and completing STEM degrees (Carnevale et al., 2011; Chen & Soldner, 2013; Doerschuk et al., 2016; Sithole et al., 2017). Sithole et al. (2017) investigated the significant factors affecting student interest, success, and persistence in STEM and recommended several solutions. One significant recommendation from the study was to implement structured pedagogical training for faculty in STEM programs. "Education should not be frozen in time and pedagogical approaches need to meet the ever-changing needs of each generation of learners" (p. 50).

Nationally, STEM disciplines enjoy one of the highest enrollments for first year college students; however, only 69% remain in a STEM major three years later (National Science Board,

2018b). An even larger percentage of students switch from STEM to non-STEM majors after their second year in college (National Science Board, 2018a). More problematic is the continued under-representation by race, ethnic minorities, and gender in the STEM fields (Kezar & Holcombe, 2019; NCSES, 2017). In recent years, the number of women earning a STEM degree has increased; however, women of color remain under-represented relative to their presence in the workforce and the U.S. population (NASEM, 2020). According to the U.S. Census Bureau's American Community Survey for 2015, White women accounted for 31% of the general population but were only represented in 18% of STEM occupations. Women of color (Black/African American and Hispanic/Latina) accounted for 15% of the general population with only a 4% representation in STEM occupations. In general, Black/African American, Hispanic/Latinx, and Native Americans are represented significantly less in STEM occupations compared to their overall representation in the general U.S. population (NASEM, 2020). Not categorized as under-represented in STEM occupations are Asian Americans who hold approximately 21% of the STEM jobs compared to holding only six percent of the general U.S. population (NASEM, 2020).

Given these shortcomings, colleges and universities have developed numerous programs centered on recruitment and retention of STEM undergraduates (Dagley et al., 2016; Schneider, Bickel, & Morrison-Shetlar, 2015). The U.S. government along with private investment groups dedicate billions of dollars annually into STEM initiatives at the K–12 and higher education levels (Carnevale et al., 2011). Yet the problem of low STEM retention continues.

Although switching from STEM has been a topic of interest to researchers in higher education for many years, Seymour and Hewitt (1997) published the first extensive study focused on college student departure from majors in science, engineering, and mathematics

(SEM). As they explained in their findings, over 60% of students initially enrolled in SEM majors left for non-science majors. When asked, students explained poor teaching was the main reason they decided to switch (p. 34). Numbers are improving and progress continues, as evidenced by the more recent data that indicated only 31% of STEM students switched to non-STEM majors, but there is still room for improvement (National Science Board, 2018b).

The students studied by Seymour and Hewitt (1997) described poor teaching as a lack of organization, lack of presentation skills, failure to understand how students learn, and lack of support for collaborative, active learning strategies.  Handelsman et al. (2007) were not surprised since college STEM professors were not required to be trained in education theory prior to holding a teaching role at a post-secondary institution. Teaching methods were often left up to the professor and, more commonly than not, the professor selects a teaching method which reflects the way in which they were taught (Mastascusa et al., 2011). Traditional teaching practices, specifically the lecture method, are not bad; they just may not be as effective for the 21st century college student (Mastacusa et al., 2011).

Mastascusa et al. (2011) explained several benefits of collaborative teaching methods. First, collaborative teaching establishes a learning community in the classroom that students come to rely on for their success. Second, it engages the students with their peers and the faculty member. Finally, a significant benefit of collaborative teaching is immediate feedback for both the student and faculty member. Immediate feedback opportunities quickly identify misconceptions in the learning that need correction.

Several other studies supported these benefits and made clear that effective teaching strategies were those that allowed students to actively engage with the course content, faculty members, and their classmates (Chickering & Gamson, 1987; Freeman et al., 2014; Froyd, 2016;

Hake, 1998; Knight & Wood, 2005; Mayer, 2010; Piaget, 1978; Prince, 2004; Vygotsky, 1978; Weimer, 2002). Other researchers have found support for collaborative classroom activities and group discussion (Johnson et al., 1998; Wood, 2004; Wright & Boggs, 2002); and the value of peer instruction as an effective technique that promotes learning by teaching others (Mazur, 1996). Gurung, Chick, and Haynie (2009) described how teaching methods used in higher education vary by discipline. The teaching practices of interest in this study are the traditional lecture and active / collaborative learning strategies using undergraduate learning assistants.

In 2001, the University of Colorado, Boulder (UCB) developed the Learning Assistant Program to improve interest in STEM education and transform STEM college courses (Learning Assistant Alliance, 2018). UCB's Learning Assistant Program model incorporates collaborative learning into its framework based on the foundational works of constructivism Piaget (1978) and social-constructivism Vygotsky (1978). Much literature has been published on the effectiveness of the UCB's Learning Assistant Program model at research intensive institutions (Finkelstein et al., 2006; Sellami et al., 2017; White et al., 2016), but little is known about the effectiveness of the model in mid-size regional comprehensive public universities (RCPUs).

## Purpose of the Study

The purpose of this study was to determine if teaching methods, specifically traditional lecture and active learning following the Learning Assistant Program, made a difference in student learning outcomes and persistence in STEM at a mid-sized regional comprehensive public university in large introductory chemistry courses. To determine if there was a difference in outcomes between the two introductory chemistry courses, I analyzed two independent variables for each outcome: student learning outcomes (ACS Final Exam score and Total Points

Earned) and STEM persistence (DFW rates and Enrolled in STEM rates the following Spring semester).

Seymour and Hewitt's (1997) study provided extensive data from seven distinct institutions across various geographic areas of the United States. However, their study did not include a regional comprehensive public university. To date, there has been no follow-up that encompasses a university of that type. The knowledge gained from this study will inform teaching and learning practices in STEM education at RCPU institutions and will highlight some issues related to retention.

## Statement of the Problem

Simply put, STEM retention is low (Chen & Soldner, 2013). STEM retention is a complex phenomenon that inspires researchers to examine various angles and aspects (Belser et al., 2018; Braxton et al., 2004; Elrod & Kezar, 2017; Sithole et al., 2017; Xu, 2016; Xu, 2018). Seymour and Hewitt (1997) described how capable, high-achieving students were leaving SEM majors for non-SEM majors primarily due to poor teaching practices. As described above, some students defined poor teaching as a lack of support for the use of collaborative learning strategies (p. 172). While this is only one aspect of the problem, it is one over which the faculty members have direct control and is therefore worth exploring along with persistence among female and under-represented minority (URM) students.

At most 4-year, public and private universities, faculty have professional freedom to decide which teaching method they use in their courses (The Princeton Review, n.d.). There is ample literature available to support positive claims for active and collaborative teaching practices (Beichner & Saul, 2003; Eddy & Hogan, 2014; Fata-Hartley, 2011; Freeman et al., 2014; Froyd, 2016; Hake, 1998; Handelsman et al., 2007; Knight & Wood, 2005; Prince, 2004;

Smith et al., 2005). Additionally, several published studies from large research institutions and large to mid-sized research focused state universities support the use of undergraduate learning assistants in large-enrollment STEM courses (Finkelstein et al., 2006; Sellami et al., 2017; White et al., 2016). However, little research was available from studies conducted at a regional comprehensive public university.

This study adds to the literature by examining results from two independent courses taught at a regional public comprehensive university comparing learning outcomes (ACS Final Exam score and Total Points Earned) and persistence (DFW grade rates and Enrolled in STEM rates the following Spring semester). One course was taught using the Learning Assistant Program model and the other course was taught using traditional lecture. This study's findings will expand the knowledge in the area of STEM education and contribute to a deeper understanding of the STEM departure phenomenon. With the problem identified, one of the goals for this study would be to possibly influence practitioners in the field of STEM education and encourage them to consider alternative teaching methods as a complement to traditional lecture.

## Description and Scope of the Research

The study was an educational research study that followed a quasi-experimental, quantitative design. As I have indicated above, the study compared student learning outcomes (ACS Final Exam scores and Total Points Earned) and persistence in STEM (DFW rates and Enrolled in STEM rates the following Spring semester) between two independent groups. The control group was the course taught with traditional lecture. The treatment group was the course taught with active collaborative learning strategies and undergraduate learning assistants. A two-

sample independent *t*-test was run on the data to determine if there was a statistically significant difference between the means of the groups (Field, 2013).

Two chemistry professors agreed to participate in the study. Professor 1 has used learning assistants for over five years. Professor 2 used learning assistants previously but has not used them within the last five years of teaching general chemistry. Data from introductory chemistry sections taught by both professors during Fall semesters of 2017, 2018, and 2019 were collected and were included in the study for comparison. The structure of both courses followed the national standards established through the discipline's accrediting body, the American Chemical Society (ACS). Both professors used the same course instructional materials such as textbook, quizzes, and worksheets. The primary difference between the courses was the teaching method used.

## Research Questions

Three research questions were:

- RQ 1: Is there a difference in student learning outcomes between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

- RQ 2: Is there a difference in persistence between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

- RQ 3: Is there a difference in student learning outcomes and persistence for women and under-represented minorities in STEM between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

**Theoretical Framework**

Vygotsky's (1978) social constructivism learning theory was used to provide a systematic framework to guide this study. Guided by the constructivist paradigm, this study emphasized teaching and learning strategies that support academic success and persistence in STEM education. Vygotsky's (1978) social constructivism theory expands Piaget's (1978) constructivist learning theory by emphasizing the significance social collaboration has for knowledge construction. Vygotsky (1978) described a gap that exists between what an individual knows independently and what they have the potential to learn when collaborating with others, specifically, others more knowledgeable than themselves. Vygotsky described this gap as the Zone of Proximal Development.

Vygotsky (1978) theorized that social interactions provided deeper meaning through communication, activity, and collaboration with others allowing individuals to progress through the zone of development. Vygotsky's (1978) learning theory, social constructivism, specifically the Zone of Proximal Development supports my hypotheses that teaching methods utilizing collaborative, active learning strategies will improve student learning outcomes and persistence in STEM compared to the traditional lecture teaching method. Vygotsky explained the Zone of Proximal Development as knowledge construction that occurs through a combination of independent thought and social interactions with others such as teachers, parents, or peers, more knowledgeable than themselves. The more knowledgeable other can assist the individual through the Zone of Proximal Development, acting as a guide or facilitator of learning utilizing specific educational skills as redirecting, elaborating, questioning, and encouraging. For Vygotsky, social interaction played a fundamental role in the development of the cognitive abilities thinking, learning, and communicating.

**Summary**

This chapter has addressed the purpose of the study, the statement of the problem, the description and scope of the research, and the research questions that will be included in the study.

Chapter 2 provides a review of the literature. This review includes a background for student retention theory and conceptual models, specific literature describing STEM student retention, common teaching practices used in STEM, and a further explanation of the Learning Assistant Program model developed at the University of Colorado, Boulder.

Chapter 3 includes a thorough description of the research design that guided the research process. The study followed a quantitative, quasi-experimental research design. The means from two independent groups were compared and analyzed using a two-independent sample $t$-test. The chapter also includes a detailed description of the procedures followed for participant selection, data collection, and data analysis. The chapter concludes with the IRB human subject approval statement.

Chapter 4 provides the detailed statistical analysis and findings using the Statistical Package for Social Sciences (SPSS) software. It is in this chapter where I detail my analysis of the findings relating to my hypotheses. In addition, the chapter will include a summary of the findings and the potential application.

Chapter 5 concludes the study with a discussion of the results, the limitations of the study, along with future implications for research, theory, and practice. By following a systematic study protocol, I believe my results will contribute to the current body of educational research and may be used to encourage the expanded use of the Learning Assistant Program in large enrollment introductory chemistry courses and beyond.

**Chapter 2: Review of the Literature**

In this chapter I will review the literature that focuses on student success and persistence in STEM courses through a teaching and learning lens. I will begin by examining the literature concerning general college student departure. Next, I will review the factors that influence college students' decisions to persist in STEM. This will be followed by a discussion of how students learn, as described in some established learning theories, and how these learning theories inform teaching practice. Following this will be an explanation of the common teaching methods used in STEM education and the literature that supports their use.

One interesting component addressed in the literature is the lack of understanding of education learning theory by many postsecondary educators, especially STEM college educators (Handelsman et al., 2007; Mastascusa et al., 2011). Teaching in postsecondary environments does not require any formal knowledge of education theory; it simply requires knowledge of the discipline (Mastascusa et al., 2011). Without a working knowledge of learning theory, it is not surprising that teaching practices reflect how the instructors themselves were taught. I will argue that the literature demonstrates that teaching practices informed by learning theories are more effective in producing positive student learning outcomes and persistence in STEM than simply employing teaching practices based on personal experiences in graduate school. This chapter will conclude with a detailed explanation of the University of Colorado, Boulder's undergraduate Learning Assistant Program model and the research that supports its effectiveness in STEM education.

# College Student Departure Theories

## Overview

Attracting and retaining students is more important than ever and is quickly becoming an institutional concern impacting not only administrators and student development professionals but academic faculty and staff as well (Aljohani, 2016). College student departure is a complex phenomenon that cannot be explained fully by one or two theoretical frameworks or models (Aljohani, 2016). The intent here is to focus on one possible approach to a specific instance of the problem.

Several scholars have tried to develop definitive explanations of the college student retention phenomenon. However, after thorough feedback and peer-review they discovered several shortcomings in their theoretical assumptions. Given the reality that college students are complex human beings, it may never be possible to accurately predict why one student stays and another leaves college (Braxton et al., 2004). With careful investigation, it is possible to acquire some deeper insight into why students decide to stay or leave which can lead to educated predictions in order to gain a proper understanding of the significant theories and models influencing today's academic practices.

Student retention is not a new concept for higher education with over six decades of literature on the topic and several theoretical models and empirical studies to draw upon (Aljohani, 2016). I will present a brief background into college student retention theories along with a review of the current literature. The goal is to provide a foundational background of general college student departure theory and compare the differences within STEM students to establish greater understanding of this population.

The first section will include an overview of the foundational works of college student departure theoretical models and provide insight into a select number of common attributes from an academic and social integration lens. Attributes such as academic performance, academic major, experiences with faculty members, interactions with peers, and social integration factors related to the academic environment such as sense of belonging and fit, engagement, and self-efficacy will be examined. The second section will focus on college STEM persistence including the literature specific to STEM programs.

**Foundational Works**

The scholars of the 1970s produced several theoretical models and conceptual frameworks for understanding college student retention and departure (Bean, 1980; Spady, 1970, 1971; Terenzini & Pascarella, 1977; Tinto 1975). Spady (1971) described the influence of two primary systems in higher education (academic and social) and how key variables within those systems impact a student's decision to leave college. The key variables identified were intellectual development, social integration, satisfaction, and institutional commitment. He explained that an imbalance between the two systems increases the likelihood of departure.

Tinto (1975) was next to publish his model of college student departure. His work, an interactionalist theory, was influenced by several scholars including Spady (1970, 1971), Van Gennep (1960), and Durkheim (1897). Tinto (1975) used Van Gennep's (1960) Rite of Passage theory to help explain the social transition that occurs when students go to college. Tinto believed that for students to be successful in college they would need to separate from their current community and fully engage with the new community within the institution. Tinto was also influenced by Durkheim's (1897) work on suicide using it as a tool to understand why students decide to leave college. Tinto established the connection between a student's departure

from college as a choice to separate from the academic community and Durkheim's belief that suicide decisions were caused by societal issues (Godor, 2017). The stark differences between these situations sparked criticism by Braxton (2019) and others. Tinto (1975) also believed it was important for students to get good grades and demonstrate institutional commitment and school pride through participation in social groups and activities. Over the years, Tinto (1987) modified his original work based on feedback and critiques from peers. Tinto expanded on the significance of academic and social integration and outlined the importance of classroom experiences on persistence and retention. He also gave more attention to the situation of women of color and adult learners.

Over the two decades following Tinto's original work, Bean (1980, 1982); Astin (1984); and Cabrera, Nora, and Castaneda (1993) expanded the literature on student departure. Bean (1980, 1982) disagreed with Tinto, explaining that his models were based too extensively on psychological factors. In Bean's opinion, psychological factors were too difficult to accurately assess. As a result, he developed a student attrition model based on several organizational workplace theories. Bean identified the factors known to influence workforce turnover and correlated them with student attrition. He expanded the discussion by identifying gender-specific factors that influenced student departure. The most significant departure factor identified for both genders was a lack of institutional commitment.

Astin's (1984) Student Involvement Theory describes students' involvement and its positive correlation with learning and personal development and retention. Astin (1984) explained student involvement as "the amount of physical and psychological energy a student devotes to the academic experience" (p. 297). Cabrera, Nora, and Castaneda (1993) created the Integrated Model of Student Retention by combining the most significant variables from the

Tinto (1975) and Bean (1982) models. The Integrated Model of Student Retention provided a better explanation of the student attrition process with evidence supporting the effects of environmental variables on student retention.

Several publications have addressed criticisms of Tinto's works (Bensimon, 2007; Bowman & Denson, 2014; Braxton et al., 2004; Braxton et al., 1997; Hurtado, 1994; Swail et al., 2003). Braxton, Sullivan, and Johnson (1997) examined Tinto's theory based on thirteen testable propositions. The findings from this study provided evidence that supported the continued use of some aspects of Tinto's theory but showed that it lacked overall support in every category. These findings led the authors to question whether Tinto's theory should be revised or abandoned. Braxton, Hirschy, and McClendon (2004) revised Tinto's theory to account for student departure in residential colleges and universities. Their updated theory better explained today's college student and included thoughts on how social integration, culture, and gender effect academic success. They also tested the appropriateness of Durkheim's (1897) suicide prediction model for the general population for use in college student departure theory and modified Tinto's College Student Departure theory by addressing both 2-year and 4-year commuter institutions, diverse student populations, and social integration concerns.

Interestingly the modifications made by Braxton et al. (2004) explained social integration as an element of institutional commitment. When students were more socially integrated into the institution, they perceived the institution to have higher levels of concern for their welfare. "Students in courses where faculty engaged in active learning practices had greater degrees of academic integration and also were less likely to depart from college" (p. 49).

In an earlier study, Braxton, Milem, and Sullivan (2000) found that when students perceived faculty teaching practices or teaching skills positively, they expressed higher levels of

institutional commitment. When asked, the students who held more positive views about their faculty members' teaching also felt that the institution was more committed to their learning. The increase in institutional commitment was shown to produce higher levels of student engagement on campus along with greater student persistence in college.

Braxton (2019) explained that even after significant criticism and effort to revise Tinto's theories, it remains a paradigmatic framework for understanding college student departure. He explained further how scholars and practitioners have drawn inspiration from Tinto's works. Braxton further predicted that Tinto's significance as a primary theoretical theory on college student departure for the 21st century may soon begin to weaken. However, the fundamental contributions of changing the language from drop-out to departure, the recognition of influence the classroom experience has on student departure, and the concept of academic and social integration remain some of Tinto's enduring legacies.

**Models for the 21st Century Student**

Scholars continue to expand college student retention / departure theories as indicated by the extensive literature published early in the 21st century. Bean and Eaton (2000) created a retention model based on the psychological processes that contribute to academic and social integration. Rendón, Jalomo, and Nora (2000) contributed a new theory based on biculturalism and its impact on departure decisions of minority students. Stage and Hossler (2000) authored a new theory focused on college choice and student departure. Kuh and Love (2000) emphasized culture as an explanation for college student departure. Tierney (2000) developed a new model based on critical theory explaining power and community to understand departure decisions of low-income and urban students of color. Reason (2009) used a comprehensive conceptual framework and categorized student characteristics and individual experiences to create a

conceptual framework for future research. Finally, Museus (2014) furthered Tinto's work and developed the Culturally Engaging Campus Environments (CECE) model accounting for factors relevant to a racially diverse student population. The modifications Museus (2014) made to Tinto's theories provide an updated lens into which retention can be viewed from the diverse college student experience.

<div align="center">

**Academic and Social Integration**

</div>

No one specific model or framework can best describe college student departure. However, after thorough review of the various theoretical perspectives and models, a common theme emerged. The most significant cause of college student departure was the extent of academic and social interaction. The literature identified academic integration as including academic performance and achievement, academic major selection, and interactions with faculty and peers. Social interaction included the sense of belonging and self-efficacy, interest and motivation, and general educational experiences.

**Academic Performance and Achievement**

Mayhew et al. (2016) explained that academic performance and achievement was a significant predictor of persistence in college with grades the common measure of academic performance. Grades can provide students with feedback to judge their own academic performance and ability (Stinebrickner & Stinebrickner, 2012). Pascarella and Terenzini (2005) described how grades were strong predictors of retention, persistence, and graduation. The significance of grades was further explained as being universal predictors consistent across institutional type (Lohfink & Paulsen, 2005), demographic categories (Reason, 2003; St. John et al., 2005), year in college (Schreiner & Nelson, 2013), and delivery methods (Cochran et al., 2014). Grades along with a positive self-perception of growth, development, and learning

significantly influenced persistence in college (Herzog, 2005; Hu et al., 2012; Kalogrides & Grodsky, 2011; Kuh et al, 2008; Stratton et al., 2008).

**Academic Major**

Pascarella and Terenzini (2005) described how "students majoring in sciences, engineering, business, and health-related fields were more likely to persist and graduate than similar students in other fields" (p. 403). Several other studies provided evidence in support of the belief that the major made a difference in persistence and retention (Chen & DesJardins, 2010; Jaeger & Eagan, 2011; St. John et al., 2004; Wohlgemuth et al., 2007). Mayhew et al. (2016) claimed that the majors with the highest retention rates explicitly prepared students for high-paying jobs. Similarly, Bettinger (2010) found that students were more motivated to complete a degree when there were clear financial payoffs for graduating. In contrast, the literature focused specifically on STEM student retention suggested otherwise.

Additionally, researchers who looked at the fit between student interest and major selection predicted greater success in college when interest and major were aligned (Bettinger, 2010; Leuwerke et al., 2004; Robbins et al., 2004; Tracey & Robbins, 2005). Recent research has questioned whether declaring a major immediately upon college enrollment made a difference in retention rates and the results were mixed (Burgette & Magus-Jackson, 2009; McKinney & Novak, 2012; Titus, 2004).

**Interactions with Faculty**

Student interaction with faculty was positively related to persistence and graduation (Mayhew et al., 2016). Pascarella and Terenzini (2005) explained that the most common interaction between faculty and students occurred during formal coursework. When students believed that faculty members were available and interested in their success, they were more

committed to persisting. Kuh et al. (2006) recommended that institutions need to invest in programs that support purposeful student and faculty contact along with active and collaborative learning, in order to provide institutional environments perceived by students as inclusive and affirming. It was important to note, Kuh and team identified a low response rate to their survey as a limitation that may have influenced the overall results.

Several studies examined retention and persistence in college that focused on students' perceptions of the quality of teaching and how those perceptions related to their decisions to stay in college. In several studies the findings indicated vast differences in student perceptions of their interactions with faculty. After accounting for confounding variables, how students' perceived instructor effectiveness was negatively correlated with course withdrawal rates (Hoffman & Oreopoulos, 2009; Madgett & Belanger, 2008; Schreiner & Nelson, 2013). The frequency of interactions did not result in significant impact on the decision to persist (Cragg, 2009; Crissman, 2002; Wolniak et al., 2012). Neither did students' perception of the faculty members' concern for their success (Hausmann et al., 2009; Otero et al., 2007). Mayhew et al., (2016) suggested that the types of faculty interactions with students may influence their decision to persist.

**Interaction with Peers**

When considering the importance of interaction with peers, quality interactions and relationships with friends in college were often positively related to retention and persistence (Mayhew et al., 2016; Pascarella & Terenzini, 2005). A study conducted by Fischer (2007) addressed the significance of informal on-campus relationships and off-campus relationships. Her findings showed that informal on-campus relationships were positively related to persistence in several demographic groups. Otero et al. (2007) described the time spent socializing on

campus with friends predicted greater retention. Wolniak et al. (2012) predicted that students having high-quality campus friendships and relationships will have a greater level of retention. It is not the quantity of friendships, but quality of friendships that matter in a student's decision to persist in college (Crissman, 2002; Swenson-Goguen et al., 2010). Additionally, Hausmann et al., (2009) found that the quality of peer-group interactions also led to a sense of belonging on campus which was positively related to retention.

National studies have found positive relationships between social engagement and persistence whether the involvement was of a general nature (Wang, 2009; Woosley, 2004); or focused on peer interactions and friendships (Swenson-Goguen et al., 2010; Wolniak et al., 2012). Hu (2011) and Stratton et al. (2007) found that high social engagement was beneficial to persistence. Conversely, Kuh et al., (2008) and Li (2010) indicated that minimum levels of socialization were sufficient to produce a persistence benefit.

Robbins et al. (2004) conducted a less conclusive study that addressed social integration and college persistence and suggested the variables associated with a students' decision to persist were far too complex to isolate in a definitive determination. Sithole et al. (2017) focused on student engagement and its effect on increases in retention. Sithole and colleagues found that it did not matter what type of social engagement occurred, it just mattered that there was some level of social interaction. Reason (2003) and Webb et al. (2017) discussed the importance of balance between the academic and social aspects of the college experience and both agreed that students having that balance were more likely to persist in college.

**Sense of Belonging and Fit**

Several studies explained that students with a strong sense of belonging tend to make decisions that lead to persistence in college (Braxton & Hirschy, 2005; Braxton et al., 2004; Kuh

et al., 2006; Pascarella & Terenzini, 2005). The literature indicated that when a student's sense

of belonging increased, their likelihood of retention from year 1 to year 2 also increased (Ishler

& Upcraft, 2005; Logan, 2017; Olbrecht et al., 2016). Opportunities to interact with like-minded

peers contributed to a sense of belonging and student satisfaction (Bowman & Culver, 2018;

Soria & Taylor, 2016). Belonging and fit also improved when students' felt satisfied with their

academic experience and supported in their learning environment (Hossler et al., 1999;

Pascarella & Terenzini, 2005; Umbach & Wawrzynski, 2005). Zumeta et al. (2015) further

considered the academic and social systems of higher education and explained the different

needs of a diverse student population.

**Self-Efficacy**

In addition to a sense of belonging, when students perceived a greater opportunity to

build community, they were more likely to persist in college. The degree of social integration

contributed to a greater sense of self-efficacy. Bandura (1986, 1997) explained self-efficacy as

the belief in the ability to engage in actions necessary to achieve a particular outcome. Bandura's

(1986, 1997) social cognitive theory emphasized self-efficacy because without it, students, when

faced with adversity, often give up. Bandura explained how human behavior changes based on

the beliefs people hold about themselves. He discussed personal agency and explained that

people are both products and producers of their own environment and social systems.

Other works from Bandura (1994) explained self-efficacy as one's beliefs about their

capabilities which affect how they think, feel, motivate themselves, and behave. He defined the

sources of self-efficacy through four major psychological processes as cognitive, motivational,

affective, and selection (p. 3). "Students' belief in their capabilities to master academic activities

affects their aspirations, their level of interest in academic activities, and their academic

accomplishments" (p. 12). He further suggested that cooperative learning structures where students work together tend to promote more positive self-evaluations of capability than individual competitive environments (p. 13). Williams and Rhodes (2016) described the value of self-efficacy as a motivator in explaining human behavior. Self-efficacy levels are highly predictive of behavior which further explained why people are more likely to do what they are motivated to do. Pintrich and Schunk (1995) focused on educational research and addressed the relationship between self-efficacy, motivation, and self-regulation.

**Interest and Motivation**

Interest and motivation are essential for student persistence. Leonard et al. (1999) described five sources of motivation. Motivation can be influenced by instructional strategies and teaching methods, personal expectations, and cultural norms and values. They argued that motivation can be quantified. Finally, they explained that given the complex nature of motivation, no one variable is significant enough to determine causation. As we move from a review of the literature on more general student departure from college to a more specific study of STEM students, it is good to remember that even with over 50 years of research there remain gaps in the understanding of why students decide to leave college (Burke, 2019).

<div align="center">

**STEM Student Departure Literature**

</div>

There is considerable literature explaining why STEM students leave college. While it does not have a direct connection on persistence in STEM majors, STEM student departure theories may throw some light on the issue. As a topic, STEM student departure is complex and not easily compartmentalized into one single cause or effect relationship. As shown in the literature STEM majors are somewhat less likely to leave college than many non-STEM majors; however, there is a serious topic of concern about the number of students who transfer out of

STEM majors during their college career. It is an important topic to get more information on because as described by Chen (2014) retention rates in STEM programs are significantly low. She explained that approximately half of the students who declared STEM as a major, changed majors to non-STEM or left college altogether. The phenomenon of low retention in STEM is of significant interest not only for higher education but also business and the national economy.

The purpose here is to uncover in the literature those explanations that support the various reasons why students leave STEM programs. The interest in this phenomenon is not new. Although they did not include technology courses in their focus, Seymour and Hewitt (1997) published the first extensive qualitative study gathering data on the reasons why students decided to leave science, engineering, or math (SEM) majors. With its rich narrative, the authors provided clear descriptions of the students' educational experiences and how they explained good and poor teaching practices in college.

This section will start with a review of Seymour and Hewitt's (1997) work to provide background into what is known about why SEM students leave their major. It will offer a focus on why students leave and the relationship leaving has on the students' experience with good or bad teaching. It will conclude with a review of the literature which offers a comparison with the factors that influence today's student.

**Talking About Leaving**

In their landmark study *Talking about Leaving: Why Undergraduates Leave the Sciences,* Seymour and Hewitt (1997) uncovered significant factors most relevant to students' decisions to switch or persist in their science, engineering, or mathematics (SEM) program. Their extensive ethnographic study sought to determine why undergraduates at 4-year colleges and universities switched from science, math, engineering majors (SEM) to non-SEM majors. Their goal was to

discover as many factors as possible that related to attrition and persistence. The 3-year study included 460 students from seven, 4-year colleges and universities (three private and four public). The participants were categorized into two groups, switchers and non-switchers. Switchers were students that decided to leave their declared SEM major for a non-SEM major. Non-switchers were students that remained in SEM, even if they switched between SEM majors (p. 14). They did not include any students that left college completely.

During the interviews, switchers and non-switchers were asked to describe the strengths and limitations of their educational experiences. Follow-up questions were asked of the switchers which focused on the factors that contributed to their decision to leave SEM. Non-switchers were asked to describe the factors that were most influential in their decision to stay in SEM. Both groups reflected on their overall undergraduate experiences through personal storytelling. The researchers used these narratives along with data from personal interviews and focus group sessions to gain a deeper understanding into the reasons why students decided to leave SEM (Seymour & Hewitt, 1997, p. 24). Analysis of hours of transcripts and data sets produced 23 factors that explained the problems stated by students' experiences in SEM education (p. 31). The authors emphasized a student's decision to leave or stay in SEM never resulted from one single factor. It was more like a push and pull process that occurred over time (p. 31).

**Similarities Between Switchers and Non-Switchers**

Seymour and Hewitt (1997) described similarities between the switchers and non-switchers in terms of personal attributes and characteristics such as academic performance, attitude, and behavior as a significant finding (p. 32). This finding debunked the wide-held belief that students left SEM only because they could not personally succeed in SEM programs due to poor grades or not working hard enough (p. 32). The traditional view of SEM switchers held by

many SEM faculty was that those students lacked the ability to cope with the difficulties of SEM majors or simply they lacked the initiative needed to put in the hard work required to be successful in SEM (p. 35). A male, White, SEM switcher described his view of the reasons why people switched:

> I don't think that many people who love science, math and engineering leave
>
> because they can't handle it or because it's too hard…More often than not, people
>
> that I know have left because there hasn't been the intellectual fulfillment there
>
> for them. (Seymour & Hewitt, 1997, p. 40)

Next, Seymour and Hewitt (1997) found several sets of problems shared by both groups. The switchers and non-switchers described the same types of concerns; however, the non-switchers seemed to be able to develop personal coping strategies that helped them persist in a SEM major (p. 30). Some non-switchers also described serendipitous actions usually in the form of faculty intervention at a critical point in their academic or personal life that positively influenced their decision to persist (p. 30).

The SEM switchers ranked and described the four highest problems in SEM education as lack or loss of interest in science, belief that a non-SEM major would be more interesting than a SEM major, poor teaching by SEM faculty, and feeling overwhelmed by pace and curriculum demands (p. 32). Criticisms of poor teaching by SEM faculty contributed to one-third (36.1%) of all switching decisions. Interestingly, 90% of switchers and 73% of non-switchers complained about poor faculty teaching (p. 34).

In addition, faculty members were described as unapproachable or unavailable for help with either academic or career-planning concerns. There was also harsh criticism of a classroom climate that favored individual competition and discouraged collaborative work (p. 35). A lack

of support for collaborative learning was difficult for students to understand particularly by those

students who had already discovered that working with classmates on problems and projects

enhanced their learning (p. 106). The students "almost universally cited collaborative learning

strategies as an important way to address intrinsically hard material" (p. 106). Yet faculty within

their programs discouraged students from working together.

Both groups explained how grades contributed to the decision to switch or persist (p.

106). About 25% of the switchers stated that problems with grades especially in their early

courses were a factor in their decision to leave the major (p. 106). The data from their study

showed a significant relationship between grades and attrition (p. 106). Interestingly, when the

authors looked at gender differences, female students with higher grades than male students

tended to leave SEM (p. 106). Finally, some students described how good grades improved their

social capital with their peers and the faculty within the major thereby increasing their

motivation to persist (p. 110).

**Switchers**

Seymour and Hewitt (1997) explained that over 30% of the respondents that switched out

of SEM specifically described the extreme workload as a reason to switch (p. 92). Participants

described this as having to take too many math and science courses during the first semester and

not being able to keep pace with their professor's requirements (pp. 92-93). Some further

clarified that they felt the extreme workload resulted from the nature of the content itself (pp.

100-101). Students that switched expressed anger toward faculty and the SEM departments for

favoring those students who were able to grasp science and math concepts quickly. This made

those students that needed extra help and time feel inadequate (p. 101). One student described

being compared to the "Little Red Engine" and told they needed to work harder to be successful in science (p.101).

**Poor Teaching Described**

As mentioned earlier, 90% of switchers and 73% of non-switchers agreed that the most significant problem in SEM education was poor teaching (p. 145). Poor teaching practices were described as: a lack of preparation and disorganized content, a lack of feedback, an inability to explain a concept in a different way and being sarcastic or degrading when answering student questions. Other factors mentioned included a lack of understanding of how much material should be presented for proper comprehension in one class period, a lack of discussions in class about application of content, and boring lectures (p. 153).

There was general criticism of lecturing by reading directly from the textbook, a lack of communication skills, and a failure to understand how students learn, especially in relation to fit between class materials, homework, and tests (p. 155). The authors determined that there was a collegial toleration and reinforcement of poor teaching based on a long-standing norm of using introductory courses as a selection process which they described as the "weed-out strategy" (p. 157). Many students described how their professors' behavior demonstrated a dislike for teaching, disrespect for teaching as a professional activity, and a clear lack of interest in learning how to teach effectively (p. 146).

**Good Teaching Described**

On the other hand, Seymour and Hewitt (1997) described good teaching practices that were mentioned by the students to be openness, respect for students, encouragement of discussion, and creating an environment where teacher and students discover things together (pp. 170-171). According to a White, male, engineering, non-switcher, "The professor is by far and

away, I think, the main determining factor in how well you do in a class, and how much you learn" (p. 156). Good teaching practices that were highlighted by both switchers and non-switchers included organization skills with strong understanding of how students learn, activities that encourage students to think and be creative in the discipline (p. 167), and an authentic concern for their students learning and appreciation for the subject. Both switchers and non-switchers agreed that a professor's attitude about the topic and enthusiasm for the discipline was an important element of a good teacher (p. 171).

The students also emphasized that good teaching was encouraging collaborative learning (p. 172). Female students preferred to work with peers and indicated a dislike for the individual competitive mindset (p. 173). Female and male students of color described how working with peers reduced the feelings of isolation in the major (p. 173). The authors also reported several observations that supported group learning and provided evidence for a relationship between participation in group study and increased persistence (p. 174). Students described participation in group study as a method which developed a sense of belonging in the discipline (p. 174). A female, White, engineering, non-switcher described it as, "It's kind of a bond, a sense of belonging, being a part of the group. I think that helps people do well too. It helped me to stay interested" (p. 174). Another participant, female, Black, science, non-switcher explained, "It's nice to know that someone else knows what you are going through, someone that can share the joys and pains of going to class" (p. 174).

Switchers and non-switchers explained the unique educational benefits of collaborative learning as including reinforcement of understanding and skills, learning at a deeper level, learning by teaching, generation of new ideas and applications, personal intellectual challenge and growth, willingness to share mistakes and learn from them, pleasure in debating intellectual

issues, and discovering the enjoyment of learning (p. 174). A male, White, science, non-switcher explained, "I learn more from going over the homework with my friends because they pick up on my mistakes and on their mistakes too. And we all benefit more than just someone showing me how to do it" (p. 175).

**Lack of Concern by SEM Faculty**

In Seymour & Hewitt (1997) poor teaching was one of the top four problems described by both switchers and non-switchers. Non-switchers expressed an anger about the lack of education they received in their SEM majors. They explained that they felt the teaching they received failed to properly help them learn. However, many SEM faculty members did not seem to be concerned by these statements or by the fact that they were losing top performing students to other majors simply because of the poor-quality teaching practices in SEM. Many SEM faculty members held a strong belief that there was no problem in the system or process (p. 165). The authors further explained that in order to truly make a difference and reduce SEM student attrition, faculty members must confront the challenge of how to address their collective shortcomings as teachers (p. 166).

Some faculty members simply described SEM attrition as a "benign phenomenon" allowing students to recognize that another major is more appropriate for them (p. 177). Seymour and Hewitt challenged that view by stating:

> Contrary to popular belief, we found switching in recognition of a stronger
> interest in a non-SEM discipline to be much rarer than switching in response to a
> pedagogy which engendered loss of enthusiasm for a SEM discipline in which the
> student was interested. (p. 178)

In summary, students explained that completing a SEM major required a combination of intrinsic interest, ability, and adequate preparation and motivation. However, even when students had adequate preparation, they often lost interest and motivation to persist in the discipline because of the educational experience itself, primarily due to poor teaching practices of SEM faculty members (p. 179). This analysis clearly set the stage for the examination of teaching methods central to this study.

**Current Literature on STEM Student Departure**

The current literature reveals three primary areas most described as predictors for student persistence in STEM: academic preparedness, academic and social integration, and educational experiences. Academic preparedness is often measured by the ability in math based on SAT / ACT scores and the amount of math classes taken in high school, the number of advanced placement courses taken in high school, and the types of STEM courses taken along with the GPA achieved during the first year in college.

Cromley, Perez, and Kaplan (2016) defined academic and social integration as a combination of academic achievement and social connectedness within the STEM program. Educational experiences are items such as teaching methods, interaction with faculty and peers inside and outside the classroom, and institutional structure. They further explained that the problem of persistence in STEM was due to several dimensions that required a partnership between faculty, students, and the institution to solve. The authors argued that it is difficult to isolate a single aspect of the STEM departure phenomenon as being crucial and that it would be unrealistic to identify a single contributing factor such as faculty teaching method or student ability as the cause for the decision to depart STEM.

Green and Sanderson (2018) sought to determine the variables that influenced persistence in STEM by analyzing the impacts of interest, ability, self-efficacy, and educational experiences. The authors surveyed 16,000 students over a seven-year period to determine the causes that influenced success in STEM, specifically persistence and degree attainment. Their findings indicated clearly that ability, especially in math, significantly influenced persistence in STEM. The authors emphasized that ability does matter; however, they explained self-efficacy levels and educational experiences, specifically participating in study groups, also contributed to STEM persistence.

However, even if they had a strong ability in math, women and under-represented minority students, specifically Latinx and African Americans, continued to leave STEM majors because of the social interactions and culture within the STEM programs (Green & Sanderson, 2018). Finally, they did not find interest as a statistically significant variable impacting persistence in STEM. Given these considerations, the remaining sections will focus on the three primary dimensions found to impact STEM persistence academic preparedness, social integration, and educational experiences.

*Academic Preparedness*

Several factors influenced a student's decision to pursue STEM in college including an interest in scientific discovery, family and cultural influences, and academic preparedness with a strong ability for math (Ackerman et al., 2013). Predictors such as the amount and type of math courses taken in high school, courses taken the first semester in college, and scores on SAT or ACT tests, also predicted STEM persistence (Ackerman et al., 2013). According to Bettinger (2010), those students who took at least high school calculus tended to stay in STEM in college. In addition, those students who took at least 60% of their credits in STEM during the first

semester in college had a higher probability of persisting in STEM. Specifically, Green and Sanderson (2018) explained it as, "increasing the number of high school students who take higher math courses is likely to lead to more STEM majors in college" (p. 90).

Hewson (2011) claimed that math skills alone do not always guarantee STEM success. As shown by Griffith (2010) some high achieving high school students may not have the academic abilities to succeed in college level engineering. This confirmed the suggestions made by Green and Sanderson (2018) that several factors influence student success and persistence in STEM with math ability being the strongest predictor of STEM persistence followed by self-efficacy and educational experiences. Xu's (2018) findings confirmed academic performance as a significant predictor of student persistence and degree completion in STEM majors. Another leading predictor of STEM persistence was a balance of academic and social integration.

### *Social Integration*

Social integration was another key to student persistence in STEM. In a qualitative study, Weidman (1989) described undergraduate socialization in STEM as interpersonal interactions between peers and faculty members, and considered the frequency of interactions, as well as the quality of interactions. He interviewed STEM students to understand their perceptions of socialization and sense of belonging. Students who indicated a strong interpersonal relationship, along with feelings of being socially connected to peers and faculty members, indicated a positive sense of belonging. Similarly, Strayhorn (2012) also found interpersonal relationships and feeling socially connected to peers and faculty members important to a positive sense of belonging.

Weidman (1989) presented four themes related to a positive sense of belonging in STEM. The first and most reported theme expressed by all demographic groups included in the study

was having interpersonal relationships within the academic program. Second, competence level in the topic was again expressed by all demographic groups as important for sense of belonging. A high level of competence in the topic areas was explained as the feeling of having understood the content and related material or having received good grades in the major and related courses. The third theme related to a positive sense of belonging was having a personal interest in the major or subject area. Finally, having and maintaining a strong self-identification as a person interested in science contributed to a positive sense of belonging in STEM.

It was interesting that, according to Xu (2018), social engagement was not a significant contributor to student persistence in STEM. She emphasized a balance between academic and social engagement but more critical to persistence was the perception of academic quality and availability of faculty members for help and support. Her findings aligned with that of Kuh et al. (2006) who also supported the idea that institutions need to invest in programs that support purposeful student and faculty interaction, active and collaborative learning strategies, and provide environments perceived by students as inclusive and affirming. Xu (2018) concluded, "an excellent undergraduate education is most likely to occur in an institution that maximizes good practices and plays a leading role in enhancing students' academic and social experiences on campus" (p. 426). While significant, Xu's (2018) study was limited given the low response rate and limited number of respondents from racial minority groups making it difficult to generalize outside of her focus area in Tennessee. Self-reported data was prone to validity concerns. However, Xu felt that her study provided a good starting point for further discovery into undergraduate STEM education.

Morganson et al. (2014) agreed a balance was needed between academic and social integration, but described how "deep rooting," was a greater predictor of persistence (p. 360).

"Deep rooting" occurred when students were involved in a program both academically and socially (p. 360). Focused on strategies to develop "deep rooting," the authors looked at STEM persistence through the construct of the Embeddedness theory, a workforce development theory, that explained why workers stay in a job. The Embeddedness theory assesses correlations between fit, links, and sacrifice as reasons to remain in a job. The researchers adjusted the Embeddedness theory for its applicability to college students and determined that fit within the major was similar to the skill / aptitude match on the job. Link equated to social relationships with peers on campus. Finally, regarding sacrifice, some students mentioned the prestige and elitism of being a STEM major and the increased social capital that it gave them was sufficient to overcome all the drawbacks and was enough to keep them in STEM.

Belser et al. (2017) also looked at STEM persistence through a career development lens, finding a clear behavior pattern in students that persist in their STEM major. Students that initially declare a STEM major and participate in STEM career planning were more likely to persist in STEM (p. 91). One year later, Belser et al. (2018) addressed intersectionality of ethnicity and gender along with ability to assess student retention in STEM. These findings were significant for females and minority students where cultural norms impacted career decisions. The authors further explained that students in STEM majors who had a greater awareness of job opportunities in the field exhibited higher levels of persistence. They described career development initiatives, like career readiness questionnaires and career counseling administered directly through the STEM programs to be the most effective at building awareness. Interestingly, Belser and colleagues (2018) also found that high achieving African American females were the least likely population group to persist in STEM even after career counseling; however, the authors provided no explanation for the negative impact experienced by this group.

Bettinger (2010) also viewed persistence through the lens of Social Cognitive Career Theory and described how the most talented students turned away from the hard sciences for majors that paid significantly higher salaries. Student persistence in STEM increased when students understood the career opportunities available along with the value associated with attaining a degree in STEM. Even with career counseling, female and minority student populations were described as requiring a more balanced combination of academic and social integration to persist in STEM (p. 49). In agreement, Xu (2018) recommended career advising as a way for institutions to help students increase their awareness about future earnings and job opportunities in STEM fields to help maintain their interest in STEM majors.

### *Sense of Belonging and Self-efficacy*

Sense of belonging and self-efficacy are affective elements or social factors affecting persistence in STEM. Sithole et al. (2017) provided insight into how specific race and genders are socialized into or away from various professions. STEM has been historically defined as a profession best suited for White men or those from high socioeconomic standing (Sithole et al., 2017), and has developed a reputation for having an unwelcoming and chilly climate to anyone outside those categories. Gender socialization is also a concern. There is the perception that STEM majors are "hard" and that only men can do "hard or difficult" things (Sithole et al., 2017). Because of this established cultural norm, it is difficult to build a sense of belonging or self-efficacy if outside the preferred group.

Studies showed that students with a higher level of self-efficacy tended to persist in STEM at higher rates than those students with lower levels of self-efficacy (Rittmayer & Beier, 2008). Similarly, STEM students with high self-efficacy demonstrated higher academic

performance (Schunk & Pajares, 2005). Green and Sanderson (2018) explained that self-efficacy levels increased when students participated in study groups.

Simon, Aulls, Dedic, Hubbard, and Hall (2015) conducted a study using the Motivated Strategies for Learning Questionnaire (MSLQ) to measure STEM students' self-efficacy levels and persistence rates. Their findings suggested that students with higher levels of positive affect were more likely to persist in STEM programs. However, the study could not predict persistence for those students with negative affect and intrinsic motivation. When the researchers focused on female students, they found that when perceptions of self-efficacy aligned with academic achievement, the rate of persistence increased.

### *Interest and Motivation*

Heilbronner (2011) argued that interest was the most important predictor of STEM persistence and emphasized that the other factors mentioned will not matter if students do not have a strong interest in STEM programs. In her view, interest increased motivation and motivation improved academic success and persistence. The literature described many different factors that influenced motivation in STEM starting with grades (Kuh et al.,2006; Lent, Brown, & Hackett, 1994; Pascarella & Terenzini, 2005; Xu, 2018); attitude (Liu, Bridgeman, & Adler, 2012); educational experiences (Heilbronner, 2011; Maltese & Tai, 2011); and perceived relevance of course materials (Ironsmith et al.,2003; Hurtado, Newman, Tran, & Chang, 2010; Jones, Paretti, Hein, & Knott, 2010, Obrentz, 2012; Zusho et al.,2003).

Obrentz (2012) cautioned the significance of students' perceived relevance of course materials because she did not believe students were qualified to evaluate course materials, yet students did express strong opinions when they were unclear as to how the content fits in with

the learning requirements. She further explained that students tend to default to a perception of irrelevance when they do not recognize a direct connection to the course materials.

### *Gender, Race, And Social Factors*

Maltese and Cooper (2017) clearly identified significant differences between gender and persistence in STEM. Often for African American, Asian, and White men, their persistence was based on a self-driven desire to succeed. What was interesting in this study was the African American men students persisted at a higher rate than the White women students, but not at a rate equivalent to their White men or Asian men peers. Men also indicated their desire to persist was based on a higher interest in future career opportunities. For women in STEM, their desire to persist was based primarily on external validation and recognition from others. They described several factors that influenced their persistence in STEM such as coursework, interactions with faculty and peers, and career opportunities (p. 1).

Grau-Talley and Martinez-Ortiz (2017) investigated women students' perceptions regarding interest and motivation and found that family socializing behavior contributed to interest and motivation. For women, an interest in STEM was developed at various points in their lives, but family support was the most significant reason for persistence. The authors referred to this source of motivation as an external self-concept. A lack of encouragement can come from cultural expectations that minority women do not belong in STEM. Often high school counselors did not recommend STEM majors to many of the minority women participating in the study. Some women also indicated their non-STEM friends were the least likely to support them though their STEM major.

Grau-Talley and Martinez-Ortiz (2017) further described how an internal self-concept played a large role in women's interest and motivation in STEM. The women experienced

feelings of internal insecurity that were based on a belief that men were smarter at STEM than women and they felt intimidated in large classes. Some women indicated holding an altruistic view of STEM professions which increased their persistence in the major. In addition, the authors revealed that some women in their study felt that if they needed extra academic help it was viewed negatively in their program. As a solution to the negative perceptions of tutoring, Grau-Talley and Martinez-Ortiz recommended including dedicated learning peers or caring professionals directly into the STEM programs.

Maltese and Cooper (2017) provided significant insight into STEM persistence by exposing the influence that outside sources had on students in STEM majors. Women and minorities tended to be more influenced by outside sources, most specifically family and peer groups. It was those significant influencers, that either contributed to or reduced their persistence in STEM.

As part of the Roots of STEM Success Project, Rainey et al., (2018) interviewed over 200 students regarding their self-perception of belonging in a STEM program. White men reported the greatest sense of belonging in STEM citing a high level of academic achievement as the main reason. Interestingly, no one cited lack of self-identification as a future scientist or lack of personal interest as a reason to leave or even as a contributing factor for a negative sense of belonging. What was significant from this study was the lack of reports describing a lack of personal interest in the topic as a reason to leave STEM. "Leavers rarely stated a lack of personal interest for their sense of not belonging in their STEM major" (p. 10). This finding indicated that students remained interested in STEM topics but simply could not tolerate the systemic and cultural features associated with STEM programs that favored White male populations.

It was interesting that, Rainey and her colleagues (2018) described how the Asian students' sense of belonging was more aligned with the STEM under-represented minority groups even though they were considered members of the STEM majority (p. 5). The authors defined under-represented minorities as those populations that were under-represented in STEM based on a comparison with the overall minority population in the U.S. (p. 5). An Asian woman physics student described her situation,

> I felt out of place especially because I was like 1 of 2 girls at the time that was a physics major. Even that other girl that was a physics major with me, I think she changed to a math major. (p. 8)

The researchers identified several limitations and expressed concern for the low sample size of the sub-populations. Even with the limitations they felt their study was a strong representation of the students' voices on campus at the time, and their findings contributed to an overall analysis of why students leave STEM (Rainey et al., 2018).

### *Educational Experiences*

Two significant meta-analyses helped clarify which educational experiences were relevant to persistence in STEM. Chickering and Gamson (1987) outlined seven principles for undergraduate education that directly influenced the quality of student learning and educational experiences. Of the seven principles, three were of interest in this study: encouraging cooperation among students, encouraging active learning, and encouraging contact between students and faculty. Active collaborative strategies that encouraged both formal and informal interactions between faculty members and students were shown to enhance student engagement and learning. They also explained that faculty members' behavior had a direct influence on student engagement and performance.

Shapiro and Sax (2011) explained that science courses in college tend to present content through lecture rather than active learning methods. In their study, they described how science programs often followed a "weed out" philosophy to eliminate low performing students from STEM programs (p. 8). The authors also added that the typical STEM classroom limited student collaboration. They further described the four factors that significantly influenced women's decisions to declare a STEM major. The four factors were self-confidence, a strong sense of belonging in STEM, family expectation or influence, and peer or social group affiliation.

Ruiz-Primo, Briggs, Iverson, Talbot, and Shepard (2011) investigated a claim that students in traditional lectures did not develop a proper understanding of concepts within the STEM disciplines. They conducted a major meta-analysis on 166 published studies investigating the effects of undergraduate learning in courses categorized as either conceptually oriented tasks, collaborative learning activities, technology, or inquiry-based projects. Their findings suggested that various combinations of conceptually oriented tasks, small-group learning, use of technology, and student-driven inquiry projects could effectively help students remember scientific facts, understand how the facts were connected, and helped students apply what they learned to new situations.

Another study conducted by Freeman et al., (2014) explained the benefits of active learning techniques in STEM. A meta-analysis of 225 published and unpublished studies on active learning techniques for college students found that active learning increased exam grades and passing rates. The effect was similar across STEM disciplines. The findings indicated active learning was more effective in smaller classes ($\leq 50$ students) but provided positive effects in large classes as well. Freeman and his colleagues were not able to test whether all active learning approaches were equally effective due to lack of detail in many of the studies they reviewed.

Xu (2018) conducted a study of 400 students using self-reported survey data examining college student educational experiences in STEM as they related to persistence and degree completion. The study included STEM majors from the "hard sciences" that required strong quantitative skills, such as biology, physics, chemistry, earth sciences, mechanical engineering, electronic engineering, civil engineering, computer sciences, and geology. Xu identified ten factors most likely to influence a student's decision to leave STEM before completing the degree (p. 419). The three most significant factors were academic quality and availability of support from the faculty members, student's GPA, and the ability to pay for college education (p. 423). Students with low GPAs had a very strong intent to leave the STEM major before degree completion. Xu also found that student with a low perception of the quality of the academic program and a lack of accessibility to their faculty members significantly influenced their decision to leave the major (p. 423).

Conversely, Xu explained that interest and a perception of a high-quality academic program increased persistence in the STEM majors (p. 423). She further described that students who felt more positive about the academic program, teaching quality, and faculty members' support were less likely to change majors (p. 423). It was interesting that for STEM students' social engagement with peers and on campus activities had less influence on persistence (p. 423). Finally, Xu found that for students to persist in STEM they needed to feel satisfied with their academic experience and supported in their learning environment.

### *Educational Practices*

Nichols and Quaye (2009) explained that STEM majors are challenging. Too much challenge with not enough support negatively impacts persistence. The authors stated that

college students are not solely responsible for their education experiences. Education must be shared by the student, institution, and faculty members.

Umbach and Wawrzynski (2005) explained that faculty members do matter. Faculty members can directly influence student engagement and learning outcomes through their contact with the students. They analyzed two national surveys, the National Survey of Student Engagement (NSSE) and the faculty response to NSSE, to determine if there was a relationship between faculty member practices and a students' engagement in their own learning. The analysis from the 2003 NSSE survey included approximately 42,000 students and over 14,000 faculty members from 137 institutions. The most significant result was that course-related interactions between students produced positive student engagement and students reported higher levels of challenge when engaged in active and collaborative learning activities.

Continuing the discussion, Umbach and Wawrzynski (2005) explained that faculty members did matter and identified specific teaching practices proven effective for increasing higher order thinking skills, student engagement and student learning outcomes. They also reported that institutional type had an impact on teaching practices. The faculty members at liberal arts colleges were more likely to use teaching practices that engaged their students directly, challenged them academically, utilized active and collaborative teaching strategies, and were willing to interact in course-related activities. Conversely, faculty members at research intensive universities engaged in less active teaching practices.

In another study, Booth, McGinn, Young, and Barbieri, (2015) tested video-taping problem-solving demonstrations in biology to determine if there was an impact on student motivation, understanding, and persistence. Feedback from students suggested that they often received instruction about content-based questions and answers but rarely got a demonstration on

the reasoning or thought process involved in figuring out how to answer the questions. They also described how they felt the video demonstrations reduced their workload in the course by reducing the time spent outside of class studying the material. Booth and colleagues suggested that the video-taped demonstrations increased content knowledge and improved student perception of the educational experience by helping them understand the thought processes involved in problem-solving.

Salomone and Kling (2017) described how the educational experience of peer-led cooperative learning improved persistence in gateway science courses. The improved persistence resulted from higher grades and an increase in academic success within the major. The authors suggested that their findings were useful even though their study did not include a defined control group.

Several other studies focused on the educational experience of peer mentors (Colvin & Ashman, 2010; Hernandez & Lopez, 2004; Strayhorn & Saddler, 2009). The teams tested the effectiveness of peer mentors in large introductory STEM courses. Common to all the studies were the findings that suggested the use of peer mentors reduced the preparedness gap often felt by some first generation and under-represented minorities and women students in STEM majors.

## Retention Summary

This review of the literature showed that there are differences between general student retention theories and retention studies specific to STEM college students. Both agreed that a balance of academic performance and social interactions increased persistence in college. In STEM persistence predictors were similar to those of general college student departure with a few clear differences such as academic ability, sense of belonging to STEM community, and perception of educational experiences within the program.

What was found was that even the most highly prepared students with a strong interest in STEM left their STEM major. The literature showed that sometimes students left STEM for rational economic decisions such as an inability to pay tuition. Other times the reasons to leave STEM were influenced by perceived quality of the educational experience. Given the complexity of STEM persistence it was difficult to isolate one specific variable as the cause for the departure.

For STEM students, social connectedness in the academic program was more influential than simply having a strong social connection on campus. Academic success was a key factor in persistence as was collaboration with peers in the classroom. Women and under-represented minority students in STEM programs were also more influenced by external social influences inside and outside the classroom. Classroom environments that encouraged collaboration with peers increased self-efficacy and a sense of belonging all led to an increase in STEM persistence and was shown especially significant for women and under-represented minority groups.

## College Teaching Methods

To fully understand the potential factors that could influence this study it was important for me to investigate the practice of college teaching. The most common teaching method used by faculty members in higher education was the lecture method (Hativa, 2000; Thielens, 1987). Along with a review of the lecture literature, this section will also examine the research focused on student-centered teaching methods.

Historically, a direct dialogue between teacher and student was the first known method of teaching (Beichner, 2014). Socrates primarily engaged his students by questioning what they thought they knew and asking them to teach him. Plato also engaged his students in direct dialog. After the founding of universities in medieval times lecture became the primary teaching method

(Beichner, 2014). It was common for those with master's degrees, which was the license to teach, to share their knowledge on topics while the students sat passively and listened to their words (Beichner, 2014; Hativa, 2000).

In the 1980s, Thielens (1987) conducted a survey of over 800 faculty members at 80 U.S. institutions investigating the types of teaching methods used most by professors. Thielens' findings revealed approximately 80-85% of college teaching was done through lecture. Finkelstein, Seal, and Schuster (1998) followed up Thielens' study with a seven-year survey of over 170,000 faculty members from 1986-1992. They found that 75% of the faculty members indicated lecture as their primary teaching method (p. 70).

Furthermore, Finkelstein and colleagues identified differences in teaching methods used between women and men faculty members. The men faculty members tended to rely more heavily on lecture compared to the women faculty members who utilized other instructional methods that were more student-centered such as discussion and collaborative problem-solving exercises in addition to lecture (p.73). The authors also investigated if differences in teaching methods used were due to academic programs and they found sharp differences in teaching practices between the liberal arts and social sciences and the natural sciences. The faculty members in the liberal arts and social sciences indicated a greater use of collaborative teaching methods compared to their colleagues in the natural sciences who indicated a predominant use of lecture (p. 74).

Kuh and colleagues (2006) created five clusters of educational practices that were intended to influence the selection of a specific teaching method. The five clusters were based on student-centered teaching strategies: providing academic challenge, active and collaborative learning, student-faculty interaction, enriching educational experiences, and a supportive campus

environment. With lecture being the most utilized teaching method in higher education, Arum and Roksa (2001) emphasized the importance of switching from faculty-focused teaching to student-centered teaching practices. They highlighted a greater need to focus on student engagement through active and collaborative instructional activities in higher education.

Bok (2006) stressed that while there have been small pockets of innovation in teaching, most professors teach as they traditionally were taught. Faculty members confidently express "what has worked in the past is sufficient for future students" (p. 311). Even though they are trained researchers, most college faculty members refused to consider published educational research that promoted teaching methods that engaged students actively in the learning process as significantly better than traditional methods (p. 312). This lack of formal preparation, Bok explained as "the anchor that deters major change of teaching practices in the professoriate" (p. 315).

It was uncommon for college professors to select teaching methods based on informed pedagogical practice of how students learn (Fink, 2013; Handelsman et al., 2007). Fink (2013) explained it best, "although faculty want their students to achieve higher kinds of learning, they continue to use teaching practices that are not effective at promoting such learning" (p. 3). According to Arum and Roksa (2001) there is a lack of urgency felt by most college professors to change their teaching methods and they defend their choice based on their workload. Contrary to the faculty members' defense, Arum and Roksa described an average workload for faculty members, "faculty spend approximately eleven hours per week on instructional preparation and delivery" (p. 8).

Instructional preparation was often spent preparing for lectures with little evidence of any time spent in reviewing scholarship about teaching methods (Anderson et al., 2011; Blaich &

Wise, 2011). It follows , according to Bok (2006), that "professors' indifference to educational research comes from a personal doubt that studies of teaching and learning in other universities can tell them much about the appropriate methods of instruction for their students at their colleges" (p. 51).

The Wabash National Study (Blaich & Wise, 2011) was a longitudinal research and assessment project designed to deepen understanding of the teaching practices, student experiences, and institutional conditions that promoted student development in college. Since the pilot was launched in 2005, over 17,000 students from 49 colleges and universities have joined the Wabash Study (Blaich & Wise, 2011, p. 5). Through their research involving thousands of students, the authors identified a set of teaching practices and conditions that predicted student development. These practices and conditions were good teaching and high-quality interactions with faculty, academic challenge and high expectations, diverse experiences, and higher-order, integrative reflective learning. Unfortunately, the study revealed that higher education has only implemented a few of these practices, "good educational practices are not being hardly used at all" (p. 7).

There was a substantial amount of literature available on how people learn. Cognitive science literature can guide a more informed teaching practice. There were studies of student learning and memory (Atkinson & Shiffren,1968; Bransford & Schwartz,1999; Kolb, 1984; Redish & Steinberg, 1999), neurological understandings of how the brain works (Medina, 2008), student engagement (Kuh, 2004) and the science of learning (Brown et al., 2014) all throw light on the topic. Bok (2006) suggested that the average student will forget most of all the facts presented in a typical lecture fifteen minutes after class ends (p. 48). Conversely, he explained

students that construct their own mental images are more likely to remember the content longer (pp. 48-49).

Nyquist, Manning, Wulff, and Austin (1999) investigated several research-intensive doctoral programs finding that only 50% of the students received training on how to teach in their respective discipline (pp. 23-24). Bok (2006) indicated college professors contributed most to the shortcomings in quality of undergraduate education. While they may have a professional intrinsic desire to be good educators, nothing forces them to go beyond the normal level to fulfill their classroom teaching duties (p. 32). According to Bok (2006), "there is no incentive for professors or administrators to search for new or better ways to teach undergraduates. College professors have considerable freedom to design their courses and teach their students as they best see fit" (p. 34).

## STEM College Teaching Methods

STEM education is not immune to the shortcomings of college instructional practices. There are several similarities between STEM pedagogical practices and general college teaching practices. As explained earlier, the teaching methods of college faculty are often the result of choices based primarily on how they were taught in graduate school (Bok, 2006; Fischer, 2011; Handelsman et al., 2007; Mazur, 2009; Stitt-Gohdes, 2001).

To better understand STEM classroom teaching practices, Stains et al. (2018) conducted an extensive study using the Classroom Observation Protocol for Undergraduate STEM (COPUS). COPUS, developed by Smith, Jones, Gilbert, and Wieman (2013) was designed to capture only classroom elements that were associated with teaching and how faculty and students were spending time in the classroom. The COPUS instrument was tested for reliability and validity and interrater reliability for large scale projects (Smith et al., 2013).

Using the COPUS protocol, Stains et al. (2018) observed over 2000 STEM classes from approximately 700 courses taught by 548 faculty members from seven STEM disciplines at 24 doctorate-granting institutions in North America. Using the observational data, the authors compiled a profile analysis that provided a clearer picture of the actual teaching strategies used. The faculty profile identified the following four techniques: lecture, posing questions, clicker questions, and one-on-one work with students. The student profile also identified four activities: group work on clicker questions, group work on worksheets, other group work, and asking questions (Stains et al., 2018). The profiles created represented the key features of active or non-active learning environments (p. 1469).

The overall findings from Stains et al. (2018) indicated that 55% of the courses taught in STEM used didactic methods. Twenty-seven percent were taught using interactive lecture and only 18% of STEM courses observed in the study were taught using student-centered instructional strategies. One significant benefit of the large sample population was that generalizations could be made from the data beyond the institutional-level descriptions that were normally available (p. 1468). Their research also encompassed the common justifications for or against certain teaching methods. It was common for the authors to hear arguments against student-centered strategies from faculty members that taught large classes. Furthermore, they found it was not only large classes that primarily used lecture, about half of the small to medium size classes were also observed using didactic teaching methods.

Stains and her colleagues found some surprising results when they looked at different disciplines. They noted that math and geology used more student-centered styles than expected; biology used more interactive styles than expected; and chemistry used more didactic styles than expected (p. 1469). The study revealed two significant findings. First, the use of the didactic

teaching method was prevalent in undergraduate STEM education even though there was ample

evidence in the literature supporting the desirability of other teaching practices. Second, the

argument that suggested student-centered practices were predominantly used in small to mid-

sized classes did not hold up given that small to medium sized classes were found to primarily

use didactic teaching methods as well.

**Definition of Didactic Teaching Method (Traditional Lecture)**

Stains et al. (2018) defined didactic courses as those taught at least 80% by traditional

lecture. In didactic teaching the faculty or instructor spent most of the time lecturing and students

were observed exhibiting low involvement in the class other than asking a sporadic question and

possibly taking notes (Stains et al., 2018). Some scholars argued in favor of the lecture. Bligh

(2000) conducted meta-review of the literature comparing acquisition of information from

lectures to other teaching methods. Bligh's findings showed "lecture is as effective as any other

method for transmitting information but not more effective," (p. 4). Harrington and Zakrajsek

(2017) explained that there was no research available to support the total abandonment of lecture

from the college classroom experience. They argued that the lecture remains a viable teaching

method especially with its prevalent use in higher education and recommended guidance for

effective lecture techniques.

**Learning Theories**

Two learning theories support the didactic teaching method: behaviorism and

cognitivism. Behaviorism is one of the most widely used learning theories in education and

workforce training environments (Leonard, 2002). In a behaviorist-based teaching environment,

the teacher is the expert who provides information to the student learner. The student is expected

to demonstrate their understanding by achieving pre-established learning objectives (Ali, 2013;

Jonassen, 1991). Classic behaviorists such as Skinner, Pavlov, and Thorndike are not interested in the internal thought processes or other conditions associated with learning (Jonassen, 1991; Leonard, 2002). Behaviorists are primarily concerned with observable learning outputs based on a controlled stimulus-response format. (Leonard, 2002).

Cognitivism focuses on internal thought and learning through information processing (Leonard, 2002). Cognitivists believe learning takes place when the learner gathers information from the external environment and processes it internally in the mind (Jonassen, 1991). Cognitivists have based their assessment of learning on how information was processed. They believe learning has occurred when the student can provide an accurate depiction of the concepts presented (Leonard, 2002). Cognitivists described how humans think, learn, disseminate information, and solve problems; essentially, they are only concerned with internal mental processes of the mind (Jonassen, 1991; Leonard, 2002). Recent developments in neuroscience have expanded our understanding of how the brain works (Medina, 2008).

**Support for Lectures**

Despite the push to move away from lecturing, it remains the most commonly used teaching method in higher education (Berrett, 2012) as well as in STEM education (Fischer, 2011; Stains et al., 2018). What was lacking in the literature was published guidance for conducting effective lectures (Harrington & Zakrajsek, 2017). Richardson (2008) recommended fixing the lecture instead of abandoning it and described how a well-conceived lecture was one of the most effective ways to integrate complex information from multiple sources. Baeten et al. (2013) conducted a quasi-experimental study of college classes taught using different teaching methods. In this study the authors found students in lecture only classes outperformed those students who were in case-based constructivist classes. The authors suggested that lectures are

important early in a course to provide the foundational knowledge needed by learners with limited prior understanding of the subject matter. Harrington and Zakrajek (2017) supported those findings and further elaborated on how lecture was an efficient teaching method for introductory courses.

**Concerns with Lectures**

Much of the literature with a negative view of lecturing and a preference for active learning argued for the limited effectiveness of lectures on student learning (Bok, 2006; Fink, 2013; Freeman et al., 2014). Bajak (2014) proposed a ban on lectures all together. Wieman (2017) doubted that lecture was ever an effective model for education, specifically science education, and stated the changes in society over the past few decades have made it clear that the lecture is unsuitable for today's science student (p. 7). Fink (2013) described the lecture as the least effective teaching method for information retention, application and transferability to other situations, thinking and problem solving, and motivation to learn. Arum and Roksa (2001), even though not specifically focusing on STEM students, explained that students want to learn something of benefit from their investment in higher education and described an observation from a student, "you know I can get out of here with a 3.5 but it doesn't really matter if I don't remember anything…It's one thing to get the grade in a class and it is another to actually take something from it, you know" (p. 5).

This concern was not lost in the discussions about STEM education. An advisory committee funded by National Science Foundation, published a report *Shaping the Future*, describing the disconnect between U.S. STEM research and U.S. STEM education. The report urged STEM faculty to promote a new kind of learning, one that developed communication and teamwork skills as well as an attitude for lifelong learning (Fink, 2013). Even with the published

critiques, Stacy (2009) suggested that like anything, "lecturing can be done well, or it can be done badly" (p. 275).

**Active Learning / Collaborative Teaching Methods**

It was important to understand that active learning was not a new concept for higher education. More recently, it has become a much more recognized teaching practice given the current push to reform undergraduate science education (AAU, 2017; NRC, 2015; Stage & Kinzie, 2009). Plato described active teaching and learning techniques of his teacher Socrates. He described how Socrates engaged his students in questioning and discussion. Socrates believed, "a teacher should not deliver information. Instead, teaching consisted of prompting students … and then asking them provocative questions to steer them towards realizing true knowledge via introspection," (Stoddard & O'Dell, 2016, p. 1092).

**Definition**

Professionals in higher education lack a comprehensive agreement on the definition of active learning. Some educators consider the learning process to be inherently active whether listening to a lecture or solving a problem in a group (Bonwell & Eison, 1991). Other educators described the learning process as intentional and purposeful requiring some physical action or act of cognition (Allen & Tanner, 2005; Bain, 2004; Bransford et al., 1999; Chickering & Gamson, 1987). Herreid (2006) defined active learning as any instructional method that required a student to do something in the classroom rather than simply listen to a lecture. Collaborative learning required students to do something with others. The "do something" often meant engaging in discussion or problem-solving using case studies. However, Herreid also believed notetaking was a form of "doing something" (p. 43).

Arum and Roksa (2001) described active and collaborative learning as engaging students in the learning process by applying what they were learning as they worked with others (pp. 131-132). Kuh et al. (2006) argued, "Active and collaborative learning is an effective educational practice because students learn more when they are intensely involved in their education and are asked to think about and apply what they are learning in different settings" (p. 68). In response to the literature and the various perspectives, Brame (2016) developed a definition of active learning: "Activities that students do to construct knowledge and understanding. The activities vary but require students to do higher order thinking about their own learning, providing the link between activity and learning" (p. 1).

**Active Learning Theories**

Active learning strategies have evolved from constructivist and social-constructivist learning theories (Mastascusa et al., 2011). In this section, the focus will be on the pedagogical strategy of active learning as originated in the 20th century during the progressive education movement of Dewey, Piaget, and Vygotsky.

*Constructivism*

Constructivism explained the process of how individuals construct knowledge by various activities or strategies that promote the cognitive work required to build knowledge (Handelsman et al., 2007). The origin for Piaget's Constructivist Learning Theory goes back to the progressive thinking of the philosopher, John Dewey, who believed education was an active process, describing it as a "meaningful activity in learning and participation in the classroom," (Schoolhouse Pioneers, n.d., Weston, 2014). Piaget (1978) expanded on Dewey's view by providing insight into how individuals process information and connect experiences to create meaning.

Piaget (1978) said that there were two different elements of the learning process. First, there was accommodation where existing knowledge changed to make sense of new information. Second, was assimilation in which the learner did something with the new information and the preexisting knowledge (replacing the old with the new, modifying the old with the new, holding on to the old but updating it, or discarding the old knowledge all together). Liu and Matthews (2005) described Piaget's view of knowledge construction as a primarily internal process involving the psychological aspects of reflection and internal processing. Von Glaserfeld (1998) expanded the work of Piaget (1978) by arguing there was no real way to know exactly what others were thinking and that educators cannot realistically "pour knowledge into their student's heads" in order to create learning (p. 4). He considered the idea of passive learning to be misguided and prevented teachers from considering how and what their students were thinking. Both Piaget (1978) and von Glaserfeld (1998) agreed that in a constructivist learning environment, students must take responsibility for their own learning but rely on their instructors to guide them and provide information and feedback as needed. In their view, it was not necessary for all knowledge or information to first pass through the instructor before it could become known by the student (Piaget, 1978; von Glaserfeld, 1998).

Matthews (2003) saw constructivism as a student-centered learning theory which altered the role of teacher to become more like that of a learning facilitator, coach, or mentor. As a learning facilitator, the instructor maintained all the responsibilities of a teacher, they continued to develop instructional content and activities and evaluate performance, while facilitating learning that allowed their students to construct their own knowledge (p. 58). Learning facilitators developed authentic problem-solving tasks and activities and methods that guided their students to work independently to solve them (p. 61). Stage, Muller, Kinzie, and Simmons

(1998) agreed, "Constructivist approaches to teaching emphasize learner's actively constructing their own knowledge rather than passively receiving information transmitted to them from teachers and textbooks" (p. 35).

*Social Constructivism*

Social constructivism falls within the constructivist paradigm. Vygotsky (1978) disagreed with Piaget in that he did not believe a single principle could explain cognitive development and argued that knowledge was created when an individual reflected upon a social activity and internalized the experience. He thought that social interactions provided deeper meaning through communication, activity, and collaboration with others. Vygotsky also theorized that there was a gap between what an individual could accomplish independently and what they could achieve when collaborating with others who were more knowledgeable than themselves. This gap was known as Vygotsky's Zone of Proximal Development (ZPD).

The critical component of the ZPD is that the more knowledgeable other assists the individual learner within and through the zone. The more knowledgeable other (MKO) can be a teacher, a mentor, or a peer. The assistance provided by the MKO resembles instructional scaffolding where no direct right or wrong answer was provided, only assistance to help them get through the zone (Bentley, 1998; Bruner 1961; Seifert & Sutton, 2009). Vygotsky recommended that the Zone of Proximal Development worked well for both individual and group settings. Typically, the MKO facilitated the learning experience by redirecting, elaborating, questioning, and encouraging.

Wass and Golding (2014) described the Zone of Proximal Development as a learning process in which the learner could get into the zone individually but could not move through the zone and reach their full potential without the help of a more knowledgeable other like a teacher

or advanced peer. Social constructivists who followed Vygotsky's theory viewed knowledge

construction as a combination of individual and social interaction with others. Researchers have

continued to explore social constructivist theory, but Vygotsky's (1978) explanation of the

cognitive process has remained strongly supported in the literature (Bunce, 2001; Staver, 1998).

**Benefits of Active Learning**

There was considerable literature available on active learning practices and its

effectiveness in undergraduate education (Beichner et al., 1999; Ebert-May et al., 2003; Hake,

1998; Mastascusa et al., 2011, Stage & Kinzie, 2009; Udovic et al., 2002; Weimer, 2002).

Armbruster et al. (2009), Freeman et al. (2014), and Prince (2004) all considered student

performance outcomes final grades or test scores as a measurement for comparison.  Braxton et

al. (2008) looked at student perceptions of active learning practices. England et al. (2017)

considered the effects of active learning and anxiety. Bonwell and Eison (1991) published a

significant work about active learning in college classrooms where they described several

recommendations for change. Svinicki (2004) considered how active learning influenced student

motivation. Barkley (2010) expanded the discussion by adding an emphasis on student

engagement. Finally, Ambrose et al. (2010) recommended several teaching methods that would

support active learning strategies in college teaching.

Other studies have investigated how active learning strategies improved higher order

thinking skills by questioning (Holmes & Gardner, 2006; Ismail & Groccia, 2018; Pedrosa-de-

Jesus et al., 2012; Pedrosa-de-Jesus & Silva Lopes, 2011), and group discussion or group

learning (Braxton et al., 2008; Ebert-May et al., 2003; Hoyt & Perera, 2000; Johnson & Johnson,

1985; Johnson et al., 1991). Numerous studies showed the effectiveness of active learning for

women students (Maltese & Cooper, 2017; Okebukola, 1986) and students of color (Beichner et al., 2007; Maltese & Cooper, 2017).

Rosser's (1990) findings suggested that what worked well for women in education would also work well for other students. This was supported by Handelsman et al. (2007) "The traditional classroom environment is competitive, fast-paced, and isolating, all elements that do not foster deep learning. This environment is less effective for women and minority students" (p. 30). Handelsman and colleagues further argued that teaching professors do not need to be experts in learning theory; however, they recommended that teachers should know why and how the teaching method they use was appropriate for the learning outcome they desired. "Great teachers get their students curious and successful STEM students are those that are curious" (p. 13).

**The Impact on Learning**

The description of active learning often included students engaged in doing, along with thinking about what they were doing. Several studies have been published describing the benefits of active learning for improved student learning outcomes (Prince, 2004; Springer et al. 1999). However, little evidence was available that compared students' learning performance between active learning practices and traditional lecture or exposition-centered methods until Freeman and his colleagues (2014) published their study.

The meta-analysis conducted by Freeman and his colleagues compared measurements of student performance taken from 225 studies which met the research criteria for courses taught using at least one element of active learning as compared to courses taught using only traditional lecture. Their findings showed that active learning was more effective in smaller ($\leq$ 50 students) classes but provided positive effects in large classes as well (Freeman et al., 2014). One limitation of their study was that they were not able to determine whether all active learning

approaches were equally effective due to lack of detail provided in the research of several studies reviewed. Nonetheless, their results were significant, indicating a 6% increase in exam scores in the active learning classrooms. Students in the lecture format classes were 1.5 times more likely to fail the class. Thus, the evidence for the success of active learning was very strong:

> If the experiments analyzed here had been conducted as randomized controlled trials of medical interventions, they may have been stopped for benefit – meaning that enrolling patients in the control condition might be discontinued because the treatment being tested was clearly more beneficial. (Freeman, et al., 2014, p. 8413)

Other studies supported these findings and added that active learning environments were beneficial for students in science by helping them gain confidence and improving their attitudes toward the topic areas (Fata-Hartley, 2011; Marbach-Ad & Sokolove, 2000; Preszler et al., 2007; Prince, 2004). Braxton et al. (2008) showed that there was a positive relationship between participation in group discussion and increased social integration with improved attitudes, and better understanding of content. This contributed to higher persistence rates in STEM. Interesting to note that students had a positive perception of the institution's commitment to student welfare when faculty members used active learning teaching methods in class.

**Concerns with Active Learning**

Concerns about the ability of constructivist teaching methods, like active learning strategies, to provide the required base level of knowledge for entry level students have been raised in the literature (Scerri, 2003). Opponents of active learning often favor the works of cognitivists like Bruner that stress that learners need an overall schema to refer to when building knowledge (Scerri, 2003). It was stated that teachers are the ones that provide this schema when using practices such as inferences, interconnections, hypotheses, and concept maps (Leonard,

2002). Conversely, constructivists believed that by being actively involved in shaping the content, the learners gained a far better understanding than they would otherwise by being given information and working from it alone (Leonard, 2002). Concern about constructivist techniques continued to surface in articles published in the *Journal of Chemical Education* claiming that there was an incompatibility between active learning and the commonly held belief that science is in search of objective truth and knowledge (Fraser et al., 2014; Scerri, 2003).

Not all science educators agreed that constructivism was the best approach to teach STEM disciplines. In chemistry for example, Wink (2014) argued that constructivism was not a relevant pedagogical strategy for chemistry. His concern was that by relinquishing control of learning there would not be an objective proof of what the students were constructing and understanding or a way to assess if their understanding had any relationship to scientific reality. It was this belief, according to Handelsman and colleagues, that most STEM educators accept constructivist pedagogy developed by Piaget (1978) and Vygotsky (1978), but do not necessarily use them in their teaching practices (Handelsman et al., 2007).

**Student Concerns**

Student resistance to active learning was another concern. Not all students are prepared for the requirements of an active learning environment (Deslauriers et al., 2019; Green & Sanderson, 2018). Felder and Brent (1996) explained that some active learning activities require students to be self-disciplined and independent with an ability to work and prepare for class beforehand. Recent studies supported this concern and explained that students resist the extra level of engagement required in active learning classrooms because they perceived it as simply additional work, not seeing it as a more effective learning strategy (Finelli et al., 2018; Seidel & Tanner, 2013).

The negative reaction to anything seen as extra work was in part explained by the fact that today's college students only set aside a few hours for study compared to the students from earlier generations. Arum and Roksa (2001) described a comparative study that indicated full-time college students in the 1960s studied approximately 40 hours per week which included class time and out of class study whereas full-time college students in the early 2000s indicated only spending thirteen hours per week on those same tasks (p. 3).

Anxiety was another concern for some students in active learning classrooms (Cooper et al., 2018; England et al., 2017). Cooper et al. (2018) interviewed 52 students enrolled in college science courses that used three active learning practices: clickers, group work, and cold call or random call. The research findings were mixed and indicated the difference in anxiety levels were dependent on which form of active learning was used. England et al. (2017) further explained that the type of active learning experienced could invoke differing levels of anxiety in some students. The authors from both studies recommended that teachers should be aware of the potential for increased anxiety in students when using active learning strategies (Cooper et al., 2018; England et al., 2017). They further agreed that there are several known techniques available that can be used to mitigate the negative effects of active learning in STEM courses.

**Faculty Concerns**

Many STEM educators defended the lecture as the most appropriate way to teach; it was after all, the way most were taught (Bok, 2006; Pedrosa-de-Jesus et al., 2012). Several studies described the barriers faculty members identified to implementation of active learning teaching methods in STEM education (Blumberg, 2015; Henderson et al., 2012; O'Meara et al., 2017; Walter et al., 2016). Lund and Stains (2015) identified one significant barrier to the implementation of active learning in STEM as having to do with concerns for tenure and

promotion. Along with these reasons, several other studies identified increased workload as a significant barrier in using active learning (Arum & Roksa, 2001; Bok, 2006; Stains et al., 2018). Handelsman et al. (2007), Henderson and Dancy (2007), Mastascusa et al. (2011), and Walter et al. (2016), focused on the perception of not teaching to departmental norms. Bratt, Sundheim, Pound, and Rogers, (2017) identified anxiety as a concern. Finally, Henderson and Dancy (2007), Henderson et al. (2012), Stains et al. (2018), and Walter, Henderson, Beach, and Williams (2016) reported the barriers for active learning as being incompatible with large class environments.

To counter the above arguments, Frederick (1986) described how active learning strategies were effective in large class environments and provided examples for implementation. McKeachie et al. (1986) explained how group discussions promoted retention, motivation, and higher order thinking skills in large class environments. Weimer (2002) examined the impact active learning had on student attitude and performance in large enrollment introductory courses. Weimer's (2002) findings agreed with Frederick (1986) and McKeachie et al. (1986) that active learning strategies can be used in large class size environments.

The Association of American Universities (AAU) published a 5-year status report on the undergraduate STEM education initiative (AAU, 2017). It highlighted the continued problem and the existence of differing philosophies about the purpose of introductory science courses. On the one hand, STEM undergraduate faculty members resisted implementing evidence-based practices in introductory courses because they believed those courses were "weed-out courses" and students not prepared for the major should be eliminated early to avoid unnecessary expense (AAU, 2017, p. 6). On the other hand, the AAU president, Mary Sue Coleman, believed introductory STEM courses should be taught using evidence-based teaching practices that

provided every student the opportunity to succeed in STEM (AAU, 2017, p. 2). Mastascusa et al.

(2011) explained that "the problem for STEM educators is that we don't think there is a

problem" (p. 1). Table 1 summarizes the differences between traditional didactic teaching

practices and active or constructivist teaching practices.

**Table 1**

*Differences Between Didactic and Active / Collaborative Teaching Methods*

| Didactic Teaching methods (Traditional Lecture) | Active / Collaborative Teaching methods |
|---|---|
| Learning Theory–behaviorist based on repetition | Learning theory constructivist based on interactive construction with others based on prior knowledge |
| Teachers are experts and authority and disseminate information to students | Teachers are experts but dialogue with students asking questions to promote construction of knowledge and understanding |
| Teacher is authority | Teacher is coach, facilitator |
| Instructional material is primarily textbook | Instructional material is textbook and other primary sources of information like video, Internet, experts |
| Follow the curriculum and textbook | Follow the curriculum but be flexible to address student questions and interests |
| Basic skills and chunk topics (parts of the whole) | Big concepts present the whole and then break down into its parts |
| Assessment is testing focused on correct answers | Assessment is varied that includes observations, discussions, groups, tests, and quizzes |
| Knowledge is inert | Knowledge is dynamic and ever changing based on our personal experiences |
| Students work independently | Students work independently and in groups |

*Table 1 was modified from Concept to Classroom (n.d.).*

There are many options available for active learning strategies including: interactive

lecture, collaborative learning, classroom response systems (clickers), peer instruction,

cooperative learning, and peer-led team learning. These active teaching methods are out of scope for this project. The focus here is on the undergraduate Learning Assistant Program and its effectiveness as a teaching method for undergraduate STEM introductory chemistry courses. The creators of the Learning Assistant Program at University of Colorado, Boulder incorporated Piaget and Vygotsky's constructivist learning theories into their model because they felt constructivist practices would meet the needs of STEM education.

<div align="center">**Undergraduate Learning Assistant Program**</div>

**Program Overview**

The University of Colorado, Boulder (UCB) created the Learning Assistant Program model in partnership with the School of Education to foster the recruitment and training of potential teachers of math, science, and engineering courses. It was first developed in the Physics department as a method to educate and prepare potential high school physics teachers more effectively. The program has grown rapidly. Over its 15-year implementation, UC Boulder has hired over 2300 learning assistants who have worked with 120 faculty members in 73 different courses from 12 departments on campus. Approximately 18,000 UC Boulder students have experienced courses taught using the Learning Assistant Program. The UC Boulder Learning Assistant Program model defined learning assistants as undergraduate students who, through the guidance of faculty or course instructors and completion of the learning assistant pedagogy course, facilitate discussion among groups of students in a variety of classroom settings. The discussions were intended to encourage student engagement in the course and increase the students' responsibility for their own learning (Learning Assistant Alliance, 2018, p. 1). In the required pedagogy course, the learning assistants received training to develop skills in teaching strategies that promoted interaction and collaboration within the classroom.

According to the Learning Assistant Alliance (2018), there were approximately 70 institutions worldwide using UC Boulder's Learning Assistant Program model in their pedagogical practices. These institutions are members of the Learning Assistant Alliance, a community that shares resources and data to help other institutions implement the model. Members of the Learning Assistant Alliance all agreed to and follow the established program requirements.

**How It Differs from Other Peer Instruction Models**

UC Boulder's Learning Assistant Program model is different in many ways from other peer instruction models such as peer tutors, supplemental instruction, peer mentors, or teaching assistants. First, the Learning Assistant Program model was created as an experiential learning program specifically designed for learning assistants. Second, it was developed around discipline-based educational research. The educational research came from the member institutions of the Learning Assistant Alliance which provided worldwide support and sharing of resources and research. The Learning Assistant Program model was based largely on Vygotsky's (1978) Social Constructivism learning theory and the Zone of Proximal Development discussed previously. In the Learning Assistant Program model, the more knowledgeable other can be considered either the faculty member, the learning assistant, or their fellow peers. The more knowledgeable other provided guidance and assistance to help the student through the Zone of Proximal Development by enabling them to reach their full potential or at least the potential available beyond what they know individually or can do alone.

Third, faculty involvement remained a critical element for the success of the undergraduate Learning Assistant Program (Learning Assistant Alliance, 2018). Encouragement between faculty members helped to expand its reach. The Learning Assistant Program model

also helped to foster a partnership between STEM educators and STEM practitioners. Scientists have long devalued teaching as a legitimate career path. By increasing participation in the Learning Assistant Program, STEM faculty members have come to recognize the value of STEM education (Learning Assistant Alliance, 2018). What sets this model apart from other peer-assisted teaching / learning models was the requirement of the three core elements: a weekly preparation meeting with learning assistants and faculty members, a learning assistant pedagogy course, and practice in the classroom. Next, I will examine each of these elements in turn.

**The Weekly Preparation Meeting**

The goal of each weekly meeting was to prepare the learning assistants and faculty members for the upcoming class sessions. The agenda for each meeting varied depending on the needs that week, but normally included discussions about content, pedagogy, and potential questions from students. The faculty members have noted a significant benefit from the weekly meetings as an opportunity to get feedback from their students earlier that has helped them adjust their teaching.  Typically, faculty members do not get this level of feedback until after the course ends through the student course evaluations.

The learning assistants have also described the benefits of the weekly meetings as a relationship builder between them and the faculty member. They described the relationships differently with some indicating it as a one-directional mentor-mentee and others described it as a fully collaborative two-way dialog. Both parties agreed that as they each gained more familiarization with the program and each other their relationship improved. One learning assistant described the improved relationship best, as we continued to work together the faculty member would often ask for feedback and solicit input to co-design instructional activities. Another learning assistant at Chicago State University described her relationship with a faculty

instructor as "colleagues where the faculty asked for my input and value my ideas" (Learning Assistant Alliance, 2018, p. 33).

On average the weekly meetings last one hour but can range anywhere from 30 to 90 minutes depending on the situation (Sabella et al., 2016). Research conducted by Otero et al. (2010) indicated that in-person, weekly meetings were best. One of the benefits of the in-person session was that it allowed the learning assistant time to reflect on the content and prepare for the class session by being able to ask the faculty member in-depth questions to better prepare for questions students may have about the content. Learning assistants have indicated that the direct relationship with the faculty member and their gaining a better understanding of the content was the two most beneficial components of the weekly meetings (Learning Assistant Alliance, 2018).

Other research provided information on how the learning assistants often complement the skills of the faculty member as they were more in touch with the lives of their current students. Faculty members have indicated how the weekly preparation meetings helped them prepare and anticipate problem areas especially when the learning assistants asked them questions (Learning Assistant Alliance, 2018). Reflection was also a valuable component. The preparation for the weekly sessions provided both the learning assistant and faculty member time to reflect on the course content, structure, and intended student learning outcomes.

**The Learning Assistant Pedagogy Course**

The second required element of UC Boulder's Learning Assistant Program model was the learning assistant pedagogy course (Otero et al., 2010) which distinguishes it from other peer instruction models (Learning Assistant Alliance, 2018). In the learning assistant pedagogy course, the learning assistants were introduced to educational research, learning theory, active learning, and other instructional strategies. After completion of the learning assistant pedagogy

course, learning assistants indicated an improved confidence in their ability to support students in

the classroom. Another feature of the learning assistant pedagogy course was that it provided an

opportunity to build community amongst the learning assistants on campus. Finally, it provided a

structured way for the learning assistants to reflect on the practice of teaching.

**Practice in the Classroom**

Practice in the classroom was the third core element of the Learning Assistant Program

model. The Learning Assistant Program required practice in the classroom as its core feature to

ensure the learning assistants received ample opportunities to interact with students in a

classroom environment (Otero et al., 2010). The learning assistants attended each class and

interacted with their assigned group of students by facilitating group discussions or other

activities planned by the professor during the class. The required pedagogy course provided the

learning assistants with several instructional strategies to use in the classroom. The instructional

strategies deployed by the learning assistants were intended to help the students in the course

gain deeper thinking skills and a more complete understanding of the content. For example, a

learning assistant indicated she used the inquiry strategy to help build an effective active learning

environment in the classroom (Learning Assistant Alliance, 2018, p. 3).

The role of the learning assistants in the classroom was to help students improve their

learning and engagement in the topic, develop their skills in thinking and problem solving, and

build skills of scientific inquiry (Learning Assistant Alliance, 2018). From these interactions, the

learning assistants were able to gain a sense for how well their group was learning and

understanding the material and could provide feedback to the faculty members on those areas

that may need additional attention. It was the intent of the Learning Assistant Program to provide

additional layers of support directly to students in the classroom as a way to improve student

success in the course. One learning assistant from Chicago State University described her role in the classroom as not a "cheat sheet" but more like a facilitator helping them discover the answers for themselves (Learning Assistant Alliance, 2018, p. 12).

**Research on Effectiveness of the Program**

There were many educational research studies that provided examples of what worked in STEM classrooms. Much of the literature described using the Learning Assistant Program model to transform individual STEM courses and curriculum (Otero et al., 2011). However, the intent of the Learning Assistant Program was to go beyond that to create supportive environments that encouraged students to think deeper about a topic and to develop a greater understanding of the content.

Van Dusen et al. (2015) described the benefits of the Learning Assistant Program in their study that looked at a multi-year performance of student learning outcomes in an introductory chemistry course. The authors found a significant difference in the student learning outcomes when holding curriculum constant and only adding learning assistants to the course.

UC Boulder has also completed numerous studies documenting the effectiveness of the Learning Assistant Program model. Langdon and Cech (2013) conducted a study of chemistry students comparing student learning outcomes, pre-test and post-test scores, in four active learning courses. Three courses used learning assistants and one course did not. The control group was the one that did not use learning assistants. Significant improvement in learning outcomes occurred in the courses taught with learning assistants. Another study from chemistry and physics courses showed the difference in the probability of failure between students with access to learning assistants and those without. There was a significant decrease in failure rates when students were in courses with learning assistants (Alzen et al., 2018).

Herrera, Nissen, and Van Dusen (2018) studied over 5900 students from 112 different physics courses who completed a pre-post Force Concept Inventory (FCI) assessment and found, by using Hierarchical Linear Modeling analysis, that students in collaborative courses with learning assistants showed 1.6 times greater learning gains than those students in traditional courses. Herrera and colleagues also compared the learning gains of men, woman, and under-represented minority students in physics classes taught with learning assistants and without them. They found that in courses with learning assistants, women and under-represented minorities experienced higher learning gains than those from courses without learning assistants.

**Chapter Summary**

In this chapter, college student departure theories, both foundational theories and models for the 21st century student, were discussed. The foundational works of Tinto (1975), Terenzini and Pascarella (1977), Bean (1980), and Astin (1984) provided a starting point on which to build a better understanding for why students tended to leave college. Next, the models for the 21st century student were examined in the literature and focused on the current college student populations and their specific needs. Higher retention rates were found in majors such as business, medicine, computer science, and engineering that provided significant job opportunities along with the potential for high salaries upon graduation. The general college departure literature was clear in that a lack of balance between academic and social interactions on campus contributed significantly to a student's decision to leave college.

The literature on STEM student departure supported these findings except in regard to retention rates in specific STEM majors. Studies focused on STEM persistence found that the most talented STEM students left STEM majors for higher paying non-STEM disciplines like

business. Even after understanding the potential job market for STEM students, they continued to leave the major.

The common factor most described by both the switchers and non-switchers, was the perception of poor teaching quality in their STEM programs. Those that decided to switch considered it most significant, those that remained in the major described it as a problem but employed various coping strategies to maintain a successful experience. Poor teaching in STEM programs resulted in higher failure rates, lower academic performance, and reduced self-efficacy and sense of belonging. The relationship between grades and attrition was found to be a significant factor in the decision to leave the major. Another aspect uncovered was that STEM faculty members may not believe that there actually was a problem with their STEM teaching practices.

In the next chapter, I will focus on the methods I used to design the research project. Given the complexities uncovered in the literature of college student departure and the various evidence based pedagogical practices available for STEM teaching methods, it will be necessary for me to narrow the focus and compare only two distinct teaching approaches. As I will explain, the intent of this research project was to discover if there was a difference in student learning outcomes and persistence in STEM based on the teaching method used in introductory chemistry.

**Chapter 3: Methods**

This chapter describes the research methodology used to guide my study. I conducted a quantitative research study using a quasi-experimental design where I investigated whether there were differences in student learning outcomes and persistence in STEM between large enrollment, introductory chemistry courses taught using different teaching methods. The teaching methods I reviewed were the traditional lecture (TRAD) and active learning using the Learning Assistant Program (LAP). The setting was a mid-sized Upper Midwest regional public comprehensive university. As indicated in Chapter 1, my research questions were:

- RQ 1: Is there a difference in student learning outcomes between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

- RQ 2: Is there a difference in persistence between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

- RQ 3: Is there a difference in student learning outcomes and persistence for women and under-represented minorities in STEM between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (active learning practices w/ LAP)?

This chapter also includes a description of the sample population along with the participant selection process. It will also present in detail the research procedures followed, as well as the data collection and analysis process used. In the Data Quality section, I present the actions taken to reduce Type I or Type II errors in this research. Finally, Chapter 3 concludes with the Institutional Review Board (IRB) human subject approval statement.

**Research Design**

To determine if teaching practices influenced student learning outcomes and persistence in STEM programs, I decided to conduct a quantitative research study using the quasi-experimental method. Quasi-experimental research is similar to experimental research without the ability to randomly assign participants to the groups (Creswell & Creswell, 2018).

Critics of quantitative research and hypothesis testing described it as overly restrictive, lacking any consideration for human complexities, and being fraught with the potential to misrepresent findings (Tijmstra, 2018). Current methodological literature provided insight into effective uses of statistical testing methods in educational research (Wainer & Robinson, 2003). Field (2013) argued that there are limitations with hypothesis testing statistics and recommended including confidence intervals along with the $p$-values to provide more useful information to properly evaluate the accuracy of any findings. I followed several of his recommendations in this study.

The literature on research methods described support for the quantitative method in educational research studies when the research question seeks to answer or explain a phenomenon with numbers (Creswell & Creswell, 2018; McMillian & Schumacher, 2010). Muijs (2004) further explained that the quantitative method worked well when the investigation demanded a broader understanding or a way to test a hypothesis. In his book, *Doing Quantitative Research in Education*, Muijs (2004) offered several examples for when to use quantitative research in education. First, as mentioned previously, a quantitative method is best suited for research questions that seek a numerical answer. By quantifying a problem its significance can be determined. Second, quantitative research is the norm in science because it can provide for an external validity of the research findings. Third, if random selection into a treatment and control

group were not possible, the quasi-experimental design offered similar controls as in a randomly selected sample. Finally, the quantitative research method works well for research questions that require hypothesis testing, because information can be collected from a sample population, analyzed, and tested to infer generalizability to a larger group. For these reasons, and after a review of the methodological literature, I decided that a quantitative, quasi-experimental design was the most appropriate method to address my research questions and test the associated hypotheses. Refer to Table 2 for the research questions and hypotheses.

My intent was to compare two independent groups: a treatment group and a control group. The independent variables were the teaching methods defined as the traditional lecture (TRAD) and active learning using the Learning Assistant Program model (LAP). The dependent variables were the American Chemical Society (ACS) Final Exam scores, Total Points Earned in the course, DFW rates, and Enrolled in a STEM course the following Spring semester after taking introductory chemistry. I recognize that the 2020 Spring semester was anything but typical; however, Institutional Research used the initial enrollment numbers at the start of the semester for the variable Enrolled in a STEM course. Based on this timing, I did not consider the negative impact from Covid-19 an issue for the Enrolled in a STEM course 2020 variable and included it for statistical analysis for the outcome persistence in STEM.

**Table 2**

*Research Questions and Hypotheses*

| Research Questions | | Hypotheses |
|---|---|---|
| RQ 1: | Is there a difference in student learning outcomes between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and (LAP)? | $H_{o1}$: Average score on ACS Final Exam traditional class is the same as the average score on ACS Final Exam LAP class. <br><br> $H_{a1}$: Average score on ACS Final Exam for LAP class is higher than average score on ACS Final Exam in traditional class. <br><br> $H_{o2}$: Average Total Points Earned in traditional class is the same as the average Total Points Earned in LAP class. <br><br> $H_{a2}$: Average Total Points Earned for LAP class is higher than Total Points Earned in traditional class. |
| RQ 2: | Is there a difference in persistence between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and active learning practices using LAP (LAP)? | $H_{o1}$: DFW rate for traditional class is the same as the DFW rate for LAP class. <br><br> $H_{a1}$: DFW rate for LAP class is lower than DFW rate in traditional class. <br><br> $H_{o2}$: Percentage of students enrolled in STEM course following semester after taking traditional class is the same as percentage of students enrolled in STEM course following semester after taking LAP class. <br><br> $H_{a2}$: Percentage of students enrolled in STEM course following semester after taking traditional class is lower than percentage of students enrolled in STEM course following semester after taking LAP class. |
| RQ 3: | Is there a difference in student learning outcomes and persistence for women and URM in STEM between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and active learning practices using LAP (LAP)? | $H_{o1}$: Percentage of female students enrolled in STEM course following semester after taking traditional class is the same as percentage of female students enrolled in STEM course following semester after taking LAP class. <br><br> $H_{a1}$: Percentage of female students enrolled in STEM course following semester after taking traditional class is lower than percentage of female students enrolled in STEM course following semester after taking LAP class. <br> $H_{o2}$: Percentage of URM students enrolled in STEM course following semester after taking traditional class is the same as percentage of URM students enrolled in STEM course following semester after taking LAP class. <br><br> $H_{a2}$: Percentage of URM students enrolled in STEM course following semester after taking traditional class is lower than percentage of URM students enrolled in STEM course following semester after taking LAP class. |

**Research Design Procedures**

The visual model in Figure 1 described my research design procedures. Group 1, formed

through non-random selection, received the treatment (teaching method: Learning Assistant

Program). Group 2, also formed through non-random selection, was the control group (teaching

method: traditional lecture). The $O_1$ in the model represented the outcomes, which were the

independent variables identified earlier. The solid line that divides the two groups indicated the

groups were independent.

**Figure 1**

*Visual Representation of Research Procedures*



NR Group 1 (P1):  —— X —— $O_1$

NR Group 2 (P2):  ———————— $O_1$
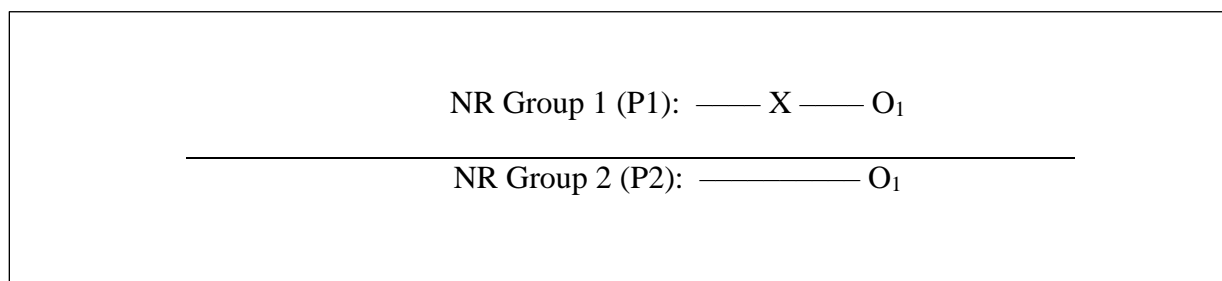
Figure 1 represents a visual description of the research design procedures. Key: NR = nonrandom assignment into group, X = represents the treatment, $O_1$ = represent the outcomes, line between indicates two separate independent groups.

**Treatment Group–Learning Assistant Program (LAP)**

The teaching method used in the treatment group involved active learning and

participated in the university's Learning Assistant Program. Unique to this university, both

STEM faculty members and the learning assistants must complete the STEM pedagogy course

prior to admission into the program. Once in the program, the professor and learning assistants

meet weekly. It was common for the professor in the LAP course to begin each class with a short

introductory lecture followed by a discussion question to the class. Each student entered their

answer into the classroom response tool. Depending on the responses, the professor either

clarified the material or asked the learning assistant to discuss with their groups. There was opportunity for each group to report their answers back to the class. The professor had the discretion to either continue discussion or move on to the next instructional segment. The learning assistants worked with their groups several times during the class period and were responsible for grading and providing feedback on activities and homework assignments.

**Control Group**

The teaching method used in the control group was a traditional lecture (TRAD). The professor did most of the talking and the students were predominately passive listeners. The instructional materials were displayed on the large screen in the front of the room. The professor lectured from these visuals, occasionally drawing diagrams and writing examples on the whiteboard. The professor remained primarily in the front of the room during the lecture. The students in the TRAD course were encouraged to ask questions during the lecture and the professor addressed the questions as needed.

<div align="center">

**Participant Selection**

</div>

**Participants**

The research design followed a quasi-experimental approach because the two groups under comparison were formed without random selection. The students included in each group were admitted to the university and they voluntarily enrolled into the introductory chemistry section that best fit within their personal schedules.  I did not pre-assign students into either group.

**Professor Selection Process**

Several considerations went into the selection of the professors for this study. In the Chemistry department there were eight professors eligible to teach introductory chemistry;

however, only three professors taught the course during the Fall semester. Of those three

professors, only one professor used active learning methods and the university's Learning

Assistant Program. The pseudonym assigned to this professor was Professor 1. When selecting

the second professor, I considered several factors that aligned with Professor 1 in areas such as

professional experience and personal characteristics.

After a personal conversation with each professor, I identified several factors and

performed a comparison between the three professors who taught introductory chemistry in the

Fall semesters. The considerations included teaching philosophy, years of teaching experience at

the university, education, rank and status in position, and other logistical factors like class

meeting times, class location and room type, and lab schedules. Course content was not an issue

because the Chemistry department used an established course curriculum from the American

Chemistry Society (ACS), the accrediting body for chemistry.

All professors followed the curriculum and used the same instructional materials

including an online textbook and homework assignments. After thoughtful consideration, I

identified Professor 2 as being the closest at holding the qualifications and characteristics to

Professor 1. In addition, Professor 2's self-described teaching style aligned with the teaching

method needed for the control group. Table 3 contains a description of the selection factors used

to identify the professors for the study.

I met individually with each professor to explain the purpose of my study and described

the types of data I would need from them regarding student learning outcomes. I answered any

questions they had and concluded the meeting by asking for their agreement to participate. Both

professors agreed to participate in the study. I met with each professor again individually to

discuss their teaching practices and then I observed each professor in their classroom. Through

this activity, I determined that both professors taught as described and each would be appropriate for use in my study.

**Table 3**

*Professor Characteristics List of Factors for Selection Process*

| Factors | Professor 1 | Professor 2 | Professor 3 |
|---|---|---|---|
| Teaching General Chemistry Fall | Y | Y | Y |
| Use active learning and Learning Assistant Program | Y | N | N |
| Years teaching experience | 16 years | 18 years | 13 years |
| Position and rank | Tenure, Full Professor | Tenure, Full Professor | Tenure, Full Professor |
| Education | PhD Chemistry mid-west | PhD Chemistry Upper mid-west | PhD Chemistry Non-U.S. |
| Classroom location and room type | On campus large auditorium | On campus large auditorium | On campus large auditorium |
| Class times | MWF T Lab | MWF T& TH Lab | T & Th T & Th Lab |
| Online textbook & Online homework | Y | Y | Y |
| Assessment strategy points earned | Y | Y | Y |
| White, U.S. Born | Y | Y | N |

## Student Population

The students taking introductory chemistry in the Fall semester were typically STEM majors in physics, chemistry, biological sciences, environmental or earth sciences, engineering, and computer science. Most physical and natural science programs offered at the university categorized the introductory chemistry course as a gateway and required a passing grade of C or better. Other STEM programs that have similar requirements included STEM education and some engineering programs. The pre-requisite for enrolling in the introductory chemistry course was one of the following: SAT math score of 530, ACT math score of 22, pre-chemistry grade C or better, Accuplacer for College Level Math score of 50, or the successful completion of a math preparation series approved by the university's Mathematics department.

Table 6, Frequencies and Descriptive Statistics: Gender and Table 7, Frequencies and

Descriptive Statistics: Ethnicity provide details of the population. The total population ($N = 458$)

included 235 students in the LAP group and 223 students in the TRAD group. I collected

descriptive statistics of student demographic information and compared it to the overall

university population to obtain a clear picture of student representation in the groups. Creswell

and Creswell (2018) indicated the importance of determining group similarity to ensure research

findings were likely due to the treatment effect and not simply a result of chance. By using the

Levene's Test I was able to account for similarity between the groups and test the assumption of

homogeneity of variance. The data used for these tests were ACT scores, the Chemistry pre-

assessment, and high school GPA.

**Group Sample Size**

Creswell (2009) described the use of a power analysis to establish appropriate sample

size for a quantitative study. If the sample were too small, the probability of a Type II error

increased; conversely, if the sample were too large the additional effort required during data

analysis would not have provided additional benefit to the study. Due to the concern for small

sample size, I increased the data set to include courses taught during the 2017, 2018, and 2019

Fall semesters. The increase in additional semesters produced a larger sample size, $N = 458$.

Chapter 4 includes the details of the sample population.

**Settings**

Both professors taught their classes in the same classroom, on the same days of the week

(M, W, F) with labs on Tuesday and Thursday. The only difference in setting between the

courses was the class start time. The classroom was a large auditorium with seating of

approximately 100. The seating arrangements included movable chairs and fixed tables. The

maximum potential enrollment in introductory chemistry was 96 students.

## Data, Data Collection, and Measurements

### Data

The two primary data sources used in this study were each chemistry professor's course

data and the student demographic data from the Office of Analytics and Institutional Research

(AIR). According to Field (2013), measurable data was the evidence gathered during a research

study used to make predictions, conclusions, or interpretations. I selected this data for three

distinct reasons. First, it fit the variables in the model, student learning outcomes as measured by

student scores on the ACS Final Exam and Total Points Earned and the persistence variable

which was measured by course DFW rates and the percentage of Enrollment in a STEM course

the following Spring semester (2018, 2019, 2020). Second, by using primary data I reduced the

opportunity to introduce a student perception bias into the results. Third, the primary data source

was an objective reflection of actual student performance. Table 4 describes the data and data

sources used in the study.

**Table 4**

*Data Sets Needed from each Professor and Office of Analytics & Institutional Research (AIR)*

| Data | Professor 1 | Professor 2 | IR |
|---|---|---|---|
| Deidentified Student ID | N | N | Y |
| Chem pre- test | Y | Y | N |
| ACS Final Exam | Y | Y | N |
| Total Points Earned | Y | Y | N |
| DFW rates | N | N | Y |
| Declared major | N | N | Y |
| Enrolled in STEM course | N | N | Y |
| Gender | N | N | Y |
| Race | N | N | Y |
| ACT/SAT scores | N | N | Y |
| High School GPA | N | N | Y |

## Data Collection

The professors in the study were the instruments for data collection. Both professors provided data from their courses for their students' Chemistry pre-assessment scores, ACS Final Exam scores, and Total Points Earned. The professors assessed the student's performance as they normally would for any of their introductory chemistry courses. I did not provide special instructions or recommendations for data collection that could have altered or influenced their results.

Also, the ACS Final Exam was a nationally recognized instrument proven to measure student learning in basic chemistry. This was a nationwide exam required for all students who enrolled in an introductory chemistry course that followed the ACS accredited program. I did not need to gain permission from ACS to use the exam because the Chemistry department purchased it for use in the chemistry curriculum.

Finally, I needed to wait for IRB approval before I could submit a request for secondary data from the Office of Analytics & Institutional Research (AIR). It took approximately two weeks for the initial data request from AIR. The AIR staff de-identified the student data provided by the professors and correlated the course records with items that I requested such as HS GPA and ACT scores. I received one large electronic data file from AIR to use during data analysis.

**Variables**

Variables are characteristics or attributes that can be measured or observed in the groups being studied (Creswell & Creswell, 2018). Variables test hypotheses by describing a proposed cause and predicted outcome relationship. The proposed cause, or independent variable, described what treatment or intervention was applied to the group. The predicted outcome, or dependent variable, described the effect (Field, 2013).

a. Independent–two groups: Introductory Chemistry courses Fall semesters 2017, 2018, 2019

    i. Professor 1–Teaching method $_{LAP}$

    ii. Professor 2–Teaching method $_{TRAD}$

b. Dependent

    i. Student learning outcomes (ACS Final Exam score & Total Points Earned)

    ii. Persistence in STEM (DFW rate & Enrolled in STEM course following Spring semesters 2018, 2019, 2020)

    iii. Persistence in STEM based on gender and under-represented minorities (DFW rate & Enrolled in STEM course following Spring semesters 2018, 2019, 2020)

**Measurements**

I used these variables to test the hypotheses using a Two Independent Sample *t*-test.

Table 5 identifies the hypotheses, models, and tests used to measure the outcomes.

**Table 5**

*Hypotheses, Tests, and Models*

| Hypotheses | | Test / Models |
|---|---|---|
| RQ 1: | $H_{o1}$: Average score on ACS Final Exam traditional class is the same as the average score on ACS Final Exam LAP class. | Two sample ind. *t*-test CI 95% $H_{01} = \mu_{trad} = \mu_{LAP}$ |
| | $H_{a1}$: Average score on ACS Final Exam for LAP class is higher than average score on ACS Final Exam in traditional class. | $H_{a1} = \mu_{trad} \neq \mu_{LAP}$ |
| | $H_{02}$: Average Total Points Earned in traditional class is the same as the average Total Points Earned in LAP class. | |
| | | $H_{02} = \mu_{trad} = \mu_{LAP}$ |
| | $H_{a2}$: Average Total Points Earned for LAP class is higher than Total Points Earned in traditional class. | $H_{a2} = \mu_{trad} \neq \mu_{LAP}$ |
| RQ 2: | $H_{01}$: DFW rate for traditional class is the same as the DFW rate for LAP class. | Two sample ind. *t*-test CI = 95% |
| | $H_{a1}$: DFW rate for LAP class is lower than DFW rate in traditional class. | $H_{01} = P_{trad} = P_{LAP}$ $H_{a1} = P_{trad} \neq P_{LAP}$ |
| | $H_{02}$: Percentage of students enrolled in STEM course following semester after taking traditional class is the same as percentage of students enrolled in STEM course following semester after taking LAP class. | |
| | $H_{a2}$: Percentage of students enrolled in STEM course following semester after taking traditional class is lower than percentage of students enrolled in STEM course following semester after taking LAP class. | |
| RQ 3: | $H_{01}$: Percentage of female students enrolled in STEM course following semester after taking traditional class is the same as percentage of female students enrolled in STEM course following semester after taking LAP class. | Two sample ind. *t*-test (Proportion) CI = 95% |
| | $H_{a1}$: Percentage of female students enrolled in STEM course following semester after taking traditional class is lower than percentage of female students enrolled in STEM course following semester after taking LAP class. | |
| | $H_{02}$: Percentage of URM students enrolled in STEM course following semester after taking traditional class is the same as percentage of URM students enrolled in STEM course following semester after taking LAP class. | |
| | $H_{a2}$: Percentage of URM students enrolled in STEM course following semester after taking traditional class is lower than percentage of URM students enrolled in STEM course following semester after taking LAP class. | |

## Data Analysis

During data analysis I used several statistical tests including a two-sample independent *t*-test, Analysis of Variance (ANOVA), correlation, and regression modeling. The two-sample independent *t*-test was used to determine if there was a statistically significant difference between two means collected from two independent samples. According to Field (2013), during data analysis it was common for researchers to make causal inferences about the treatment when their research focused on finding differences between groups. There are multiple statistical assumptions that must be followed when conducting quantitative data analysis. During data analysis, I considered the statistical assumptions additivity and linearity, normal distribution, homogeneity of variance, and independence.

It was extremely important not to violate the assumption of homogeneity of variance when using the two-sample, independent *t*-test. The Levene's Test checked for equality of variance between groups (Field, 2013). The variables used to check academic preparedness were high school GPA, ACT scores, and the Chemistry pre-assessment scores.

According to Field (2013), if Levene's test is significant at $p \leq .05$, meaning the null hypothesis was incorrect, a violation of homogeneity of variance occurred and the variances between groups was found to be significantly different. If Levene's test produced a non-significant result ($p > .05$) the variances were found to be roughly equal and sound for comparison. I reduced the impact of a homogeneity of variance violation by removing the obvious outliers prior to testing. The outliers were any values in the dataset outside the expected ranges such as a value higher than 70 on the ACS Final Exam.

Inferential statistics were used as estimates to make decisions and interpret the data collected. Decision making in hypothesis testing was based on the observed outcomes. The two

possible decisions to make during hypothesis testing was either reject the null hypothesis or accept it. Statistical power was expressed as 1- $\beta$ where $\beta$ estimates the probability that a given test will find an effect if one exists in the population. During the null hypothesis testing, I considered the confidence interval ($\alpha$-level), sample size, and effect size to interpret the findings.

With each hypothesis test there was a possibility for a false positive (Type I error) or a false negative (Type II error). A Type I error could occur if I believed there was a genuine effect in the population when in fact there was not. Conversely, a Type II error could occur if I believed there was no effect when in actuality there was an effect in the population. I followed the specific research procedures and accounted for any assumption to reduce the likelihood of these errors occurring. I used the SPSS statistical software to perform the statistical analysis on the models and data collected.

**Steps in Data Analysis**

There were several steps in the data analysis process. First, I cleaned the data records to ensure the student records were complete. Second, student data was de-identified for publication. The AIR staff completed this step during the initial data collection phase. Third, I reviewed the datasets provided by AIR and checked for outliers and missing entries such as values higher than 45 on the Chemistry pre-assessment or 70 on the ACS Final Exam. I flagged any outliers and discussed them with the professor prior to importing the data into SPSS for analysis. Next, I removed the entire record from the sample if any of the essential variables such as overall grade or score on the ACS Final Exam was missing. Finally, I imported the cleaned data file into SPSS and ran specific test outputs and analysis.

**Data and Study Quality**

According to McMillan and Schumacher (2010), there are four types of design validity in quantitative research: statistical conclusion, construct, internal, and external. Design validity measured the degree to which the research explanation matched reality. Validity and reliability are measurements commonly used to reduce the possibility of errors occurring during data collection. Design validity will provide credibility to the research findings and conclusions.

**Design Validity**

To strengthen my findings, I considered each category of design validity starting with statistical conclusion. Statistical conclusion referred to the statistical tests used to determine if a relationship or difference existed between the groups. During the design phase, I considered several issues known to invalidate research findings such as small sample size, violating statistical assumptions, restriction of range, and extraneous variables. To alleviate a small sample size violation, I collected three semesters worth of course data. A test for similarity between the groups found equal variances assumed which indicated no violation of statistical assumptions occurred. Finally, I did not find any rival hypotheses that could have influenced the outcomes.

Next, I focused on the internal design validity and concentrated on any possible internal threats that could have influenced the outcomes. The internal threats considered were selection, maturation, attrition, and diffusion of treatment. Regarding selection threat, it was possible that the introductory chemistry students selected the LAP course because of the professor's reputation and known teaching style. However, given the fact that most students who took introductory chemistry were first year students, the probability of this being a concern was low. To strengthen the internal validity, I gave great thought to the selection process when deciding which professors to select for the study. To avoid an issue with a "time of day" factor, I selected

professors that taught on the same days (MWF) at relatively close times of day (9 and 11 am) to reduce any negative impact on the outcomes.

Regarding attrition threat, I assessed the attrition levels using the DFW rate for each course and found no significant issues that could have influenced the data. To account for attrition threat, Creswell (2009) recommended increasing the group size. I followed this recommendation and added additional semesters to the data set which increased the sample size to $N = 458$.

Next, regarding the possibility of a Diffusion of Treatment threat, I realized that it would be possible for the outcomes to be influenced if the students became aware of the study and knew about the different teaching styles used by each professor. High achieving students could have intentionally selected LAP because of their preference for this style or motivation to improve performance for a specific professor. I discussed both possibilities with each professor and both strongly agreed that introductory chemistry students predominantly selected a course based on how it fit into their schedule without regard to a specific professor's teaching style.

A significant risk to internal validity was uncontrollable events like the COVID-$19$ outbreak. Uncontrollable events can significantly impact study results. For my study, COVID-$19$ was not a factor and was not a factor that could have influenced the data collected during Fall semesters 2017, 2018, and 2019. I am unaware of other notable events during that period that could have influenced the outcomes.

Construct validity refers to the inferences that were made about the intervention used in the study. To improve construct validity more than one testing method was used to assess the findings or independent variable under investigation. To increase credibility of my interpretation of the findings, I decided to use two measures to test each independent variable under

investigation. The two variables used to measure student learning outcomes were the scores achieved on the standardized American Chemical Society (ACS) Final Exam and the Total Points Earned in the course. The two variables used to measure persistence in STEM were course level DFW rates and percentage Enrolled in a STEM course the following Spring semester after taking introductory chemistry. Using standard measurements for assessing student performance and persistence, the credibility of my findings can be more generalizable to other similar introductory chemistry courses.

Finally, Creswell (2009) also explained how external threats to validity could occur if incorrect inferences were drawn from the sample data and wrongly generalized to a larger group. External design validity referred to the extent the findings could be generalized to other populations or settings. Statistical assumptions reduced the impact of external threats to validity. To reduce the likelihood of external threats impacting the validity of my study, I followed the appropriate procedures and consulted the statistical experts on campus.

Given the narrow student population used in this study, my findings will have a limited generalizability to other similar students in introductory chemistry at a regional comprehensive public university. With such specificity of population, I maintained caution not to generalize my findings across an entire population to avoid possible errors in interpretation. With these considerations, my findings and interpretations will make a sound contribution to educational research focused on STEM teaching and learning in higher education.

## Human Subject IRB Approval

I followed the standard protocol for research involving human subjects and applied for Institutional Review Board (IRB) approval before I began my research. The purpose of the IRB approval was to ensure the protection of the rights and welfare of human subjects involved in

research activities on campus. For my research I compared two independent samples of existing data provided by each professor participating in my study. To satisfy a concern over student identification, an Institutional Research staff member collected the existing data from the professors and de-identified the students prior to me receiving the final dataset. My research questions did not require direct student contact to answer; therefore, I did not need to obtain informed consent from the students. As an additional level of anonymity, I assigned a pseudonym to each professor; Professor 1 (Treatment) and Professor 2 (Control). I received IRB approval in early June 2020. The Appendix includes the approved IRB Protocol determination.

## Summary

This chapter has explained the research methodology that guided my study. I selected a basic quantitative research design and followed the quasi-experimental method. Several reasons supported my decision. First, the quantitative method was the best approach to address the research questions. Second, the variables I identified to measure the results were best answered with numbers categorized as either nominal or ordinal. Nominal or ordinal types of data is best suited for testing with statistical modeling. Finally, quantitative research was most familiar and widely accepted by my primary audience, chemistry professors teaching at a comprehensive public university. The population sample included introductory chemistry students who attended a regional public comprehensive university. The study compared two introductory chemistry courses to determine if there was a difference in student learning outcomes and persistence in STEM between the treatment and control groups.

This chapter also identified the primary data sources used and procedures implemented during data collection. I followed the standard quantitative research procedures to ensure the study could be easily replicated in the future. The research design included a thorough

description of the research procedures, how the participating professors were selected, the data

collection process, and a detailed explanation of the data analysis. I used the SPSS statistical

software to analyze the data and generate tests for the hypotheses. The statistical tests used were

a two independent sample *t*-test, Analysis of Variance (ANOVA), correlation, and regression

analysis. Finally, the chapter concluded with the IRB human subject approval statement.

## Chapter 4: Data Analysis

This chapter includes a detailed analysis of the data collected for each research question under investigation. As a background for this analysis, there will be a short review of the overall research problem and the specific research questions as well as the research methods used.

**Problem and Research Questions**

Chapter 1 discussed the shortage of STEM graduates and the failure of many students who start taking STEM courses to persist in the major. One of the frequently cited reasons for this is the quality of teaching. It was my intent to shed light onto one aspect of teaching and learning to determine if teaching method affects student learning outcomes and persistence in STEM looking at an overall college student population and specific populations of women and students of color in introductory chemistry. In this study the traditional teaching method (TRAD) was compared with an active learning teaching method that used undergraduate learning assistants in the classroom (LAP).

To determine if teaching methods mattered at a regional comprehensive public university, I conducted a comparative study using data from two independent courses taught over a 3-year period in the Fall semesters of 2017, 2018, and 2019. Three research questions provided guidance for the study.

- Research Question 1: Is there a difference in student learning outcomes between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and active learning practices with LAP (LAP)?

- Research Question 2: Is there a difference in student persistence in STEM between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and active learning practices with LAP (LAP)?

- Research Question 3: Is there a difference in student learning outcomes and persistence in STEM for women and under-represented minorities (URM) in STEM between large enrollment, introductory chemistry courses taught using traditional teaching practices (TRAD) and active learning practices with LAP (LAP)?

To test for the homogeneity assumption, similarity between the groups was compared using a *t*-test and comparing the standard college readiness indicators high school GPA (HSGPA), and ACT scores. Also, preparedness for general chemistry was compared using score on the Chemistry pre-assessment. I tested the null and alternative hypotheses from the three research questions using a two-sample independent *t*-test, Analysis of Variance (ANOVA), and regression modeling. Regression modeling helped to identify and predict other possible influencers on the dependent variables described earlier.

## Data Collection and Analysis

The data collection process required several steps to complete. First, each professor provided their course data to the Office of Analytics and Institutional Research (AIR). This was primary data collected under normal course activities. Next, I followed IRB protocol and submitted a request for IRB approval. I received approval from IRB after assurance from AIR that student records would be kept confidential. After receiving IRB approval, I was able to submit a request for additional data from AIR. The additional data included information such as high school GPA, ACT scores, and a grade of a D or F or withdrawal (DFW) rates for each course. Finally, the AIR staff collected all requested data, matched the data with student records provided by the professors, and created a unique student identifier to ensure no student information was identifiable. AIR staff compiled the data into one large electronic dataset.

To initially prepare the dataset for analysis I reviewed all the data fields included in the file. I included only those entries that contained all essential data fields which resulted in a sample population ($N = 458$). The essential data points included the general Chemistry pre-assessment score, the ACS Final Exam score, and the Total Points Earned. Entries that indicated a withdrawal were removed from the sample population and included in a separate sub-population for further analysis.

I used the Statistical Package for the Social Sciences (SPSS) software to analyze the data. First, the electronic file was imported into the application for analysis and output. Tests for statistical significance were run that included central tendency mean and standard deviation, $t$-test and ANOVA for comparison of population means, Pearson correlation coefficients for identification of strength in relationship between variables, and regression. When combined, these analysis techniques provided a deeper perspective into the sample results.

**Distribution of Data / Descriptive Statistics**

Tables 6 and 7 list the descriptive statistics of the sample population and include a breakdown between composite scores for each group, the traditional lecture (TRAD) course and the active learning using undergraduate learning assistants (LAP) course. The population sample size ($N = 458$) included 50.7% men (232/458) and 49.3% women (226/458) with more men students (124/223) enrolled in the TRAD course compared to only (107/235) men enrolled in the LAP course. Fewer White students and more women students were enrolled in the LAP course. Overall, the sample size included approximately 70% White, 8.5% International (Intl) and 21.5% students of color (SOC). SOC representation was 7% Asian, 5% Black, African American, 5% Latinx, 4% Multi-racial, and .5% Other.

**Table 6**

*Frequencies and Descriptive Statistics*: *Gender*

| Variable | | N | Percent | TRAD | Percent | LAP | Percent |
|---|---|---|---|---|---|---|---|
| **Gender** | Men | 231 | 50.7 | 124 | 55.60 | 107 | 45.53 |
| | Women | 227 | 49.3 | 99 | 44.40 | 128 | 54.47 |
| | Total | 458 | 100.00 | 223 | 100.00 | 235 | 100.00 |

**Table 7**

*Frequencies and Descriptive Statistics: Ethnicity*

| Variable | N | Percent | TRAD | Percent | LAP | Percent |
|---|---|---|---|---|---|---|
| **Ethnicity** | | | | | | |
| White | 321 | 70 | 161 | 72.20 | 160 | 68.00 |
| Intl | 39 | 8.5 | 16 | 7.20 | 23 | 10.00 |
| Asian | 30 | 7 | 16 | 7.20 | 14 | 06.00 |
| Black or African America | 24 | 5 | 08 | 3.60 | 16 | 07.00 |
| Latinx | 22 | 5 | 08 | 3.60 | 14 | 06.00 |
| Multi-race | 17 | 4 | 12 | 5.40 | 05 | 02.00 |
| Other/unknown* | 5 | .5 | 02 | 0.80 | 03 | 01.00 |
| Total | 458 | 100.00 | 223 | 100.00 | 235 | 100.00 |

* Other/unknown includes: Pacific Islander, Native American, and un-answered.

Table 8 provides the breakdown of student classification in the population sample and showed nothing unexpected. Most students in the sample population were in their first year of college, 37%, followed next by sophomores 34%, juniors 16%, and seniors 7%. The remaining 6% were special enrollment students either post-secondary (PSEO) or non-traditional/non-degree seeking students.

**Table 8**

*Frequencies and Descriptive Statistics*: *Student Classification*

| Variable | | N | Percent |
|---|---|---|---|
| **Student Class** | FR | 169 | 37.0 |
| | SO | 156 | 34.0 |
| | JR | 74 | 16.0 |
| | SR | 32 | 7.0 |
| | SP* | 27 | 6.0 |
| | Total | 458 | 100.00 |

* SP means special student class either PSEO or non-degree seeking student.

Finally, the declared majors of students in this sample population varied widely from accounting and athletic training, to music and pre-med. Of all the declared majors, Biomedical Sciences was the majority (76/458) 16.6% of the population. Mechanical Engineering (56/458) followed next at 12.2%. Not surprising, given that most of the students in the sample population were first year, another 12.2% of the population were either general studies / undeclared or unknown major (56/458). Biochemistry and Molecular Biology rounded out fourth place with (26/458) contributing to approximately 6% of the declared majors. Finally, approximately 5% of the population were Radiologic Technology majors (24/458). Table 9 lists the declared STEM and Non-STEM majors.

**Table 9**

*Frequencies: STEM and Non-STEM Majors*

| STEM Majors | Frequency | Non- STEM Majors | Frequency | |
|---|---|---|---|---|
| Biochemistry and Molecular Biology | 27 | Accounting | 3 | |
| Biology | 19 | Athletic Training | 14 | |
| Biomedical Sciences | 76 | General Business | 4 | |
| Chemistry Professional ACS Approved | 9 | General Studies (Undecided) | 34 | |
| Computer Engineering | 3 | Liberal Arts and Sciences | 4 | |
| Computer Science | 18 | Life Sciences | 11 | |
| Earth Sciences | 3 | Nursing | 5 | |
| Ecology and Field Biology | 7 | Other | 14 | |
| Electrical Engineering | 21 | Unknown Major | 22 | |
| Environmental Engineering | 1 | | | |
| Environmental Science | 6 | | | |
| Environmental Studies | 8 | | | |
| Hydrology | 2 | | | |
| Manufacturing Engineering | 3 | | | |
| Manufacturing Engineering Technology | 6 | | | |
| Mechanical Engineering | 56 | | | |
| Medical Laboratory Science | 10 | | | |
| Nuclear Medicine Technology | 5 | | | |
| Physics | 4 | | | |
| *Pre-Professionals | 34 | | | |
| Radiologic Technology | 24 | | | |
| Software Engineering | 1 | | | |
| STEM Ed** | 4 | | | |
| | | | | |
| Total | 349 | | 109 | 458 |
| Percent STEM Majors | | | | .76 |
| Percent Non-STEM Majors | | | | .24 |

*Pre-Chiropractic, Pre-Dentistry, Pre-Engineering, Pre-Medicine, Pre-Pharmacy, Pre-Physical Therapy, Pre-Physician Assistant., Pre-Veterinary Med
** Earth & Space Science/General Science Gr 5-12, Chemistry/General Science Ed Gr 5-12, Life Science/General Science Ed Gr 5-12

The college preparedness indicators were high school grade point average (HS GPA) and

scores on a college preparedness standardized entrance exam ACT. The institution involved in

this study commonly used the ACT for admissions criteria and most of the student records

included ACT scores. The average high school GPA was 3.45 (*SD* = .48). The students included in the sample population held a strong B+ average in high school, above the average student accepted by this institution, which was 3.23. The average ACT Composite and ACT Math scores were *M* = 23.31, (*SD* = 3.98) and *M* = 24.03, (*SD* = 4.20), respectively.

The results from the Chemistry pre-assessment showed a mean score of 17.20 (*SD* = 9.03). The students in the TRAD course scored higher on average (*M* = 19.06, *SD* = 8.17) compared to the LAP course (*M* = 15.44, *SD* = 9.47). Twenty-seven percent of the students in the LAP course scored 16 or below on the Chemistry pre-assessment. According to the Chemistry department, a score of 16 or below indicated a low understanding of basic chemistry concepts and predicted a higher probability for not passing the course. Those students who scored 16 or below on the Chemistry pre-assessment were considered at risk and encouraged to enroll in the pre-requisite course prior to taking introductory chemistry. Table 10 includes the frequencies and descriptive statistics for college preparedness indicators.

**Table 10**

*Frequencies and Descriptive Statistics: College Preparedness Indicators*

| Variable | | N | Mean | Std. Dev | Min. | Max. |
|---|---|---|---|---|---|---|
| **HS GPA** | TRAD | 193 | 3.49 | .46 | 2.19 | 4.51 |
| | LAP | 204 | 3.41 | .50 | 1.15 | 4.55 |
| | Total | 397 | 3.45 | .48 | 1.15 | 4.55 |
| **ACT COMP** | TRAD | 179 | 23.92 | 3.59 | 15.00 | 33.00 |
| | LAP | 190 | 22.74 | 4.25 | 13.00 | 35.00 |
| | Total | 369 | 23.31 | 3.981 | 13.00 | 35.00 |
| **ACT Math** | TRAD | 177 | 24.75 | 3.85 | 15.00 | 34.00 |
| | LAP | 189 | 23.36 | 4.40 | 15.00 | 34.00 |
| | Total | 366 | 24.03 | 4.20 | 15.00 | 34.00 |
| **Pre-Test** | TRAD | 223 | 19.06 | 8.17 | 00.00 | 39.00 |
| | LAP | 235 | 15.44 | 9.47 | 00.00 | 43.00 |
| | Total | 458* | 17.20 | 9.03 | 00.00 | 43.00 |

* 458 total population (n) not including students receiving W final grade for the course.

**Research Question Results**

This section begins with an analysis of the research questions and associated hypotheses. To provide answers to the research questions, tests of the hypotheses were run, and the results were analyzed using Analysis of Variance (ANOVA) and two-independent sample *t*-tests. The decision rule was applied, and a conclusion was made based on a 95% level of confidence.

**Homogeneity Assumption**

First, I analyzed several variables to provide insight into the sample population as well as explain the level of similarity between groups to determine homogeneity between the groups. To test the homogeneity assumption, the groups were compared based on four college preparedness indicators:  high school grade point average (HS GPA), ACT Composite score (ACT COMP), ACT Math score (ACT Math), and the general Chemistry pre-assessment score. I used a *t*-test to compare population means for HS GPA, ACT COMP, ACT Math, and Chemistry pre-assessment. The results did not indicate a statistically significant difference between the groups for HS GPA which meant both groups were similar in HS GPA scores. However, the other three indicators revealed a statistically significant difference in ACT Comp, ACT Math, and Chemistry pre-assessment. What was of interest in the results were that the students in the TRAD course had higher mean scores in all four indicators. Table 11 provides the independent samples *t*-test statistics.

**Table 11**

*Independent Samples t-Test: College Preparedness Indicators for LAP and TRAD Course*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **HS GPA** | LAP | 204 | 3.41 | .50 | .04 |
| | TRAD | 193 | 3.49 | .46 | .03 |
| $t = -1.70$ df = 395 sig. = .089 | | | | | |
| **ACT Comp** | LAP | 190 | 22.74 | 4.25 | .31 |
| | TRAD | 179 | 23.92 | 3.59 | .27 |
| $t = -2.86$ df = 367 sig. = .004 | | | | | |
| **ACT Math** | LAP | 189 | 23.36 | 4.40 | .32 |
| | TRAD | 177 | 24.75 | 3.85 | .29 |
| $t = -3.20$ df = 364 sig. = .002 | | | | | |
| **Pre-Assessment** | LAP | 235 | 15.44 | 9.47 | .62 |
| | TRAD | 223 | 19.06 | 8.17 | .55 |
| $t = -4.38$ df = 456 sig. = .000 | | | | | |

Upon a closer look into gender and college preparedness, HS GPA was the only indicator found to have significant difference between the groups. Table 12 provides the independent samples *t*-test for college preparedness indicators and gender.

**Table 12**

*Independent Samples t-Test:  College Preparedness Indicators for Gender*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **HS GPA** | M | 196 | 3.34 | .50 | .04 |
| | F | 201 | 3.54 | .45 | .03 |
| $t = -4.19$ df = 387.78 sig. = .089 | | | | | |
| **ACT Comp** | M | 186 | 23.15 | 3.96 | .29 |
| | F | 183 | 23.47 | 4.01 | .30 |
| $t = -764$ df = 366.67 sig. = .446 | | | | | |
| **ACT Math** | M | 184 | 24.29 | 4.27 | .32 |
| | F | 182 | 23.77 | 4.11 | .31 |
| $t = 1.184$ df = 363.74 sig. = .237 | | | | | |
| **Pre-Assessment** | M | 232 | 17.13 | 9.77 | .64 |
| | F | 226 | 17.28 | 8.23 | .55 |
| $t = -.19$ df = 456 sig. = .852 | | | | | |

When accounting for ethnicity and college preparedness using an ANOVA test, significant differences were found between groups for all four college preparedness indicators

HS GPA, ACT COMP, ACT Math, and Chemistry pre-assessment. Table 13 shows the

descriptive statistics and ANOVA for College Preparedness Indicators and Ethnicity Types.

**Table 13**

*ANOVA College Preparedness Indicators: Ethnicity Types*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **HS GPA** | White | 307 | 3.51 | .44 | .03 |
| | SOC | 87 | 3.21 | .56 | .06 |
| | INTL | 3 | 3.60 | .28 | .16 |
| *F* (2,394) = 13.94, *p* < .001 | | | | | |
| **ACT Comp** | White | 283 | 24.00 | 3.64 | .22 |
| | SOC | 83 | 20.87 | 4.13 | .45 |
| | INTL | 3 | 26.25 | 4.63 | 2.67 |
| *F* (2,366) = 23.15, *p* < .001 | | | | | |
| **ACT Math** | White | 281 | 24.74 | 3.90 | .23 |
| | SOC | 83 | 21.57 | 4.28 | .47 |
| | INTL | 2 | 27.00 | 1.41 | 1.00 |
| *F* (2,363) = 20.84, *p* < .001 | | | | | |
| **Pre-Assessment** | White | 323 | 18.14 | 8.09 | .45 |
| | SOC | 96 | 15.00 | 9.77 | 1.00 |
| | INTL | 39 | 14.90 | 12.79 | 2.05 |
| *F* (2,455) = 5.98, *p* = .003 | | | | | |

Since a significant difference was found, a post hoc test was computed to identify where

the difference was between the groups. The tests identified significant difference between White

students and Students of Color (SOC) for all college preparedness indicators HS GPA (*M* = 3.51,

*SD* = .44) (*M* = 3.21, *SD* = .56); ACT Comp (*M* = 24.00, *SD* = 3.64) (*M* = 20.88, *SD* = 4.13);

ACT Math (*M* = 24.74, *SD* = 3.90) (*M* = 21.57, *SD* = 4.28); and the Chemistry pre-assessment

scores (*M* = 18.14, *SD* = 8.09) (*M* = 15.00, *SD* = 9.77). Table 14 provides the Post Hoc Tukey

HSD Test for multiple comparisons for college preparedness indicators and ethnicity type.

**Table 14**

*Post Hoc Test–Tukey HSD Ethnicity and College Preparedness Variables*

| Variable | | | Mean Difference | Std. Error |
|---|---|---|---|---|
| HS GPA | White | SOC** | 0.30* | .06 |
| ACT COMP | White | SOC | 3.13* | .47 |
| ACT Math | White | SOC | 3.17* | .50 |
| Pre-Assessment | White | SOC | 3.14* | 1.04 |

* Indicates mean difference is significant at 0.05 level.
** Indicates means Students of Color (Black, African American, Asian, Latinx, Multi-race, International, other / unknown includes Native American and Pacific Islander).

Based on the data and the demographic breakdown within the groups shown earlier in Tables 6 and 7, one would expect the students in the TRAD course to perform higher than the students in the LAP course. Demographics in the TRAD course showed fewer SOC, more men, and fewer women students compared to the LAP course that had fewer White students, more women, and more SOC.

In summary, comparing the two groups in aggregate (TRAD vs. LAP courses), there was not a statistically significant difference found in HS GPA but for the other three indicators there was a statistically significant difference found (ACT Comp, ACT Math, and Chemistry Pre-assessment). When factoring for gender, a statistically significant difference was only found in HS GPA. Isolating for ethnicity type, a statistically significant difference was found for all college preparedness indicators between the White students and the Students of Color.

**Research Question 1—Student Learning Outcomes**

Research question one analyzed two specific learning outcomes: the scores on the American Chemical Society (ACS) Final Exam and Total Points Earned in the course. I used the test statistic, *t*-test to compare the difference between the means of the two groups. The decision rule for significance followed a 95% confidence level and sample size 458 ($p < .05$, *N* = 458).

The null hypothesis ($H_{o1}$) stated that there will not be a significant difference between the groups

for mean scores on the ACS Final Exam. The alternative hypothesis ($H_{a1}$) stated that there will

be a statistically significant difference between the groups mean scores on the ACS Final Exam.

$H_{o1}$: ACS Final Exam score (Trad) = ACS Final Exam score (LAP)

$H_{a1}$: ACS Final Exam score (Trad) $\neq$ ACS Final Exam score (LAP)

There was not a statistically significant difference found for the ACS Final Exam scores

between the groups. Therefore, I must accept the null hypothesis. Table 15 shows the *t*-Test

Group Statistics for the ACS Final Exam score.

**Table 15**

*t-Test Group Statistics: ACS Final Exam Score*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **ACS Final Exam** | LAP | 235 | 34.14 | 13.03 | .85 |
| | TRAD | 223 | 33.72 | 12.14 | .81 |
| *t* = .359 df = 456 sig. = .720 | | | | | |

For the variable Total Points Earned, the null hypothesis ($H_{o2}$) can be rejected because

statistical significance was found. The difference found in the overall Total Points Earned in the

TRAD course was statistically significant compared to the LAP course. Table 16 shows the *t*-

Test Group Statistics for Total Points Earned.

**Table 16**

*t-Test Group Statistics: Total Points Earned*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **Total Points Earned** | LAP | 235 | 78.21 | 12.59 | .82 |
| | TRAD | 223 | 72.00 | 14.70 | .98 |
| *t* = 4.85 df = 437.49 sig. = .000 | | | | | |

**Research Question 2—Student Persistence in STEM**

Research question two focused on persistence in STEM and analyzed: percentage of students Enrolled in a STEM course the subsequent Spring semester and the DFW rate for the course. I again used the test statistic $t$-test to compare the means of two independent groups. I applied the decision rule using a 95% confidence interval and a sample size of 458.

The data for DFW rate came from the institution's official record of what was recorded on the student's transcript. For purposes of this study, the DFW rate was split into two groups, one group was made up of students who received a grade D or F in the course and the other group included students who received a W grade. To receive a W grade on their transcript, a student had to take action to withdraw from the course before a specific deadline. I kept the students in the W group as a separate sub-population and did not include them in the total population sample because they did not complete all the course requirements.

To conclude, I compared the percentages of students Enrolled in a STEM course the subsequent semester and did not find a statistically significant difference. For both the TRAD and LAP courses, the percentage of students Enrolled in a STEM course the subsequent Spring semester was similar. These results indicated that the proportions of students who enrolled in STEM the following semester 79% (LAP) and 81% (TRAD) were considered statistically equal. Table 17 provides the Independent Samples $t$-test for the variable Enrolled in STEM.

**Table 17**

*Independent Samples t-Test: Enrolled in STEM*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **Enrolled in STEM** | LAP | 235 | .79 | .41 | .03 |
| | TRAD | 223 | .81 | .39 | .03 |
| *t* = -.651 df = 456 sig. = .515 | | | | | |

However, there was a difference found in DFW rate as indicated by rejecting the null

hypothesis. The traditional teaching course (TRAD) reported a higher DFW rate when compared

to the LAP course. These findings showed an almost two to one higher success rate for students

in the LAP course. Table 18 lists the Independent Samples *t*-test for the variable DFW rate.

**Table 18**

*Independent Samples t-Test: DFW Rate*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **DFW Rate** | LAP | 235 | .17 | .38 | .02 |
| | TRAD | 223 | .34 | .47 | .03 |
| *t* = -4.17 df = 456 sig. = .000 | | | | | |

**Research Question 3—Difference in Learning Outcomes and Student Persistence in STEM Based on Gender and Ethnicity**

The third research question looked more specifically at two sub-populations, gender, and

ethnicity, to determine if teaching method mattered to student learning outcomes and student

persistence in STEM. As stated earlier, the student learning outcomes were the score on ACS

Final Exam and Total Points Earned in the course. The independent variables used to measure

student persistence in STEM were the percentages Enrolled in a STEM course the subsequent

Spring semester and DFW rate. The categorical variables were gender and ethnicity type.

### *Does Gender Matter?*

I used a one-way Analysis of Variance (ANOVA) test of the hypothesis to determine if there was a statistically significant difference in student learning outcomes based on gender. Hypotheses ($H_{o1}$) represented variable ACS Final Exam Score and hypothesis ($H_{o2}$) represented the variable Total Points Earned. The gender breakdown between groups showed the LAP course having approximately an even split between women and men. As compared to the TRAD course which included more men. Table 19 provides the frequencies for gender between groups.

**Table 19**

*Frequencies for Gender Variable by Course*

| Variable | | Frequencies | Percent | TRAD | Percent | LAP | Percent |
|---|---|---|---|---|---|---|---|
| **Gender** | M | 229 | 50.00 | 124 | 55.36 | 105 | 44.87 |
| | F | 225 | 49.13 | 99 | 44.20 | 126 | 53.85 |
| | Unknown | 4 | .87 | 1 | .45 | 3 | 1.28 |
| | Total | 458 | 100.00 | 224 | 100.00 | 234 | 100.00 |

M means men and F means women. Unknown was students that did not identify a specific gender. TRAD means traditional course. LAP means active learning with undergraduate learning assistants.

First, when considering ($H_{o1}$), the difference in ACS Final Exam score based on gender, there was no statistically significant difference found ($F(1,456) = 3.140$, $p = .077$). Next, testing the variable Total Points Earned by gender ($H_{o2}$), again no statistically significant difference was found ($F(1, 456) = 1.643$, $p = .201$). In both cases, gender was not found to be a significant factor in the difference between student learning outcomes for either ACS Final Exam Score or Total Points Earned.

Next, using the same models, I tested the dependent variables for Persistence in STEM based on gender. Again, no statistically significant difference was found for the variable, Enrolled in STEM subsequent Spring semester ($F(1,456) = .139$, $p = .709$); however, there was a

statistically significant difference found in the DFW rate by gender ($F$ (1,456) = 4.436, $p$ =.036).

Approximately 29% of the men received a D or F grade compared to only 21% of the women.

Table 20 provides the descriptive statistics and ANOVA for DFW and Gender.

**Table 20**

*Descriptive and ANOVA: Gender and DFW Rate*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **DFW rate** | M | 232 | .29 | .46 | .03 |
| | F | 226 | .21 | .41 | .03 |
| F = 4.43 df = 1,456 Sig. = .036 | | | | | |

*Does Ethnicity Matter?*

To test the variables against ethnicity type: White (non-SOC), students of color (SOC) and international (Intl), a one-way Analysis of Variance (ANOVA) was used to test the hypotheses to determine if there was a statistically significant difference in student learning outcomes and student persistence in STEM. First, I looked at the variable ACS Final Exam Scores, and found a statistically significant difference in population mean scores based on the three groups of ethnicities. Table 21 provides the descriptive statistics and ANOVA for Ethnicity and ACS Final Exam scores.

**Table 21**

*Descriptive and ANOVA: ACS Final Exam Scores by Ethnicity*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **ACS Final Exam** | White | 323 | 34.51 | 12.03 | .67 |
| | SOC | 96 | 30.02 | 13.34 | 1.36 |
| | Intl | 39 | 38.85 | 13.00 | 2.08 |
| F = 8.19 df = 2, 455 sig. = .000 | | | | | |

To know where the difference was, I used the Tukey HSD post hoc test to compare the outcomes on the ACS Final Exam between the ethnicity types finding that all ethnicity types

showed a statistically significant difference. The mean and standard deviation for each ethnicity type were: International ($M = 38.85$, $SD = 13.00$), White ($M = 34.51$, $SD = 12.32$), and SOC ($M = 30.02$, $SD = 13.34$). International students performed better on the ACS Final Exam ($M = 38.85$, $SD = 13.00$) above both their White and Students of Color peer groups ($F (2,456) = 8.19$, $p < .001$). In Table 22, the Tukey HSD Post Hoc Test provided the details of where the difference in mean scores between ethnicity type occurred.

**Table 22**

*Post Hoc Test–Tukey HSD ACS Final Exam Score by Ethnicity*

| Variable | | | Mean Difference | Std. Error | Sig. | 95% CI lower bound | 95% CI upper bound |
|---|---|---|---|---|---|---|---|
| **ACS Raw Score** | Intl | Black or African American | 11.80449 | 3.22184 | .005* | 2.2623 | 21.3466 |
| | | Asian | 9.21282 | 3.01581 | .038* | .2809 | 18.1448 |

* indicates mean difference is significant at .05 level.

Interestingly, the statistically significant difference in ACS Final Exam score was not between the White students and their diverse peer groups, but rather the statistical difference was found between the International students and their Black, African American, and Asian peer groups. With a 95% confidence interval the International students achieved higher scores on the ACS Final Exam approximately 12 points higher than their Black African American peers and nine points higher than their Asian peers. There was no statistically significant difference in mean scores for ACS Final Exam for any other ethnicity types included in the study.

When I looked at Total Points Earned and Ethnicity Type there was a statistically significant difference between ethnicity groups, ($F (2,455) = 4.354$, $p = .013$). The Tukey HSD post hoc comparison showed that White ($M = 76.06$, $SD = 13.28$), and SOC ($M = 71.50$, $SD =$

14.95) were significantly different. The White group scored 4.55 points higher, on average, than the SOC group. Table 23 provides the Post Hoc Test–Tukey HSD for Ethnicity and Total Points Earned variable.

**Table 23**

*Post Hoc Test–Tukey HSD–Total Points Earned by Ethnicity*

| Variable | | | Mean Difference | Std. Error | Sig. | 95% CI lower bound | 95% CI upper bound |
|---|---|---|---|---|---|---|---|
| **Total Points Earned** | White | SOC | 4.55 | 1.61 | .014* | .76 | 8.35 |

*indicates means difference is significance at .05 level.

## Student Persistence in STEM and Ethnicity Type

When testing the variables for student persistence in STEM, there was no statistically significant difference found in the variables Enrolled in STEM subsequent Spring semester ($F$ (2,455) = 2.05 $p$ = .418) or DFW rate ($F$ (2, 455) = 2.79, $p$ = .202) based upon ethnicity. In conclusion, when addressing ethnicity and persistence in STEM, there was no statistically significant difference between the groups.

## Analysis of DFW Rate

The students who received a grade D or F were included in the original population sample ($N$ = 458). However, for a better understanding of student persistence in STEM, the students who took an action to withdrawal from the course and received a W on their transcript were grouped separately and analyzed. There were 68 students who received a W, a 13% withdrawal rate (68/526). Thirty-seven withdrawals (W) in the TRAD course and 31 withdrawals in the LAP course. The further breakdown in each course showed the student withdrawal rate in

the TRAD course was 19 women and 18 men, 26 White and 11 SOC. The LAP course showed

similar results with 17 men, 14 women, 17 White, 13 SOC, and 1 International.

Alone, the W rate may not be significant; however, when combined with the D and F rate

it is more informative. In total, 115 students received either a D or F grade and when added to

the 68 students who withdrew, the result totaled 183 students or 35% who did not pass the course

with a C- or better. This group was less likely to persist in STEM. Table 24 provides the

frequencies for DFW rates between groups. In conclusion there remains ample room for reducing

the DFW rate in introductory chemistry. Retention rates at regional comprehensive universities

are often lower and this institution's is no different with a retention rate of approximately 70%

for the first-year students. The persistence shown in introductory chemistry was slightly lower

than the institution's overall retention average.

**Table 24**

*Frequencies for DFW Variable Overall and by Course*

| Variable | | Frequencies | Percent | TRAD | Percent | LAP | Percent |
|---|---|---|---|---|---|---|---|
| **D or F** | 0 | 343 | .75 | 148 | .43 | 195 | .57 |
| | 1 | 115 | .25 | 75 | .65 | 40 | .35 |
| | Total | 458 | | | | | |
| | | | | | | | |
| **W** | | 68 | .13 | 37 | .54 | 31 | .46 |
| | Total | 526 | | 112 | | 71 | |

(0) means did not receive a D or F grade. (1) means received a D or F grade.
W means withdrew from course within specific deadline.
TRAD means traditional course. LAP means active learning & undergraduate learning assistants.

**Correlation**

I used correlation to determine the strength of a relationship or strength of association

between two variables (*r*). The Pearson correlation coefficient provided the *r* value. The *r* value

is the slope of a line, with the independent variable placed on the X axis and the dependent

variable on the Y axis. There will either be a positive slope ($r = +1$), a negative slope ($r = -1$), or no slope ($r = 0$). The slope provides explanation of the strength of the relationship between the variables. Correlation provided further explanation into the strength between variables and identified any other possible relationships that may or may not be influencing the variance found between the groups.

When examining Total Points Earned with HS GPA, ACT math score, and Chemistry pre-assessment, the $r$ value showed a weak, or very weak, positive, linear relationship ($r = .48$ ($p < .001$), .35 (p < .001), .21 ($p < .001$)), respectively. This means that when the values of these variables increased, the Total Points Earned in the course also increased. Conversely, I found the relationship between Total Points Earned and teaching method (TRAD vs LAP) to be negative and weak ($r = -.22$ ($p < .001$)).

When examining DFW rate with HS GPA, ACT math score, and Chemistry pre-assessment, the $r$ value also showed a weak or very weak, negative, linear relationship ($r = -.36$ (p < .001), -.23 ($p < .001$), -.19 ($p < .001$), respectively. As high school GPAs, ACT math scores, and scores on the Chemistry pre-assessment increased, the DFW rate decreased. Conversely, the relationship strength between teaching method (TRAD vs LAP) and DFW rate was positive and very weak ($r = .19$ ($p < .001$) meaning that the TRAD teaching method showed an increase in DFW rate by 19%.

Finally, I found a few other noteworthy relationships between the variables during data analysis. First, the ACS Final Exam score and Total Points Earned ($r = .79$, $p < .001$) indicated a strong, positive, linear relationship. Second, a negative relationship was found with a moderate strength between score on the ACS Final Exam and DFW rate ($r = -.55$, $p < .001$). Finally, I found a positive relationship with moderate strength between ACT math score and the ACS Final

Exam score ($r = .53$, $p < .001$). Table 25 lists the correlations for HS GPA, ACT Math,

Chemistry Pre-assessment, Teaching Method, DFW rate, ACS Final Exam, and Total Points

Earned.

**Table 25**

*Pearson Correlations*

| Variable | HS GPA | ACT Math | Chem. Pre-Asses. | Teach Method | DFW | ACS Final Exam | Total Points Earned |
|---|---|---|---|---|---|---|---|
| HS GPA | 1 | .373** | .136** | .085 | -.363** | .428** | .475** |
| ACT Math | | 1 | .269** | .165** | -.234** | .526** | .347** |
| Chem Pre-Asses. | | | 1 | .201** | -.194** | .339** | .217** |
| Teach Method | | | | 1 | .191** | -.017 | -.222** |
| DFW | | | | | 1 | -.552** | -.753** |
| ACS Final Exam | | | | | | 1 | .793** |
| Total Points Earned | | | | | | | 1 |

** correlation is significant at the 0.01 level (2-tailed).
* correlation is significant at the 0.05 level (2-tailed).

**Regression Modeling**

This study started with a comparison of population means, a sound statistical test of

hypothesis and the starting point for regression modeling. I used regression modeling to estimate

a relationship between a dependent variable and one or more independent variables. By using

regression modeling I was able to build a predictive model to determine if any of the available

independent variables could predict the outcome in the dependent variables under investigation.

The statistic Adjusted $R^2$ is an indicator of how well the model fits the data to explain

predictability. I identified several significant variables that contributed to variance in the

dependent variable using SPSS and a Stepwise regression model. Below is an example of a

predictive model with four predictor variables:

$$Y = a \ (constant) + b_1(x_1) + b_2(x_2) + b_3(x_3) + b_4 \ (x_4)$$

**Regression Model: Total Points Earned**

$$Y_{\text{(Total Pts. Earned)}} = 19.91 + 11.51 \text{ (HSGPA)} -9.04 \text{ (Teach)} + .68 \text{ (ACT Math)} + .20 \text{ (PreA)}$$

$$(t = 8.97) \qquad (t = -8.13) \qquad (t = 4.79) \qquad (t = 2.97)$$

$$(p < .001) \qquad (p < .001) \qquad (p < .001) \qquad (p = .003)$$

The model indicated HS GPA, teaching method, ACT Math score, and the Chemistry pre-assessment score all contributed significantly to the outcome Total Points Earned. The unstandardized regression coefficients, HS GPA, teaching method, ACT math, and Chemistry pre-assessment score significantly predicted over 37.6% of the variance in Total Points Earned ($R^2 = .376$, $F_{(4,356)} = 55.303$, $p = .003$).

When I looked closer at the unstandardized beta coefficients, it appeared that the TRAD course teaching method had a negative relationship on Total Points Earned by nine points. Holding other variables constant, the model predicted lower, Total Points Earned for students taught introductory chemistry using the TRAD teaching method. This finding aligns with the earlier findings that showed students in the TRAD course had lower Total Points Earned than the students in the LAP course. The model also used the score on the Chemistry pre-assessment to predict performance in the course. The Chemistry pre-assessment variable contributed significantly to the predictability of the outcome in overall Total Points Earned by 20% ($\beta = .201$). In conclusion, the regression model showed that the teaching method influenced the students' overall performance in the course.

**Regression Model: DFW Rate**

When I considered persistence in STEM, I used the same variables in the stepwise regression model to predict variance in the DFW rate. The variables included in the model below accounted for 22.2% of the variance in the DFW rate ($F_{(4,360)} = 26.72$, $p < .001$).

$$Y_{\text{(DFW Rate)}} = 1.65 - .316 \text{ (HS GPA)} + .24 \text{ (Teach)} - .01 \text{ (ACT Math)} - .01 \text{ (PreA)}$$

$$(t = -6.65) \quad (t = 5.71) \quad (t = -2.55) \quad (t = -2.34)$$

$$(p < .001) \quad (p < .001) \quad (p = .011) \quad (p = .020)$$

It was interesting that the model found a significant positive relationship between TRAD teaching method and an increase in DFW rate holding all the other variables the same. Due to the coding when entering teaching method into the regression model, an unstandardized coefficient of .24 indicated that the TRAD teaching method had a .24 higher DFW rate than the LAP teaching method. In this case, the findings tell us that we can predict that the TRAD teaching method will have a higher DFW rate, holding the other variables constant.

This further strengthens the argument that the teaching method influenced students' overall performance in the course. The predictive nature of the regression model further supported previous analysis that indicated a higher DFW rate in the TRAD course compared to the LAP course. Finally, after running other regression models neither gender nor ethnicity explained significance in variance for Total Points Earned or DFW rate. Table 26 includes the Adjusted $R^2$ values for the regression models specifically focused on gender and ethnicity type.

**Table 26**

*Variables and Regression Models*

| Variables | | Adjusted R Square |
|---|---|---|
| Gender & Total Points Earned | ($\beta = 1.675$, $t\,(456) = 1.282$, $p = .201$) | .001 |
| Gender & DFW Rate | ($\beta = -.4.552$, $t\,(455) = -2.819$, $p = .005$) | .014 |
| Ethnicity & Total Points Earned | ($\beta = -.085$, $t\,(456) = -2.106$, $p = .036$) | .007 |
| Ethnicity & DFW Rate | ($\beta = .005$, $t\,(455) = .065$, $p = .948$) | .008 |

## Application of Results

I analyzed the data provided by the Chemistry department professors and Institutional Research to test and evaluate the three research questions and corresponding hypotheses included in this study. The findings were significant in several areas specifically in sub-populations of women and students of color. Next is a snapshot of the data and relevant analysis refined into three significant findings. An explanation of generalizability concludes the section.

**Results: Research Questions 1 and 3: Learning Outcomes**

I decided to group the results of research questions one and three for synthesis in the description given the similarity of these two questions. The questions compared student learning outcomes between groups as well as the specific variables gender and ethnicity. As a reminder, the null hypotheses for both questions found no difference between the groups.

*Analysis of ACS Final Exam Score*

The conclusions in the hypotheses tests found to accept ($H_{o1}$) no statistical difference in scores on ACS Final Exam between the groups which meant that both teachers provided the

same level of knowledge and understanding of basic chemistry ($t$ $(456)$ = .359, $p$ = .720) as measured by the ACS Final Exam. The scores between groups were similar: TRAD ($M$ = 33.72, $SD$ = 12.14) and LAP ($M$ = 34.14, $SD$ = 13.03). At first glance, a finding of failing to reject the null for difference between ACS Final Exam score was concerning because based on the literature, my expectations were that the active learning course with undergraduate learning assistants would outperform the traditional lecture group. However, after further inquiry, while not statistically significant, the students in the LAP course did perform higher on the ACS Final Exam compared to students in the TRAD course.

Over 54% of the students scored in the fortieth percentile meaning 250 out of 458 students achieved a score between 11 and 34 on the ACS Final Exam. Nine students achieved scores in the 90th percentile, six from the LAP course and three from the TRAD course. More students in the LAP course achieved top scores in the high 60s with a White male student achieving the top score 68/70 and a Latina student scoring 65/70. The Pearson correlation ($r$ = .793) showed a strong and positive relationship between score on the ACS Final Exam and Total Points Earned in the course. Calculating the coefficient of determination $r^2$ indicated 63% of the variance in Total Points Earned can be explained by ACS Final Exam score. While not found to be a statistically significant difference between the groups, the variable ACS Final Exam score, with 95% confidence was found to be a strong predictor of overall student performance in the course.

Gender and Ethnicity: ACS Final Exam score. Regarding gender, what was noteworthy was that statistical tests did not find gender to be a significant factor in determining significance, the ACS Final Ex Baddeley am score found ($F$ (1,456) = 3.140, $p$ > .05). Regarding ethnicity, there was a statistically significant difference found for ACS Final Exam ($F$ (2,455) = 8.193, $p$ <

.05). The significant difference in the ACS Final Exam score was found between International students ($M = 38.85$, $SD = 13.00$) and both White ($M = 34.51$, $SD = 12.32$) and Students of Color (SOC) ($M = 30.02$, $SD = 13.34$). International students achieved on average a higher score on the ACS Final Exam as compared to their White and SOC peers.

### *Analysis Total Points Earned*

The conclusions in the hypotheses tests found to reject ($H_{o2}$) because a statistically significant difference in Total Points Earned was found between the groups. The Total Points Earned variable measured how well the students performed as students in introductory chemistry. Items such as attendance, preparation, and performance on assignments and exams all contributed to the students' Total Points Earned and was true for both teaching methods. The *t*-test found a statistically significant difference ($t$ $(437.49) = 4.85$, $p < .001$) between the groups TRAD course ($M = 72.00$, $SD = 14.70$) and LAP course ($M = 78.21$, $SD = 12.59$).

As expected, the students in the LAP course performed better than the students in the TRAD course overall with LAP students achieving a strong C+ average (78/100) and the TRAD students achieving a C- average (72/100). The findings in my study showed students in active learning environments earned higher grades than those students in the traditional lecture course. These findings echoed several studies in the literature that presented similar results.

Gender and Ethnicity: Total Points Earned. Regarding gender, what was noteworthy was that statistical tests did not find gender to be a significant factor in determining significance between the groups when comparing men and women and Total Points Earned ($F$ $(1, 456) =$ 1.643, $p > .05$). Taking a closer look at the independent variable, Total Points Earned, with a lens on gender revealed that women students in LAP earned ($M = 79.37$, $SD = 10.77$) as compared to the women students in the TRAD course ($M = 71.75$, $SD = 13.63$). When comparing the

performance of women students, the overall findings indicated that the women students in LAP

performed better in Total Points Earned than their women peers in the TRAD course. Recall, the

college preparedness variables, HS GPA, and ACT Math scores indicated women students were

as prepared or more prepared for science than their men peers yet performed similarly in both

student learning outcomes. Table 27 lists the student learning outcomes for women and SOC.

**Table 27**

*Student Learning Outcomes Women and SOC: TRAD vs LAP*

| Variable | | Mean | Std. Dev |
|---|---|---|---|
| ACS Final Exam | | | |
| | LAP | 34.14 | 13.03 |
| | TRAD | 33.72 | 12.14 |
| Women | | | |
| | LAP | 33.41 | 11.27 |
| | TRAD | 32.21 | 10.78 |
| SOC | | | |
| | LAP | 28.57 | 12.98 |
| | TRAD | 31.67 | 13.70 |
| Total Points Earned | | | |
| | LAP | 78.21 | 12.59 |
| | TRAD | 72.00 | 14.70 |
| Women | LAP | 79.37 | 10.77 |
| | TRAD | 71.75 | 13.63 |
| SOC | LAP | 72.72 | 15.09 |
| | TRAD | 70.12 | 14.85 |

Regarding ethnicity, there was a statistically significant difference found for Total Points

Earned ($F_{(2,455)} = 4.354$, $p < .05$). The statistically significant difference in Total Points

Earned, was found between White students ($M = 76.05$, $SD = 13.28$) and SOC ($M = 71.50$, $SD = 14.95$). However, when the performance within the same ethnicity types were compared between

the courses, the White students in LAP ($M = 79.59$, $SD = 11.29$) earned statistically significant

higher grades compared to the White students in TRAD ($M = 72.54$, $SD = 14.18$).

Similarly, SOC in LAP ($M = 72.72$, $SD = 15.09$) earned higher grades compared to the SOC in TRAD ($M = 70.12$, $SD = 14.85$). While not stating causation, this analysis provided statistically significant evidence that teaching methods make a difference in student learning outcomes especially for women and SOC in the overall grade achieved in the course. Table 27 shows student learning outcomes for women and SOC between groups.

**Results: Research Questions 2 and 3**

Again, because of the similarities between the two research questions, the results of research question two and research question three were grouped together for synthesis. The questions compared student persistence in STEM between groups as well as the specific variables gender and ethnicity.

*Analysis Enrolled in STEM*

The conclusion in the hypotheses tests found to accept the null ($H_{o1}$) because no statistical difference in percentage of students Enrolled in a STEM course subsequent Spring semester was found between the groups ($t (456) = -.651$, $p = .515$). Similar findings for Enrolled in STEM were found for gender ($F (1,456) = .139$, $p > .05$) and ethnicity ($F (2,455) = 2.051$, $p > .05$).

*Analysis DFW Rate*

The conclusion in the hypotheses tests found to reject the null ($H_{o2}$) because a statistically significant difference in the DFW rate was found between the groups,
($t (456) = -4.17$, $p < .001$) TRAD ($M = .34$, $SD = .47$) and LAP ($M = .17$, $SD = .38$).

*Gender, Ethnicity, and Persistence.* When focused on gender, a statistically significant difference was found in the DFW rate ($F (1,456) = 4.44$, $p < .05$). More men ($M = .29$, $SD = .46$) than women ($M = .21$, $SD = .41$) received a D or F grade and specifically, more men received a

D or F grade in the TRAD course ($M = .36$, $SD = .48$) than the men in the LAP course ($M = .21$, $SD = .41$). Conversely, fewer women in LAP course received a D or F ($M = .13$, $SD = .34$) compared to the women in TRAD course ($M = .30$, $SD = .46$). For ethnicity, there was no statistical significance found ($F (2, 455) = 2.79$, $p > .05$). However, more SOC received a D or F in the TRAD course ($M = .42$, $SD = .50$) compared to SOC in LAP ($M = .27$, $SD = .45$). Table 28 lists student persistence in STEM for women and SOC between groups.

**Table 28**

*Student Persistence in STEM Women and SOC: TRAD vs LAP*

| Variable | | Mean | Std. Dev |
|---|---|---|---|
| **DFW Rate** | | | |
| | LAP | .17 | .38 |
| | TRAD | .34 | .47 |
| | | | |
| **Women** | LAP | .13 | .34 |
| | TRAD | .30 | .46 |
| | | | |
| **SOC** | LAP | .27 | .45 |
| | TRAD | .42 | .50 |

**Summary**

This chapter provided the details of the data and data collection process along with the analysis process that I used to shed light onto the three research questions. The purpose of the study was to determine if there was a difference in student learning outcomes and student persistence in STEM between two different teaching methods. Table 29 includes a summary of the findings along with answers to the research questions.

Chapter 5 will provide my interpretation of the findings along with several recommendations for practice and future research. Also included in the chapter will be any

identified limitations of the study and any possible sources of error and personal bias that could

influence the results.

**Table 29**

*Research Question Summary, Null Hypotheses, and Answers to the Questions*

| Question | Null Hypotheses | Reject/Fail to Reject? | Answer to Question |
|---|---|---|---|
| RQ 1: Is there a difference in student learning outcomes between large enrollment, introductory chemistry courses taught using practices (TRAD) and (LAP)? | $H_{o1}$: Average score on ACS Final Exam traditional course is equal to the average score on ACS Final Exam LAP course. | Fail to Reject | There was no statistically significant difference in the average score on the ACS Final Exam between courses taught using traditional lecture and active learning using undergraduate learning assistants. |
| | $H_{o2}$: Average Total Points Earned in traditional course is equal to the average Total Points Earned in LAP course. | Reject the null | There was a statistically significant difference in the average Total Points Earned in the course between courses taught using traditional lecture and active learning using undergraduate learning assistants. |
| RQ2: Is there a difference in student persistence in STEM between large enrollment, introductory chemistry courses taught using practices (TRAD) and (LAP)? | $H_{o1}$: DFW rate for traditional course is equal to the DFW rate for LAP course. | Reject the null | There was a statistically significant difference in the DFW rates between courses. |
| | $H_{o2}$: Percentage of students enrolled in STEM course the following semester after taking traditional course is equal to the percentage of students enrolled in STEM course the following semester after taking LAP course. | Fail to Reject | There was no statistically significant difference in the percentage of students enrolled in STEM the subsequent semester. |
| R3: Is there a difference in student learning outcomes and persistence in STEM for women and (SOC) in large enrollment, introductory chemistry courses taught using practices (TRAD) and (LAP)? | | | |

**Table 29 Continued**

*Research Question Summary, Null Hypotheses, and Answers to the Questions*

| | | | |
|---|---|---|---|
| Gender / Learning | $H_{o1}$: Average score on ACS Final Exam traditional course is equal to the average score on ACS Final Exam LAP course. | Fail to Reject | Based on gender, there was no statistically significant found between groups for ACS Final Exam score comparing men and women students. |
| | $H_{o2}$: Average Total Points Earned in traditional course is equal to the average Total Points Earned in LAP course. | Fail to Reject | Based on gender, there was no statistically significant found between groups for Total Points Earned comparing men and women students. |
| Gender / Persistence in STEM | $H_{o1}$: DFW rate for traditional course is equal to the DFW rate for LAP course. | Reject the Null | Based on gender there was statistical significance found between groups comparing DFW rates against men and women students. |
| | $H_{o2}$: Percentage of students enrolled in STEM course the following semester after taking traditional course is equal to the percentage of students enrolled in STEM course the following semester after taking LAP course. | Fail to Reject | For gender, no statistically significant difference was found between the groups for percentage of students enrolled in a STEM course the subsequent spring term. |
| Ethnicity / Learning | $H_{o1}$: Average score on ACS Final Exam traditional course is equal to the average score on ACS Final Exam LAP course. | Reject the null | For ethnicity, there was found statistically significant difference between groups on the ACS Final Exam score. |
| | $H_{o2}$: Average Total Points Earned in traditional course is equal to the average Total Points Earned in LAP course. | Reject the null | For ethnicity, there was found statistically significant difference between groups comparing Total Points Earned. |
| Ethnicity / Persistence in STEM | $H_{o1}$: DFW rate for traditional course is equal to the DFW rate for LAP course. | Fail to Reject | For ethnicity, no statistically significant difference was found between groups comparing DFW rate. |
| | $H_{o2}$: Percentage of students enrolled in STEM course the following semester after taking traditional course is equal to the percentage of students enrolled in STEM course the following semester after taking LAP course. | Fail to Reject | For ethnicity, no statistically significant difference was found between groups comparing percentage enrolled in a STEM subsequent spring term. |

## Chapter 5: Discussion

In this chapter I will provide an interpretation of my findings and recommendations for practice and future research. I will explain the possible impact the study will have on teaching and learning practices through a focus on undergraduate students in the introductory chemistry courses at regional comprehensive public universities. The recommendations provided will address teaching practices and institutional policies and processes that impact the utilization of innovative teaching practices. The limitations section will highlight the identified limitations inherent in the study along with any possible sources of error and potential bias. Finally, the chapter will conclude with an overall synopsis of the research study.

## Study Conclusions

In this comparative study, I sought to find out which of two teaching methods was the most effective for students in the introductory chemistry courses. The two teaching methods compared were a traditional lecture and active learning using undergraduate learning assistants. I used the available measures of student learning outcomes and persistence in STEM to assess the difference. The two independent variables used to measure student learning outcomes were scores on the ACS Final Exam and Total Points Earned. The two independent variables used to measure persistence in STEM were percentage Enrolled in a STEM course the following Spring semester and DFW rates. These four independent variables were selected because they were often described in the literature and are commonly used in practice to measure student performance and persistence (Ohia, 2011; Walvoord, 2004).

The research project began with a question about college teaching methods. From there, a peek in my curiosity sparked the development of the research hypotheses. To test my hypotheses, I used statistical tests and analysis: *t*-test, ANOVA, and regression. To help formulate possible

answers to my research questions, I tested my hypotheses using empirical data and statistical

analysis. My findings were clear that in some carefully defined instances, active learning using

undergraduate learning assistants worked better and was shown to improve student success for

some students in the introductory chemistry courses.

When the research involves human subjects there are no single, clear answers. Many

factors influence students' success in college. Some of these are outside the college environment

and would require a more invasive study. The internal validity of my research design considered

those extraneous variables that could be identified and controlled for their impact. The purpose

of this study was to see if there was evidence to support the use of active learning using the

Learning Assistant Program in the introductory chemistry courses by looking at specific results.

**Findings**

My findings showed that there was not a statistically significant difference between the

groups (LAP and TRAD courses) for two of the selected performance indicators: ACS Final

Exam scores (ACS Final) and the percentage of students Enrolled in a STEM course the

following Spring semester. However, the other two variables Total Points Earned and DFW rates

did result in a statistically significant difference between the groups. Further investigation into

the differences provided a clearer picture.

*Student Learning Outcomes*

There was no statistically significant difference found between the groups for score on

the ACS Final Exam ($t = .359$, $p = .720$). Finding no statistically significant difference meant

that both professors provided equivalent instruction and both groups of students were similarly

prepared for the ACS Final Exam. However, when looking more closely at the scores, the

students in the LAP course performed better on the ACS Final Exam ($M = 34.14$, $SD = 13.03$)

compared to their peers in the TRAD course ($M = 33.72$, $SD = 12.14$) with one exception. The students of color (SOC) in the LAP course achieved lower scores on the ACS Final Exam ($M = 28.57$, $SD = 13.00$).

When Total Points Earned were examined, there was a statistically significant difference found between the groups. In this case, I rejected the null hypothesis ($t = 4.85$, $p < .001$). The LAP students performed better ($M = 78.21$, $SD = 12.59$) than their peers in the TRAD course ($M = 72.00$, $SD = 14.70$). The LAP students achieved a strong C+ average whereas the average grade in the TRAD course was a C-.

Upon further investigation, a noteworthy difference was found in the performance of women and students of color. The women in the LAP course earned over 79% of the total points available, decimal points away from achieving a B- grade, as compared to their women peers in the TRAD course who earned just below 72%, a low C- grade. A focus on ethnicity revealed that the SOC in the LAP course earned more total points ($M = 72.72$, $SD = 15.09$) than their peers in the TRAD course ($M = 70.12$, $SD = 14.85$).

### *Persistence in STEM*

There was no statistically significant difference found between the groups for percentage of students Enrolled in a STEM course the following Spring semester ($t = -.651$, $p = .515$). Eighty-one percent of the students in TRAD enrolled in a STEM course the following semester after completing the introductory chemistry course compared to only 79% of students from the LAP course. Clearly, this was not a statistically significant difference. However, upon further review of the sample population, 92 students did not enroll in a STEM course the following semester. Within that group, 18% were undecided in their major followed next by Biomedical sciences majors (14%). Of those Biomedical Science students, five received either a grade of D

or F or W in introductory chemistry and eight students, who successfully completed introductory chemistry, did not enroll in a STEM course the following semester. The Biomedical Science program required a grade C or higher in introductory chemistry. This finding spurred a question for future research.

The results did show a statistically significant difference between the groups for DFW rates ($t = -4.17$, $p < .001$). Seventeen percent of the students in the LAP course received either a grade of D or F compared to a significantly larger 34% in the TRAD course. By the numbers, 40 LAP students received a grade D or F compared to 75 students in the TRAD course. The women and SOC in the LAP course received fewer D or F grades compared to their peers in the TRAD course.

These results were significant and shed light on a teaching method shown to be effective for student learning at a regional comprehensive public university. During the comparison of teaching methods in introductory chemistry, the LAP method was found to produce more positive effects on its students compared to the TRAD method. These positive effects from the LAP teaching method were seen particularly in the women and students of color. The next section will highlight the findings and the literature to explain their impact on practice.

**Discussion**

Today, undergraduate education is continually under the microscope (Bok, 2006; Brint, 2018; Mintz, 2019). Students expect a high-quality undergraduate education (Mayhew et al., 2016). A high-quality education starts with the highest quality instruction (Mayhew et al., 2016; Nilson, 2016; Weaver et al., 2016). Effective teaching and learning practices require a strong partnership between the students, faculty members, and the institution (Fink, 2013; McKeachie et al., 1986).

While it is true that not every teaching method will work for every student, typically college students have not used good teaching practices as a reason to quit college, switch majors, or drop a course (Sithole et al., 2017; Umbach & Wawrzynski, 2005; Xu, 2016, 2018). On the contrary, it is more likely that poor teaching practices contribute to a students' decision to quit college, switch majors, or drop a course (Bettinger, 2010; Cromley et al., 2016; Seymour & Hewitt, 1997). The study by Seymour and Hewitt (1997) described poor teaching as the primary reason students left science. Good teaching, as described in the literature included active learning (Bain, 2004; Chickering & Gamson, 1987; Mastascusa et al., 2011; Wieman, 2017). However, active learning did have its critics and various levels of resistance of its use in college (Cooper et al., 2018; Deslauriers et al., 2019; Khatri et al., 2017).

In this section, I show how my findings shed light on the effectiveness of a specific teaching and learning practice, the Learning Assistant Program. My evidence, along with the literature (Alzen et al., 2018; Van Dusen et al., 2015) provided support for the use of the Learning Assistant Program in the introductory chemistry courses taught at a regional comprehensive public university. Students in the LAP course, especially women and SOC showed greater positive outcomes in the introductory chemistry course.

**Learning Assistant Program Found Effective**

My study found that students in active learning courses that included the Learning Assistant Program (LAP) achieved higher student learning outcomes and levels of persistence in STEM compared to the students in the TRAD courses. My findings mirrored the results found in other studies conducted at research-intensive institutions (Freeman et al., 2014; Mayhew et al., 2016; Prince, 2004). According to Mayhew et al. (2016), there was "irrefutable evidence" of

improved learning in support of active learning methods over traditional lecture-based formats (p. 550).

When I focused on gender and race my findings also showed positive results for women and SOC in the LAP course. This too was echoed in the literature (Green & Sanderson, 2018; Herrera et al., 2018; Shapiro & Sax, 2011). Conversely, Cooper, Downing, and Brownell (2018) found that active learning strategies increased student anxiety in the classroom and when coupled with a chilly and competitive environment resulted in a more negative impact for women in STEM. Since I did not directly address anxiety in the classroom, I cannot conclude whether it influenced the performance of women students or not. However, the net results were clear. There was a positive effect on the performance by the women in the active learning LAP course. Anxiety in the STEM classroom is a significant issue for teaching and learning both in TRAD and LAP courses but it is an issue that goes beyond my data. However, it does warrant future investigation.

**Learning Assistant Program and the Public Comprehensive University**

Higher education institutions are not equal. The profiles of students differ significantly between institutions. Henderson (2007) explained how state comprehensive universities (SCU), research-intensive institutions, and the more selective liberal arts colleges differ in many ways predominantly in their student characteristics.

In comparison, the typical characteristics of students at universities that are similar to the one in this study, the students are more "diverse in ability" than at the other kinds of institutions mentioned and tend to have lower college preparedness attributes, as measured by HS GPA and ACT scores (Henderson, 2007, p. 121). Students tend to work more, commute longer, and are often responsible for the care for dependent family members (Deane & Schneider, 2015). With

these additional responsibilities, students tend to spend less time studying, preparing for class, and participating in co-curricular activities on campus (Henderson, 2007). Kuh and colleagues (2006) explained that not much was known about how these characteristics effect student learning and persistence in college; however, they explained that these characteristics were strong predictors of lower retention and lower graduation rates. Any teaching method will work well for high ability, high achieving students, the challenge for higher education is to find the teaching method that meets the needs of their general student body (McTighe & Willis, 2019).

The students in this study demonstrated an above average college preparedness score for this institution. Their average high school GPA was 3.45 ($SD = .48$) and ACT composite scores were 23.31 ($SD = 3.98$). The students in the TRAD course had higher scores for all the college preparedness metrics collected indicating that these students were better prepared for college compared to the students in the LAP course. Table 10 and Table 11 represent the figures for college preparedness data.

With that information, it was not unreasonable to expect that the TRAD students would perform better overall than the LAP students, but that was not what I found. The students in the TRAD course scored lower on the ACS Final Exam and earned fewer total points than the students in the LAP course. In addition, the students in the TRAD course had a lower persistence rate as shown by higher DFW rates. This would seem to suggest that the LAP teaching method contributed to greater overall student learning and persistence in the introductory chemistry courses even when students were less prepared for college.

**Learning Assistant Program and Women Students**

The debate continues as to why women students leave science. Some argue it is due to a lack of academic preparedness for college science, an inability to do math, or simply they

received poor grades and decided to withdraw (Hill et al., 2010). The findings from my study described a slightly different story. In my study, the population of women students were slightly more prepared for college than the men students based on their HS GPA and ACT scores, as shown in Table 12 College Preparedness Indicators by Gender. If it was just college preparedness that was a predictor of performance, the women students should have outperformed the men. However, I found no statistically significant difference between the genders for score on the ACS Final Exam or Total Points Earned.

When focused on persistence, while not statistically significant, the women persisted at higher levels in both courses compared to the men. More women in this study achieved a passing grade of C- or higher compared to the men. This would be expected given they were better prepared for college. More interesting for my purpose was the fact that the women in the LAP course showed lower DFW rates ($M = .13$, $SD = .34$) compared to the women in the TRAD course ($M = .30$, $SD = .46$). This contributed to a higher pass or completion rate for women in the LAP course.

This finding differed from the literature that showed women leave STEM at higher rates than men due to lower grades (Blickenstaff, 2005; Green & Sanderson, 2018; Hill et al., 2010; Whitcomb & Singh, 2020). While women in both groups persisted at a higher rate than the men, the women in the LAP course persisted at slightly higher rates as shown in Table 30.

**Table 30**

*t-Test Group Statistics: Teaching Method, Gender, DFW Rate*

| Variable | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **DFW: TRAD** | M | 124 | .36 | .48 | .043 |
| | F | 99 | .30 | .46 | .046 |
| $t\,(221) = .94, p = .349$ | | | | | |
| **DFW: LAP** | M | 108 | .21 | .41 | .040 |
| | F | 127 | .13 | .34 | .030 |
| $t\,(233) = 1.61, p = .109$ | | | | | |

Additionally, after isolating the withdrawal rate, there was an even split between the men and women taking action to drop the course and receive a W on their transcript; however, more women in the TRAD course withdrew with a W on their transcript compared to the women in the LAP course. When I focused only on the women students' performance, a statistically significant difference was found between the women in the two groups for Total Points Earned ($t\,(224) = 4.70, p < .001$) and DFW rates ($t\,(224) = -3.16, p = .002$). The women students in the LAP course earned almost 8 points higher ($M = 79.37, SD = 10.77$) than the women in the TRAD course ($M = 71.75, SD = 13.63$). This difference accounted for the LAP students achieving almost a half grade point higher in the course compared to the women in the TRAD course.

Finally, to check for possible gender bias, I compared overall performance by gender for each group and did not find a statistically significant difference. The Total Points Earned between the men and women were comparable within each group, and no statistically significant difference was found. Table 31 provides the details for the *t*-test group statistics for teaching method, gender, and Total Points Earned. Together, these findings contributed to a greater understanding of the positive impact the LAP teaching method had on the women students in introductory chemistry.

**Table 31**

*t-Test Group Statistics Teaching Method, Gender, Total Points Earned*

| Variable: Total Points Earned | | N | Mean | Std. Dev | Std. Error Mean |
|---|---|---|---|---|---|
| **TRAD** | M | 124 | 72.19 | 15.56 | 1.40 |
| | F | 99 | 71.75 | 13.63 | 1.37 |
| *t* (221) = .221, *p* = .825 | | | | | |
| **LAP** | M | 108 | 76.85 | 14.38 | 1.38 |
| | F | 127 | 79.37 | 10.77 | .955 |
| *t* (233) = -1.54, *p* = .126 | | | | | |

**Results Due to Variance in Grading Strategies**

Extraneous variables such as grading leniency may have contributed to the difference in performance found between the groups. To alleviate this concern, I reviewed both course syllabi, observed the classrooms, and had a personal conversation with each professor regarding their grading philosophy. Based on the findings, I determined a similarity in grading philosophy and grading strategies between both professors. Grades were determined by percentage of Total Points Earned, with only a half percentage point difference between the two. Each professor assessed the students using objective measurements such as chapter exams, quizzes, lab activities, online homework assignments, and the ACS Final Exam.

The LAP course provided more opportunities for students to earn points such as in-class activities and clicker quizzes along with an option for extra credit. The TRAD course provided fewer opportunities for students to earn points with most points determined by scores on the exams, lab activities, the ACS Final Exam, and online homework assignments. Given these findings, I found no evidence to suggest the differences in student performance between teaching methods were due to a variance in grading philosophy between the professors.

**ACS Final Exam and Overall Performance**

Negative critiques about standardized testing were found in the literature (Nettles, 2019; Worthen & Spandel, 1991). The American Chemical Society (ACS) has determined that the ACS General Chemistry Final Exam is the benchmark for evaluating learning in college level general chemistry courses. The ACS general chemistry final exam measured basic knowledge of chemistry concepts and quantitative problem-solving skills (American Chemical Society, n.d.). My findings showed a strong positive relationship between the score on the ACS Final Exam and Total Points Earned in the course ($r = .79$, $p < .001$). Review Table 25 for the correlation details. Each professor weighted the ACS Final Exam similarly, between 11.5% and 12.5% of the overall Total Points Earned. This indicated that the overall course performance was not solely dependent on the performance on the ACS Final Exam.

In a conversation with a chemistry professor, it was explained that the Chemistry department views the ACS Final Exam as a valid instrument to determine basic chemistry understanding and does not consider their students' lower performance, as measured by the national percentile averages, a negative indicator of their learning (Dr. Petitto, personal conversation email July 30, 2020). The professor also indicated that the ACS Final Exam scores have declined over the past 10 years but was not concerned about the students' current performance (Dr. Petitto, personal conversation email July 30, 2020). Additionally, she explained that the score on the ACS Final Exam does not guarantee success or failure since there are many other ways to earn points in the course (Dr. Petitto, personal conversation email July 30, 2020).

After consideration of these factors, I believe that the teaching method used in the introductory chemistry courses does make a difference in student learning and persistence in STEM. The

positive results shown by the students in the LAP course further support its use as an effective teaching and learning strategy. The improvements shown for both the women and SOC should increase its appeal and use in Chemistry and other science disciplines.

While the positive results that the LAP courses provided for women and SOC are clear, the possibility of negative consequences for the majority sub-population, white men, needed to be considered. The literature indicated an indifference to active learning approaches by the majority STEM student, the white male (Riegle-Crumb & King, 2010). Since my findings showed that students at this RCPU achieved different results from those cited in the literature, I looked at the effect of the teaching method on the white men students enrolled at a RCPU. The sub-population of white men consisted of 69 in the LAP courses and 84 in the Trad courses.

A *t*-test found a small positive improvement in Total Points Earned for those enrolled in the LAP courses. This sub-population also realized a slight improvement in the DFW rate in the LAP courses. From this additional analysis, I found no decline in performance from the white men students in the LAP courses. None of the individual population groups were harmed as a result of the LAP active learning teaching method. Some groups benefitted more than others, but no group did worse. While this study only focused on introductory chemistry, its findings contributed additional information about teaching and learning that can be used to determine which teaching method is most effective for students in introductory chemistry courses at regional comprehensive public universities.

### Limitations

In this section, I identified several limitations that warrant disclosure. The first limitation worth noting relates to sample selection. The research design followed a quasi-experimental approach because it was not possible to randomly assign students into each course. The students

self-selected into each course during the normal enrollment process. I do not have information from the students to know why or how they determined which course to take. During personal conversations with both professors, both agreed that most students taking introductory chemistry pick the course that fits best with their schedule rather than because of the professor's reputation. Even though the samples were not randomly selected, I have confidence that this sample population is a sound representation of the students taking introductory chemistry at a regional comprehensive public university. I selected the professors based on their individual teaching style and teaching method used along with their comparable professional characteristics.

Second, I only collected and analyzed data from undergraduate students enrolled at a regional comprehensive public university. Students at RCPUs exhibit a wide range of academic abilities based on college preparedness indicators such as high school GPA and ACT scores (Henderson, 2007). The broad range of academic abilities may influence student learning outcomes and persistence rates. However, the two groups included in the study showed similar academic ability.

A third limitation worth noting was that I only collected data from two introductory chemistry professors who only taught during Fall semesters 2017, 2018, and 2019. It was possible that the difference in student performance was due to a difference in teaching experience between the professors. After a thorough review of their professional characteristics, years of teaching experience, and education both professors appeared to be equally well-prepared to teach chemistry. Couple this with my personal observation of their classes, I have no reason to believe the difference in student performance was due to a possible disparity in teaching experience between the professors.

The fourth limitation was that I only used two student learning variables, the score on the ACS Final Exam and the Total Points Earned in the course, to measure and compare student learning outcomes between the two teaching methods. I selected the ACS Final Exam as a student learning metric because the Chemistry department used it as one measure of student learning in the introductory chemistry courses. To reduce any concerns about standardized test results based on national norms, I only used the raw quantitative score achieved on the exam as the comparative metric.

The variable Total Points Earned in the course, is a standard metric commonly used to measure student learning. To counter any possible concerns with the subjectivity of grading, I conducted a thorough review of each professors' grading strategy. From this review, nothing presented a concern that would suggest the difference in student performance was due to differences in grading strategy between the professors.

The fifth limitation, while not a direct consideration in this study, I was unable to isolate and focus on the individual effects the learning assistants brought to the learning environment as a measure of student learning performance. This would have required a different approach to the research method requiring a much greater focus on the interaction between students and the learning assistants. Albeit an interesting topic for future research, I did not find this limitation to substantially impact the results in any way.

Another limitation of this study involved the generalizability of the research findings. Several methodology texts agreed that research can be generalized to different populations with similar characteristics when the research design is sound and the analysis is reliable (Creswell & Creswell, 2018; McMillian & Schumacher, 2010). This study's research design could be easily replicated at other similar institutions that offer introductory chemistry courses. As described

later in the recommendations for research, replication of this study at other institutions will increase the possibility for generalization to a broader group in the future. More research into teaching methods will expand the available knowledge in this area. Even with its narrow focus and limited generalizability outside the institution, this study's findings will be beneficial to the local campus community.

Finally, and probably the most significant limitation, was the limited ethnic diversity in the sample population. The student population was primarily White, while an expected limitation, based on the institution it could possibly have influenced the results of the study and reduced generalizability of the findings. Refer to Table 7, Frequencies and Descriptive Statistics: Ethnicity. Even with the smaller sample size, it was sufficient to run statistical analysis on this sub-population. Future studies should attempt to increase the SOC population to improve the statistical significance of the findings. While my data cannot provide a direct cause and effect determination for why students leave STEM; it can provide information about the effectiveness of the Learning Assistant Program shown for some students taking introductory chemistry at a regional comprehensive public university.

## Implications for Theory

In this section, I will the review the implications of my study for the theories that underlay it. These were Vygotsky's Social Constructivism Zone of Proximal Development and a variety of theories for College Student Departure.

### Vygotsky's (1978) Zone of Proximal Development

Vygotsky's (1978) Social Constructivist Learning Theory Zone of Proximal Development was the theoretical model most relevant to this study. Vygotsky's (1978) theory stated that individuals construct their own knowledge through a combination of independent

thought and social interactions with others more knowledgeable than themselves. Vygotsky's model transformed the role of the teacher into that of a facilitator of learning; one who redirects, coaches, and guides students to think, question and build their own knowledge as they work though the zone of proximal development.

During the design of the Learning Assistant Program, the original creators at University of Colorado: Boulder followed Vygotsky's theory incorporating several social constructivist elements (Langdon & Cech, 2013; Otero et al., 2010). I witnessed several of these elements in practice when I observed the LAP course that I believed contributed to an inherent sense of community and support for students in the LAP class. The students in the course received instructional support from the professor, learning assistants, and their peers. Considering these observations and the fact that most students in the LAP course achieved higher scores on the ACS Final Exam and Total Points Earned may be evidence in support of its use in introductory chemistry courses. In my discussion of limitations, I have considered some of the other factors that could account for the observed differences. Vygotsky's Zone of Proximal Development learning theory and the Learning Assistant Program can be possible models for teaching introductory chemistry.

**College Student Departure Theories**

Tinto (1987), Bean (1980, 1982), Astin (1984), Pascarella and Terenzini (2005), Braxton, Hirschy, and McClendon (2004) and others agreed that persistence in college increased when students experienced a balance between academic and social integration. Morganson et al. (2014) focused on STEM students and developed the concept of "Deep Rooting" which described college students that were involved both academically and socially on their college campus. Deep Rooting plus the intentional social constructivist design of the Learning Assistant Program

may explain the increased persistence rate found in the LAP course. Students in STEM are often too busy with coursework, lab work, and outside work to make additional time for other socialization efforts or support groups (Mayhew et al., 2016). Students who attend RCPUs have other obligations besides education that also detract from their ability to participate in activities on campus.

The literature supports the Learning Assistant Program as a teaching model that integrates academic and social elements directly into the classroom (Learning Assistant Alliance, 2018). The Learning Assistant Program was intentionally designed to create community and build student support networks right into the course. The literature was clear: persistence levels increased when students had a strong sense of belonging and felt connected to the peers in their courses (Braxton & Hirschy, 2005; Kuh et al., 2006; Xu, 2018).

**Success and persistence of women and SOC.** Seymour and Hewitt's (1997) study described how working with peers reduced the feeling of isolation in the major and was shown to improve persistence levels for women and SOC in science. They further described being a part of a group or community increased their motivation to succeed. Shapiro and Sax (2011) explained how collaboration strategies were effective for women and SOC in STEM and further described a need by women students for external validation by faculty members and peers to build self-confidence and self-efficacy. Green and Sanderson (2018) found that women and SOC left STEM because of a lack of social integration. The design of the LAP course required students to collaborate and work together in groups on instructional activities guided by the learning assistant.

After analyzing the data, women and SOC in the LAP course achieved higher results compared to the women and SOC in the TRAD course. While my study did not investigate why

students, specifically women and SOC, persisted more in the LAP course, the quantitative evidence did show that those students achieved higher scores on the student learning variables. I am not able to answer definitively that the Learning Assistant Program was the actual cause of the students increased success, but collectively the results from my study, along with the literature on college student departure and Vygotsky's Social Constructivist learning theory does contribute a deeper understanding for its use in introductory chemistry.

## Implications for Practice

As previously mentioned, the results from this study showed higher student learning outcomes and persistence in STEM by most students in the LAP course compared to the TRAD course. The Implications for Practice section consists of two parts. The first part, Recommendations for Practice, includes broad scale recommendations intended for consideration at the department, college, and institutional levels. The second part, Recommendation for Teaching, is specifically focused on faculty members.

### Recommendations for Practice

The following recommendations could be done in stages on a carefully analyzed experimental basis. The first recommendation would be to expand the Learning Assistant Program to other introductory chemistry courses. If the results align with those from this study, the expansion of the Learning Assistant Program could result in an increase in student success for more students in introductory chemistry. If the expanded Learning Assistant Program within the Chemistry department was shown to be a success, the next expansion of the Learning Assistant Program could be to other introductory courses within the College of Science and Engineering. The most reasonable choice for such an expansion would be to the introductory courses in physics. These courses were the first successful trial of the program at the University

of Colorado at Boulder. Here we would need to first consider the appropriate measurements for determining any increase in student success and persistence and investigate the effect of the introduction of learning assistants. Again, further expansion would only be considered after demonstrated success to other areas in the College of Science and Engineering.

There may be other potential opportunities for the use of the Learning Assistant Program outside of the STEM fields. These would be possibly in other areas that teach large introductory courses such as psychology or sociology. It would be worth investigating whether any of these areas have similar problems with persistence as described in the STEM areas. If this is true, then either a serial or parallel expansion of the Learning Assistant Program could be considered to determine if it produces positive effects. Whether it is worth considering the program as a campus wide recommendation should be clear as these carefully stepped expansions are examined for demonstratable success.

The additional costs of these expansions of the program should be affordable and would include a modest increase in administration costs, learning assistant stipends, training for learning assistants, and costs of time and materials associated with faculty development workshops. Mayhew et al. (2016) argued that instructional expenditures clearly contributed to an increase in graduation rates, but it was not so clear that expenditures on academic or student support services had the same effect.

As an instructional investment, expansion of the Learning Assistant Program could be expected to contribute to improved student success and persistence for students in introductory college courses. Even though I was unable to gather the specific costs associated with withdrawal rate or course failure rates, the potential increase in persistence alone should warrant further consideration for its expanded use. The positive impact found in this study of students in

introductory chemistry courses leads to the conclusion that expanding its use to other

introductory STEM and non-STEM areas could result in greater student success and overall

persistence.

While not the direct focus of my study, the success of my recommendations for

expansion of the program would certainly be influenced by the administrative support for the use

of the Learning Assistant Program as a viable supplement to traditional lecture. Policies that

encourage, support, and reward faculty members' use of active teaching practices such as the

Learning Assistant Program in their courses would be the first step toward their wide-spread use.

Brownell and Tanner (2012) suggested that it is time to implement an administrative plan that

improves the quality of undergraduate education. This could be one element in such a plan.

Concerns for tenure and promotion and the influence of "publish or perish" are often

cited as the primary reason faculty members resist implementing innovative teaching practices in

their courses (Henderson, 2007, p. 7). For change to occur, institutions need to modify the

criteria for tenure and promotion to include a greater focus on teaching effectiveness. In this

study, I found that the LAP teaching method did make a difference to student learning and

persistence for students in introductory chemistry. To support its expansion as a viable teaching

option would be dependent on building a strong partnership between students, faculty members,

and the institution.

**Recommendations for Teaching**

In the literature, most of the educational research comes from research-intensive

institutions, yet few of the recommendations are being implemented in undergraduate education

(Landrum et al., 2017). Moreover, faculty members at regional comprehensive public

universities commonly dismiss the findings from research-intensive institutions as

unrepresentative of their students or their work environments (Deane & Schneider, 2015; Henderson, 2007). The challenge is that little research is available from comprehensive universities. My study strives to shed light on students at RCPUs in introductory chemistry to demonstrate that teaching methods do matter for students in these settings.

For students in regional comprehensive public universities, good teaching methods can bridge the differences in preparedness by challenging those that are more prepared and assisting those that need additional support. The findings from my study showed that the LAP course did make a difference in student learning and persistence in introductory chemistry. As Henderson (2007) explained, students at more selective institutions will most likely do well no matter what teaching method was used; however, teaching method does matter for those students at RCPUs.

In general, the students in the LAP courses achieved higher grades and better persistence in STEM compared to the students in the TRAD courses. The women students in the LAP courses performed better on the ACS Final Exam and Total Points Earned in the courses compared to the women in the TRAD courses. These findings suggest that faculty members and departments from other regional comprehensive public universities should consider the use of the Learning Assistant Program as a way to improve student success in their large lecture courses.

When considered as an alternative teaching method to the traditional lecture, the Learning Assistant Program requires a minimal investment of time and effort to implement into a course and there are few requirements to participate in the program (Dr. Krystyniak, personal communication, July 29, 2020). The Learning Assistant Program can be used in any size class, but it is especially effective for large class environments (Learning Assistant Alliance, 2018).

A desire to change teaching methods can be either from extrinsic incentives or intrinsic personal rewards, and regardless of the reason, change should be done with intention and

purpose. The teaching method selected should be shown to be effective for the student population and aligned with the best research into pedagogical practice. Faculty members are typically committed to providing the best possible learning experience for their students. For these reasons, I recommend the consideration of the Learning Assistant Program as one possible supplement to the traditional lecture approach.

**Implications for Research**

In this section, I present several recommendations for future study to help expand the knowledge base of teaching and learning practices in STEM education. The first set of recommendations is for the same institution where the original research was conducted.

The first recommendation is to build on this study by including other introductory chemistry professors and additional course offerings beyond Fall semester. I would then suggest, expanding the study into other science and STEM disciplines. Finally, it would be useful to seek out non-science disciplines within the institution to determine if the LAP program is an effective teaching strategy for those areas. I also recommend expanding the study to other similar institutions within the same system to provide more opportunity to generalize the results for regional comprehensive public universities.

The second set of recommendations were focused on the Learning Assistant Program itself to gain more insight into why it works. One question that needs further investigation is whether the addition of a learning assistant into the course increases the affective elements associated with learning such as motivation, engagement, and sense of belonging. Further research should be aimed at expanding our knowledge by looking at the implementation of the program to determine the nature of the impact that participating in the Learning Assistant Program has on students, faculty members, and the learning assistants. There appears to be a need for more comparative studies between the different types of active learning strategies to determine how their use could impact the learning of students at regional comprehensive public universities.

Finally, I recommend future research focused on administrative issues, such as budgetary considerations, cost/benefit analysis, and policy review to further expand our understanding of

how the system within higher education influences instructional activities and the impact

teaching and learning has on students. One area of interest would be to conduct an extensive

cost/benefit analysis comparing the Learning Assistant Program to other academic student

support services such as tutoring. Another aspect of great interest would be a study that

investigates the impact the current administrative policies and procedures have on the faculty

members' teaching and learning decisions.

## Summary

My study found that teaching methods do matter. Teaching methods make a difference in

student learning outcomes and persistence in STEM. While this study focused only on chemistry

professors, its findings are transferable to all faculty teaching at RCPUs. The findings were clear,

an active learning teaching method that used undergraduate learning assistants produced higher

student learning outcomes and greater persistence in STEM and was shown to be more effective

for women and SOC compared to students in the traditional lecture course. However, student

success does not fall solely on the shoulders of the faculty members, it is the responsibility of all

the stakeholders in higher education: students, faculty members, and the institution.

Higher education is a public good. Contributing to the quality of that public good is

everyone's responsibility. The student must put in the work to learn. The faculty members must

put in the work to teach. The institution must put in the work to ensure their policies and

procedures do not get in the way of the other two. If change to policies or procedures is needed,

administrators are encouraged to embrace the necessary changes on behalf of improved

undergraduate education. For change to be effective, people need both extrinsic rewards and

intrinsic motivation.

Teaching quality and effective teaching practices are the foundation on which higher education was built. It is the people, policies, and procedures that fuel a passion for teaching, a passion that ignites a love-affair with learning. High quality active teaching methods, such as the Learning Assistant Program, provide students the opportunities to build and construct their own knowledge and achieve academic success.

**References**

Ackerman, P., Kanfer, R., & Beier, M. (2013). Trait complex, cognitive ability, and domain

knowledge predictors of baccalaureate success, STEM persistence and gender

differences. *Journal of Educational Psychology*, *105*(3), 911-927.

Ali, M. (2013). From objectivism to constructivism: The effect of a multimedia constructivist

learning environment on form four students' achievement in science and its impact on

computer usage in learning. *IOSR Journal of Research & Method in Education*, *2*(4), 32-

51.

Aljohani, O. (2016). A comprehensive review of the major studies and theoretical models of

student retention in higher education. *Higher Education Studies, 6*(2), 1-18.

Allen, D., & Tanner, K. (2005). Infusing active learning into the large-enrollment biology class:

Seven strategies, from simple to complex. *Cell Biology Education, 4*, 262-268.

Alzen, J., Langdon, L., & Otero, V. (2018). A logistic regression investigation of the relationship

between the learning assistant model and failure rates in introductory STEM courses.

*International Journal of STEM Education, 5*(56), 1-12.

Ambrose, S. A., Bridges, M., DiPietro, M., Lovett, M., & Norman, M. (2010). *How learning

works: 7 research-based principles for smart teaching*, San Francisco, CA: Jossey-Bass.

American Chemical Society (ACS), (n.d.). Education Resources: Undergraduate Chemistry

Education Resources for Faculty. Retrieved on October 15, 2020,

https://www.acs.org/content/acs/en/education/resources/undergraduate.html

Anderson, W. A., Banerjee, U., Brennan, C. L., Elgin, S. C. R., Epstein, I. R., Handelsman, J.,

Hatfull, G. F., Losick, R., O'Dowd, D. K., Olivera, B. M., Strobel, S. A., Walker, G. C.,

& Warner, I. M., (2011). Changing the culture of science education at research universities, *Science*, *331*(6014), 152-153.

Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE Life Sciences Education, 8*, 203-213.

Arum, R. & Roksa, J. (2001). *Academically adrift: Limited learning on college campuses*. Chicago, IL: University of Chicago Press.

Association of American Universities (AAU). (2017). *Progress toward achieving systematic change: A five-year status report on the AAU undergraduate STEM education initiative.* Washington, DC: Author.

Astin, A. (1984). Student involvement: A developmental theory for higher education. *Journal of College Student Personnel*, *25*(4), 297-308.

Atkinson, R., & Shiffrin, R. (1968). Human memory: A proposed systems and its control processes. In K. W. Spence & J. T. Spence (Eds.), The psychology of motivation and motivation: Advances in research and theory (pp. 89-195). New York, NY: Academic Press.

Baeten, M., Dochy, F., & Struyven, K. (2013). The effects of different learning environments on students' motivation for learning and their achievement. *British Journal of Educational Psychology, 83*(3), 484-501.

Bain, K. (2004). *What the best college teachers do*. Boston, MA: Harvard University Press.

Bajak, A. (2014). Lectures aren't just boring, they're ineffective, too, study finds. *ScienceMag.org*. https://www.sciencemag.org/news/2014/05/lectures-arent-just-boring-theyre-ineffective-too-study-finds

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), Encyclopedia of human behavior (Vol. 4, pp. 71-81). New York: Academic Press. (Reprinted in H. Friedman [Ed.], *Encyclopedia of mental health*. San Diego: Academic Press, 1998).

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: W. H. Freeman and Company.

Barkley, E. F. (2010). *Student engagement techniques*. San Francisco, CA: Jossey-Bass.

Bean, J. (1980). Dropouts and turnover: The synthesis and test of a causal model of student attrition. *Research in Higher Education, 12*(2), 155-187. Available at: https://doi.org/10.1007/BF00976194

Bean, J. (1982). Conceptual models of student attrition: How theory can help the institutional researcher. *New Directions for Institutional Research, 1982*(36), 17-33. Available at: http://dx.doi.org/10.1002/ir.37019823604

Bean, J., & Eaton, S. (2000). A psychological model of college student retention. In J. M. Braxton (Ed.), Reworking the student departure puzzle (pp. 48-61). Nashville, TN: Vanderbilt University Press.

Beichner, R. (2014). History and evolution of active learning spaces. *New Directions for Teaching and Learning, 137* (spring), 9-16.

Beichner, R., Bernold, L., Burniston, E., Dail, P., Felder, R., Gastineau, J., Gjertsen, M., & Risley, J. (1999). Case study of the physics component of an integrated curriculum. *American Journal of Physics, 67*(1), 16-24.

Beichner, R., & Saul, J. M. (2003). Introduction to the SCALE-UP (student-centered activities for large enrollment undergraduate programs) project. *Proceedings of the International School of Physics "Enrico Fermi,"* Varenna, Italy. WWW.ncsu.edu/per/scaleup.html. http://scaleup.ncsu.edu/

Beichner, R., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D. L., Allain, R. J., Bonham, S. W., Dancy, M. H., & Risley, J. S. (2007). The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project. In E. Redish & P. Cooney (Eds.), *Research-based reform of introductory physics*.

Belser, C., Prescod, D., Daire, A., Dagley, M., & Young, C. (2017). Predicting undergraduate student retention in STEM majors based on career development factors. *The Career Development Quarterly*, *65*, 88-93.

Belser, C., Shillingford, M. A., Daire, A., Prescod, D., & Dagley, M. (2018). Factors influencing undergraduate student retention in STEM majors: Career development, math ability, and demographics. *The Professional Counselor*, *8*(3), 262-276.

Bensimon, E. M. (2007). The underestimated significance of practitioner knowledge in the scholarship of student success. *Review of Higher Education*, *30*(4), 441-469.

Bentley, M. (1998). Constructivism as a referent for reforming science education. In M. Larochelle, N. Bednarz, & J. Garrison (Eds.), *Constructivism and education* (pp. 234-249). New York, NY: Cambridge University Press.

Berrett, D. (2012, February 19). How flipping the classroom can improve the traditional lecture. *The Chronicle of Higher Education*.

Bettinger, E. (2010). To be or not to be: Major choices in budding scientists. In C. Clotfelter (Ed.), *American universities in a global market* (pp. 69-98). Chicago, IL: University of Chicago Press.

Blaich, C., & Wise, I. (2011). The Wabash National Study–The impact of teaching practices and institutional conditions on social growth. *2011 American Education Research Association Annual Meeting*. Wabash College, Center of Inquiry in the Liberal Arts, Crawfordsville, IN.

Blickenstaff, J. C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education, 17*(4), 369-386.

Bligh, D. A. (2000). *What's the use of lectures?* San Francisco, CA: Jossey-Bass.

Blumberg, P. (2015). Factors that influence faculty adoption of learning-centered approaches. *Innovative Higher Education*, *41*, 303-315.

Bok, D. (2006). *Our underachieving colleges: A candid look at how much students learn and why they should be learning more*. Princeton, NJ: Princeton University Press.

Bonwell, C., & Eison, A. (1991). Active learning: Creating excitement in the classroom. *ASHE-ERIC Higher Education Report No. 1*. Washington, DC: The George Washington University, School of Education and Human Development.

Booth, J. L., McGinn, K. M., Young., L. K., & Barbieri, C. (2015). Simple practice doesn't always make perfect: Evidence from the worked example effect. *Policy Insights from the Behavioral and Brain Sciences*, *2*, 24-32.

Bowman, N. A., & Culver, K. C. (2018). When do honors programs make the grade? Conditional effects on college satisfaction, achievement, retention, and graduation. *Research in Higher Education, 59*(3), 249-272.

Bowman, N. A., & Denson, N. (2014). A missing piece of the departure puzzle: Student-institution fit and intent to persist. *Research in Higher Education*, *55*(2), 123-142.

Brame, C. (2016). *Active learning*. Vanderbilt University Center for Teaching. Retrieved March 30, 2019, from https://cft.vanderbilt.edu/active-learning/

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school. Washington, DC:* National Academy Press.

Bransford, J., & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. In Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (pp. 61-100). Washington, DC: American Educational Research Association.

Bratt, K., Sundheim, N., Pound, K., & Rogers, M. E. (2017). Echoes of student learning modes in the learning processes of STEM faculty: The LASSI provides themes for faculty development. *Journal of College Reading and Learning*, *47*(2), 123-142.

Braxton, J. (2019). Leaving college: Rethinking the causes and cures of student attrition by Vincent Tinto (review). *Journal of College Student Development*, *60*(1), 129-134.

Braxton, J., & Hirschy, A. (2005). Theoretical developments in the study of college student departure. In A. Seidman (Ed.), *College student retention: Formula for student success* (pp. 61-87). Greenwood Publishing Group.

Braxton, J., Hirschy, A., & McClendon, S. (2004). *Understanding and reducing college student departure.* Association for the Study of Higher Education (ASHE). San Francisco, CA: Jossey-Bass.

Braxton, J., Jones, W., Hirschy, A., & Hartley, H. (2008). The role of active learning in college student persistence. *New Directions for Teaching and Learning, No. 115*, Wiley Periodicals.

Braxton, J. M., Milem, J. F., & Sullivan, A. S, (2000). The influence of active learning on the college student departure process: Toward a revision of Tinto's theory. *Journal of Higher Education*, *71*, 569-590.

Braxton, J. M., Sullivan, A. V., & Johnson Jr., R. M. (1997). Appraising Tinto's theory of college student departure. In J. Smart (Ed.), *Higher education research* (pp. 107-164). Agathon Press.

Brint, S. (2018). *Two cheers for higher education: Why American universities are stronger than ever and how to meet the challenges they face*. Princeton, NJ: Princeton University Press.

Brown, P., Roediger, H., & McDaniel., M. (2014). *Make it stick: The science of successful learning*. Cambridge, MA: The Belknap Press of Harvard University Press.

Brownell, S., & Tanner, K., (2012). Barriers to faculty pedagogical change: Lack of training, time, incentives, and tensions with professional identify. *CBE Life Sciences Education*, 11(4): 339-346.

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review, 31*(1), 21-32.

Bunce, D., (2001). Does Piaget still have anything to say to chemists? *Journal of Chemical Education, 78*(8), 1107.

Burgette, J., & Magun-Jackson, S. (2009). Freshman orientation, persistence, and achievement: A longitudinal analysis. *Journal of College Student Retention*, *10*(3), 235-263.

Burke, A. (2019). Student retention models in higher education: A literature review. *AACRAO Research publications quarterly, 94*(2). https://www.aacrao.org

Cabrera, A., Nora, A., & Castaneda, M. (1993). College persistence: Structural equations modeling test of an integrated model of student retention. *The Journal of Higher Education, 64*(2), 123-139. http://dx.doi.org/10.2307/2960026

Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM: Science, technology, engineering, mathematics.* Washington, DC: Georgetown University.

Chen, R., & DesJardins, S. L. (2010). Investigating the impact of financial aid on student dropout risks: Racial and ethnic differences. *Journal of Higher Education*, *81*(2), 179-208.

Chen, X. (2014). *STEM attrition: College students' paths into and out of STEM fields*. Retrieved from the National Center for Education Statistics website: http://nces.ed.gov/pubs2014/2014001rev.pdf

Chen, X., & Soldner, M. (2013). STEM attrition: College students' paths into and out of STEM fields. (NCES 2014-001). Washington, DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences. https://nces.ed.gov/pubs2014/2014001rev.pdf

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *American Association for Higher Education [AAHE] Bulletin, 39*(7), 3-7.

Cochran, J., Campbell, S., Baker, H., & Leeds, E. (2014). The role of student characteristics in predicting retention in online courses. *Research in Higher Education*, *55,* 27-48.

Colvin, J., & Ashman, M. (2010). Roles, risks, and benefits of peer mentoring relationships in higher education. *Mentoring & Tutoring: Partnership in Learning, 18*(2), 121-134.

Concept to Classroom, (*n.d.).* https://www.thirteen.org/edonline/concept2class/constructivism/index.html

Cooper, K., Downing, V., & Brownell, S. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education, 5*, 23. https://doi.org/10.1186/s40594-018-0123-6

Cragg, K. M. (2009). Influencing the probability for graduation at four-year institutions: A multi-

model analysis. *Research in Higher Education*, *50*(4), 394-413.

Creswell, J. W. (2009). *Research design qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research design qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage Publications.

Crissman, J. L. (2002). The impact of clustering first year seminars with English composition courses on new students' retention rates. *Journal of College Student Retention*, *3*(2), 137-152.

Cromley, J., Perez, T., & Kaplan, A. (2016). Undergraduate STEM achievement and retention: Cognitive, motivational, and institutional factors and solutions. *Policy Insights from the Behavior and Brain Sciences, 3*(1), 4-11.

Dagley, M., Georgiopoulos, M., Reece, A., & Young, C. (2016). Increasing retention and graduation rates through a STEM learning community. *Journal of College Student Retention: Research, Theory & Practice, 18*(2), 167-182.

Deane, K. C., & Schneider, M. (Eds.). (2015). *The university next door: What is a comprehensive university, who does it educate, and can it survive?* New York, NY: Teachers College Press Columbia University.

Deslauriers, L., McCarty, L., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *PNAS, 116*(39), 19251-19257.

Doerschuk, P., Bahrim, C., Daniel, J., Kruger, J., Mann, J., & Martin, C. (2016). Closing the gaps and filling the STEM pipeline: A multidisciplinary approach. *Journal of Science Education and Technology*, *25*, 682-695.

Durkheim, E. (1897). *Suicide: A study in sociology.* J. A. Spaulding & G. Simpson (trans.). London and New York: Routledge Classics.

Ebert-May, D., Batzli, J., & Lim, H. (2003). Disciplinary research strategies for assessment of learning. *BioScience*, *53*(12), 1221-1228.

Eddy, S., & Hogan, K. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE Life Sciences Education*, *13*(fall), 453-468.

Elrod, S., & Kezar, A. (2017, July/August). Increasing student success in STEM: Summary of a guide to systemic institutional change. *Change*, pp. 26-34.

England, B., Brigati, J., & Schussler, E. (2017). Student anxiety in introductory biology classrooms: Perceptions about active learning and persistence in the major. *PLoS ONE*, *12*(8), e0182506.

Fata-Hartley, C. (2011). Resisting rote: The importance of active learning for all course learning objectives. *Journal of College Science Teaching*, *40*, 3.

Fedler, R., & Brent, R. (1996). Navigating the bumpy road to student-centered instruction. *College Teaching, 4*(2), 43-48.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). Thousand Oaks, CA: Sage Publications.

Finelli, C., Nguyen, K., DeMonbrun, M., Borrego, M., Prince, M., Husman, J., & Waters, C. (2018). Reducing student resistance to active learning: Strategies for instructors. *Journal of College Science Teaching, 47*(*5*), 80-91.

Fink, D. (2013). *Creating significant learning experiences, revised and updated*: *An integrated approach to designing college courses.* San Francisco, CA: Jossey-Bass.

Finkelstein, N., Otero, V., & Pollock, S. (2006). Teaching to learn: The Colorado Learning Assistant programs' impact on learning content. *American Physical Society Forum on Education Newsletter,* (Fall 2006/Spring 2007), 11-13.

Finkelstein, N., Seal, R., & Schuster, J. (1998). *The new academic generation: A profession in transformation.* Baltimore, MD: Johns Hopkins University Press.

Fischer, C. (2011). Changing the science education paradigm: From teaching facts to engaging the intellect. *Yale Journal of Biology and Medicine, 84*, 247-251.

Fischer, M.J. (2007). Settling into campus life: Differences by race/ethnicity in college involvement and outcomes. *Journal of Higher Education*, 78, 125-161.

Fraser, J., Timan, A., Miller, K., Dowd, J., Tucker, L., & Mazur, E. (2014). Teaching and physics education research: Bridging the gap. *Reports on Progress in Physics, 77*(3), 032401-032417.

Frederick, P. (1986). The lively lecture eight variations. *College Teaching, 34*, 43-50. (1987). Student involvement: active learning in large classes. in teaching lame classes well. In M. G. Weimer, (Ed.), *New directions for teaching and learning no. 32*. San Francisco: Jossey-Bass.

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *National Academy of Sciences, 111*(23), 8410-8415.

Froyd, J. (2016). *White paper on promising practices in undergraduate STEM education*. Texas A&M University.

Godor, B. (2017). Academic fatalism: Applying Durkheim's fatalistic suicide typology to student drop-out and the climate of higher education. *Interchange*, *48*, 257-269.

Grau-Talley, K., & Martinez-Ortiz, A. (2017). Women's interest development and motivation to persist as college students in STEM: A mixed methods analysis of views and voices from a Hispanic-serving institution. *International Journal of STEM Education*, *4*(5), 1-24.

Green, A., & Sanderson, D. (2018). The roots of STEM achievement: An analysis of persistence and attainment in STEM majors. *The American Economist*, *63*(1), 79-93.

Griffith, A. L. (2010). *Persistence of women and minorities in STEM field majors: Is it the school that matters?* http://digitalcommons.ilr.cornell.edu/workingpapers/122/

Gurung, R., Chick, N., & Haynie, A. (2009). *Exploring signature pedagogies: Approaches to teaching disciplinary habits of mind.* Sterling, VA: Stylus.

Hake, R. R. (1998). Interactive-engagement vs. traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64-74.

Handelsman, J., Miller, S., & Pfund, C. (2007). *Scientific teaching*. New York: W. H. Freeman.

Harrington, C., & Zakrajsek, T. (2017). *Dynamic lecturing: Research-Based Strategies to enhance lecture effectiveness*, Sterling, VA: Stylus Publishing.

Hativa, N. (2000). *Teaching for effective learning in higher education.* Dordrecht, Netherlands: Kluwer Academic Publishers.

Hausmann, L., Ye, F., Schofield, J., & Woods, R. (2009). Sense of belonging and persistence in white and African American first-year students. *Research in Higher Education, 50*, 649-669.

Heilbronner, N. N. (2011). Stepping onto the STEM pathway: Factors affecting talented students' declaration of STEM majors in college. *Journal for the Education of the Gifted*, *34*, 876-899.

Henderson, B., (2007). *Teaching at the people's university: An introduction to the state comprehensive university.* Boston, MA: Anker Publishing Company.

Henderson, C., & Dancy, M. (2007). Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics. *Physics Education Research, 3*, 0201021-02010214

Henderson, C., Dancy, M., & Niewiadomska-Bugaj, M. (2012). Use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process? *Physics Education Research*, *8*(2), 0201041-02010415.

Hernandez, J., & Lopez, M. (2004). Leaking pipeline: Issues impacting Latino/A college student retention. *Journal of College Student Retention: Research, Theory, & Practice*, *6*(1), 37-60.

Herreid, C. F. (2006). "Clicker" cases: Introducing case study teaching into large classrooms. *Journal of College Science Teaching*, *36*(2), 43-47.

Herrera, X., Nissen, J., & Van Dusen, B. (2018). *Student outcomes across collaborative learning environments*. Retrieved at https://arxiv.org/abs/1808.07076

Herzog, S. (2005). Measuring determinants of student return vs. dropout/stopout vs. transfer: A first-to-second year analysis of new freshman. *Research in Higher Education, 46*, 883-928.

Hewson, S. (2011). *The mathematical problems faced by advanced STEM students*. NRICH.maths.org. University of Cambridge.

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: AAUW.

Hoffman, F., & Oreopoulos, P. (2009). A professor like me: The influence of instructor gender on college achievement. *The Journal of Human Resources*, *44*(2), 479-494.

Holmes, B., & Gardner, J. (2006). *E-Learning concepts and practice*. London: Sage Publications.

Hossler, D., Schmit, J., & Vesper, N. (1999). *Going to college: How social, economic, and educational factors influence the decisions students make*. Baltimore, MD: The Johns Hopkins University Press.

Hoyt, D., & Perera, S. (2000, June). Teaching approach, instructional objectives, and learning. *IDEA Research Report #1*, IDEA Center.

Hu, S. (2011). Reconsidering the relationship between student engagement and persistence in college. *Innovative Higher Education*, *36*(2), 97-106.

Hu, S., McCormick, A., & Gonyea, R. (2012). Examining the relationship between student learning and persistence. *Innovative Higher Education, 37*(5), 387-395.

Hurtado, S. (1994). The institutional climate for talented Latino students. *Research in Higher Education*, *35*(1), 21-41.

Hurtado, S., Newman, C., Tran, M., & Chang, M. (2010). Improving the rate of success for underrepresented racial minorities in STEM fields: Insights from a national project. *New Directions for Institutional Research*, *148*, 5-15.

Ironsmith, M., Marva, J., Harju, B., & Eppler, M. (2003). Motivation and performance in college students enrolled in self-paced versus lecture format remedial mathematics courses. *Journal of Instructional Psychology*, *30*(4), 276-284.

Ishler, J. L., & Upcraft, M. L. (2005). *The keys to first-year student persistence. Challenging and supporting the first-year student.* San Francisco: Jossey-Bass.

Ismail, E., & Groccia, J. (2018). Students engaged in learning. *New Directions for Teaching and Learning, no. 154*. Wiley Periodicals, pp. 45-54.

Jaeger, A. J., & Eagan Jr., M. K. (2011). Examining retention and contingent faculty use in a state system of public higher education. *Educational Policy*, *25*(3), 507-537.

Johnson, D., & Johnson, R. (1985). Classroom conflict: Controversy versus debate in learning groups. *American Educational Research Journal*, *22*(2), 237-256.

Johnson, D., Johnson, R., & Smith, K. (1991). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Company.

Johnson, D., Johnson, R., & Smith, K. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change*, *30*, 26-35.

Jonassen, D. (1991). Objectivism vs constructivism: Do we need a new philosophical paradigm? *Educational technology, Research and Development, 39*(3), 5-13.

Jones, B., Paretti, M., Hein, S., & Knott, T. (2010). An analysis of motivation constructs with first year engineering students: Relationships among expectancies, values, achievement, and career plans. *Journal of Engineering Education, 99*(4).

Kalogrides, D., & Grodsky, E. (2011). Something to fall back on: Community colleges as a safety net. *Social Forces*, *89*(3), 853-877.

Kezar, A., & Holcombe, E. (2019). The role of collaboration in integrated programs aimed at supporting underrepresented student success in STEM. *American Behavioral Scientist, 64*(3), 325-348. https://doi.org/10.1177/0002764219869421

Khatri, R., Henderson, C., Cole, R., Froyd, J., Friedrichsen, D., & Stanford, C. (2017). Characteristics of well-propagated teaching innovations in undergraduate STEM. *International Journal of STEM Education*, *4*(1), 1-10.

Knight, J., & Wood, W. (2005). Teaching more by lecturing less. *Cell Biology Education*, *4*, 298-310.

Kolb, D. (1984). *Experiential learning experiences as a source of learning and development*. Englewood Cliffs, NJ.: Prentice Hall.

Kuh, G., Cruce, T., Shoup, R., & Kinzie, J. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *Journal of Higher Education*, *79*(5), 540-563.

Kuh, G., Kinzie, J., Schuh, J., & Whitt, E. (2006). *What matters to student success: A review of the literature*. Washington, D.C.: National Postsecondary Education Cooperative.

Kuh, G. D. (2004). What we are learning about student engagement from NSSE, *Change, 35*, 24-32.

Kuh, G. D., & Love, P. G. (2000). A cultural perspective on student departure. In J. M. Braxton (Ed.), *Reworking the student departure puzzle* (pp. 196-212). Nashville, TN: Vanderbilt University Press.

Landrum, R. E., Viskupic, K., Shadle, S., & Bullock, D. (2017). Assessing the STEM landscape: The current instructional climate survey and the evidence-based instructional practices adoption scale. *International Journal of STEM Education*, *4*(25), 1-10.

Langdon, L., & Cech, T. (2013). Recruiting future teaching while improving student learning: Colorado Learning Assistant model in general chemistry. *Journal of College Science Teaching*. Retrieved from https://serc.carleton.edu/sp/library/learning_assistants/index.html

Learning Assistant Alliance. (2018). *Learning Assistant Program*. Learning Assistant Aliance.org. Accessed on March 28, 2019, from https://www.learningassistantalliance.

org

Lent, R., Brown, S., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior*, *45*(1), 79-122.

Leonard, D. C. (2002). *Learning theories A to Z.* Westport, CT: Greenwood Publishing.

Leonard, N. H., Beauvais, L. L., & Scholl, R. W. (1999). Work motivation: The incorporation of self-concept-based processes. *Human Relations, 52*(8), 969-998.

Leuwerke, W. C., Robbins, S. B., Sawyer, R., & Hovland, M. (2004). Predicting engineering major status from mathematics achievement and interest congruence. *Journal of Career Assessment*, *12*(2). 135-149.

Li, S. (2010). The effectiveness of corrective feedback in SLA: A meta-analysis. *Language Learning*, *60*, 309-365.

Liu, C., & Matthews, R. (2005). Vygotsky's philosophy: Constructivism and its criticisms examined. *International Education Journal*, *6*(3), 386-399.

Liu, O., Bridgeman, B., & Adler, R. (2012). Measuring learning outcomes in higher education: Motivation matters. *Educational Researcher*, *41*(9), 352-362.

Logan, M. L. (2017). *Provisional admission in higher education: A case study in retention, persistence, and matriculation in academia*. Ann Arbor, MI: ProQuest LLC. https://eric.ed.gov/?id=ED578548

Lohfink, M. M., & Paulsen, M. B. (2005). Comparing the determinants of persistence for first-generation and continuing generation students. *Journal of College Student Development*, *46*(4), 409-428.

Lund, T., & Stains, M. (2015). The importance of context: An exploration of factors influencing the adoption of student-centered teaching among chemistry, biology, and physics faculty. *International Journal of STEM Education*, *2*(13), 1-21.

Maltese, A., & Cooper, C. (2017). STEM pathways: Do men and women differ in why they enter and exit? *AERA Open*, *3*(3), 1-16.

Maltese, A., & Tai, R. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students, *Science Education Policy*, *95*, 877-907.

Madgett, P., & Belanger, C. (2008). First university experience and student retention factors. *Canadian Journal of Higher Education, 38*(3), 77-96.

Marbach-Ad, G., & Sokolove, P., (2000). Can undergraduate biology students learn to ask higher level questions? *Journal of Research in Science Teaching*, *37*(8), 854-870.

Mastascusa, E., Snyder, W., & Hoyt, B. (2011*). Effective instruction for STEM disciplines: From learning theory to college teaching*. San Francisco, CA.: Jossey-Bass.

Matthews, W. J. (2003). Constructivism in the classroom: Epistemology, history, and empirical evidence. *Teacher Education Quarterly, 30*(3), 51- 64.

Mayer, R. (2010). *Applying the science of learning*. Upper Saddle River, NJ: Pearson.

Mayhew, M., Rockenbach, A., Bowman, N., Seifert, T., Wolniak, G., with Pascarella, E., & Terenzini, P. (2016). *How college affects students Volume 3: 21st Century evidence that higher education works*. San Francisco, CA: Jossey-Bass.

Mazur, E., (1996). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice-Hall.

Mazur, E. (2009). Farewell lecture? *Science*, *323*, 50-51.

McKeachie, W. J., Pintrich, P. R., Lin, Y. G., & Smith, D. A. F. (1986). *Teaching and learning in the college classroom: A review of the research literature.* Ann Arbor: Regents of The University of Michigan. ED 314 999. MF-01; PC-05.

McKinney, L., & Novak, H. (2012). The relationship between FAFSA filing and persistence among first-year community college students. *Community College Review*, *41*(1), 63-85.

McMillan, J. H., & Schumacher, S. (2010). *Research in education evidence-based inquiry* (7th ed.). Upper Saddle River, NJ: Pearson.

McTighe, J., & Willis, J. (2019). *Upgrade your teaching: Understanding by design meets neuroscience.* Alexandria, VA: ASCD.

Medina, J. (2008*). Brain rules*. Seattle, WA: Pear Press.

Mintz, S. (2019). Higher education under the microscope. *Inside Higher Education* Retrieved February 12, 2019, from https://www.insidehighered.com/blogs/higher-ed-gamma/higher-education-under-microscope

Morganson, V., Major, D., Streets, V., Litano, M., & Myers, D. (2014). Using embeddedness theory to understand and promote persistence in STEM majors. *The Career Development Quarterly*, *63*, 348-362.

Muijs, D. (2004). *Doing quantitative research in Education with SPSS*. Thousand Oaks, CA: Sage Publications.

Museus, S. D. (2014). The culturally engaging campus environments (CECE) model: A new theory of college success among racially diverse student populations. In M.B. Paulsen (Ed.), *Higher education: handbook of theory and research* (pp. 189-227). New York, NY: Springer.

National Academies of Sciences, Engineering, and Medicine (NASEM). (2020). *Promising practices for addressing the underrepresentation of women in science, engineering, and medicine: opening doors.* Washington, DC: The National Academies Press. https://doi.org/10.17226/25585

National Research Council (NRC). (2015). *Reaching students: What research says about effective instruction in undergraduate science and engineering.* Washington, DC: The National Academies Press.

National Science Board (NSB). (2018a). *Science & engineering indicators*. Retrieved March 24, 2019, from https://www.nsf.gov/statistics/2018/nsb20181/report/sections/higher-education-in-science-and-engineering/highlights

National Science Board (NSB). (2018b). *Science and engineering indicators 2018*. Alexandria, VA: National Science Foundation (NSB-2018-1).

National Science Board (NSB). (2018c). *Science and engineering indicators 2018 digest*. Alexandria, VA: National Science Foundation (NSB-2018-2). https://www.nsf.gov/statistics/digest/

National Science Foundation, & National Center for Science and Engineering Statistics (NCSES). (2017). *Women, minorities, and persons with disabilities in science and engineering: 2017*. Arlington: Special Report NSF 17–310 Available at www.nsf.gov/statistics/wmpd/

Nettles, M. (2019). History of testing in the United States: Higher education. *ANNALS, AAPSS, 683*, 38-55.

Nichols, A. H., & Quaye, S. J. (2009). Beyond accommodation: Removing barriers to academic and social engagement for students with disabilities. In S. R. Harper & S. J. Quaye (Eds.),

*Student engagement in higher education: Theoretical perspective and practical approaches for diverse population.* New York, NY: Routledge.

Nilson, L. (2016). *Teaching at its best: A research-based resource for college instructors* (4th ed.). San Francisco, CA: Jossey-Bass.

Nyquist, J., Manning, L., Wulff, D., & Austin, A. (1999), On the road to becoming a professor: The graduate student experience. *Change,* (31), 18-27.

Obrentz, S. (2012). Predictors of science success: The impact of motivation and learning strategies on college chemistry performance. Ann Arbor, MI: Georgia State University, ProQuest Dissertations Publishing.

Ohia, U. (2011). A model for effectively assessing student learning outcomes. *Contemporary Issues in Education Research. 4*(3), 25-32.

Okebukola, P. (1986). Impact of extended cooperative and competitive relationships on the performance of students in science. *Human Relations*, *39*(7), 673-682.

Olbrecht, A. M., Romano, C., & Teigen, T. (2016). How money helps keep students in college: The relationship between family finances, merit-based aid, and retention in higher education. *Journal of Student Financial Aid, 46*(1). Available at: https://publications. nasfaa.org/jsfa/vol46/iss1/2/

O'Meara, K., Rivera, M., Kuvaeva, A., & Corrigan, K. (2017). Faculty learning matters: Organizational conditions and contexts that shape faculty learning. *Innovative Higher Education*, *42*, 355-376.

Otero, V., Pollock, S., & Finkelstein, N. (2010). A physics department's role in preparing physics teachers: The Colorado learning assistant model. *American Journal of Physics*, *78*(11), 1218-1224.

Otero, R., Rivas, O., & Rivera, R. (2007). Predicting persistence of Hispanic students in their first year of college. *Journal of Hispanic Higher Education*, *6*(2), 163-173.

Pascarella, E., & Terenzini, P. (2005). *How college affects students Vol 2: A third decade of research.* San Francisco, CA: Jossey-Bass.

Pedrosa-de-Jesus, H., & Silva Lopes, B. (2011). The relationship between teaching and learning conceptions, preferred teaching approaches and questioning practices. *Research Papers in Education, 26*(2), 23-243.

Pedrosa-de-Jesus, H., Da Silva Lopes, B., Moreira, A., & Watts, M. (2012). Contexts for questioning: Two zones of teaching and learning in undergraduate science. *Higher Education, 64*(4), 557-571.

Piaget, J. (1978). *The development of thought*. Oxford, UK: Basil Blackwell.

Pintrich, P., & Schunk, D. (1995). Motivation in education: Theory, research, and applications. Englewood Cliffs, NJ: Prentice Hall.

President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* Washington, DC: Executive Office of the President, President's Council of Advisors on Science and Technology.

Preszler, R., Dawe, A., Shuster, C., & Shuster, M. (2007). Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE Life Science Education, 6,* 29-41.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*, 223-231.

*Princeton Review* (*The*). (n.d.). A day in the life of a professor. https://www.princetonreview.

    com/careers/127/professor

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender

    differences in how sense of belonging influences decisions to major in STEM.

    *International Journal of STEM Education*, *5*(10), 1-14.

Reason, R. (2003). Student variables that predict retention: Recent research and new

    developments. *NASPA Journal, 40*(4), 172–191. Available at: https://doi.org/10.2202/

    1949-6605.1286

Reason, R., (2009). An examination of persistence research through the lens of a comprehensive

    conceptual framework. *Journal of College Student Development*, *50*(6), 659-682.

Redish, E., & Steinberg, R. (1999). Teaching physics: Figuring out what works. *American*

    *Journal of Physics.*

Rendón, L. I., Jalomo, R. E., & Nora, A. (2000). Theoretical considerations in the study of

    minority student retention in higher education. In J. M. Braxton (Ed.), *Reworking the*

    *student development puzzle* (pp. 127-156). Nashville, TN: Vanderbilt University Press.

Richardson, D. (2008). Don't dump the didactic lecture; fix it. *Advanced Physiology Education*,

    *32*, 23-24.

Riegle-Crumb, C., & King, B., (2010). Questioning a white male advantage in STEM:

    Examining disparities in college major by gender and race/ethnicity. *Educational*

    *Researcher*, 39(9), 656-664.

Rittmayer, A. D., & Beier, M. E. (2008). Overview: Self-efficacy in STEM. Retrieved from

    http://www.engr.psu.edu/awe/misc/ARPs/ARP_SelfEfficacy_Overview_122208.pdf

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do
psychosocial and study skill factors predict college outcomes? A meta-analysis.
*Psychological Bulletin*, *130*(2), 261-288.

Rosser, S. (1990). *Female-friendly science: Applying women's studies methods and theories to
attract students.* New York: Pergamon Press.

Ruiz-Primo, M., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. (2011). Impact of
undergraduate science course innovations on learning. *Science*, *331*(6022), 1269-1270.

Sabella, M., VanDuzor, A. G., & Davenport, F. (2016). Leveraging the expertise of the urban
STEM student in developing an effective LA Program: LA and Instructor partnerships.
*Physics Education Research Conference (PERC)*, Sacramento, CA.

Salomone, M., & Kling, T. (2017). Required peer-cooperative learning improves retention in
STEM majors. *International Journal of STEM Education*, *4*(19), 1-12.

Scerri, E. R. (2003). Philosophical confusion in chemical education research. *Journal of
Chemical Education, 80*, 468−474.

Schneider, K., Bickel, A., & Morrison-Shetlar, A. (2015). Planning and implementing a
comprehensive student-centered research program for first-year STEM undergraduates.
*Journal of College Science Teaching*, *44*(3), 37-43.

Schoolhouse Pioneers. (n.d.). *Only a teacher*. Accessed at: https://www.pbs.org/onlyateacher/
pioneers.html

Schreiner, L. A., & Nelson, D. D. (2013)., The contribution of student satisfaction to persistence.
*Journal of College Student Retention*, *15*(1), 73-111.

Schunk, D. H., & Pajares, F. (2005). Competence perceptions and academic functioning. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 85-104). New York, NY: Guilford Press.

Seidel, S., & Tanner, K. (2013). What if students revolt? Considering student resistance: Origins, options, and opportunities for investigation. *CBE Life Sciences Education, 12*(4), 586-595.

Seifert, K., & Sutton, R. (2009). *Global text educational psychology* (2nd ed.). Zurich, Switzerland: Jacobs Foundation.

Sellami, N., Shaked, S., Laski, F., Eagan, K., & Sanders, E. (2017). Implementation of a Learning Assistant Program improves student performance on higher-order assessments. *CBE Life Science Education. 16*(ar62) winter, 1-10. DOI:10.1187/cbe.16-12-0341

Seymour, E., & Hewitt, N. (1997). *Talking about leaving. Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Shapiro, C., & Sax, L. (2011). Major selection and persistence for women in STEM. *New Directions for Institutional Research, 152*, 5-18.

Simon, R., Aulls, M., Dedic, H., Hybbard, K., & Hall, N. (2015). Exploring student persistence in STEM programs: A motivational model. *Canadian Journal of Education*, *38*(1), 1-27.

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017). Student attraction, persistence and retention in STEM programs: Successes and continuing challenges. *Higher Education Studies, 7*(1), 46-59.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2005, January). Pedagogies of engagement: Classroom-based practices. *Journal of Engineering Education*, pp. 1-16.

Smith, M., Jones, F., Gilbert, S., & Wieman, C. (2013). The classroom observation protocol for undergraduate STEM (COPUS): A new instrument to characterize university STEM classroom practices. *CBE-Life Sciences Education*, *12*(4), 618-627.

Soria, K. M., & Taylor Jr., L. (2016). Strengths-based approaches in college and university student housing: Implications for first-year students' retention and engagement. *Journal of College and University Student Housing, 42*(2), 60-75.

Spady, W. (1970). Dropouts from higher education: An interdisciplinary review and synthesis. *Interchange, 1*(1), 64-85.

Spady, W. (1971). Dropouts from higher education: Toward an empirical model. *Interchange, 2*(3), 38-62.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology. *Review of Educational Research*, *69*, 21-51.

St. John, E. P., Hu, S., Simmons, A., Carter, D. F., & Weber, J. (2004). What difference does a major make? The influence of college major field on persistence by African American and White students. *Research in Higher Education*, *45*(3), 209-232.

St. John, E. P., Paulsen, M. B., & Carter, D. F. (2005). Diversity, college costs, and postsecondary opportunity: An examination of the financial nexus between college choice and persistence for African Americans and Whites. *Journal of Higher Education*, *76*(5), 545-569.

Stacy, J. (2009). The guide on the stage: In defense of good lecturing in the history classroom. *Social Education*, *73*(6), 275-278.

Stage, F., & Hossler, D. (2000). Where is the student? Linking student behaviors, college choice, and college persistence. In J. M. Braxton (Ed.), *Reworking the student departure puzzle* (pp. 170-195). Nashville, TN: Vanderbilt University Press.

Stage, F., & Kinzie, J. (2009). Reform in Undergraduate science, technology, engineering, and mathematics: The classroom context. *The Journal of General Education, 58*(2), 85-105.

Stage, F. K., Muller, P., Kinzie, A., & Simmons, J. (1998). *Creating learner-centered classrooms: What does learning theory have to say?* Washington, DC: ERIC Clearinghouse on Higher Education and the Association for the Study of Higher Education.

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., Eagan, Jr., M.K., Esson, J. M., Knight, J. K., Laski, F. A., Levis-Fitzgerald, M., Lee, C. J., Lo, S. M., McDonnell, L. M., McKay, T. A., Michelotti, N., Musgrove, A., Palmer, M. S., Plank, K. M., . . . & Young, A. M. (2018). Anatomy of STEM teaching in North American universities. *Science, 359*(6383), 1468-1470.

Staver, J. (1998). Constructivism: Sound theory for explicating the practice of science and science teaching. *Journal of Research in Science Teaching*, *35*(5), 501-520.

Stinebrickner, R., & Stinebrickner, T. R. (2012). Learning about academic ability and the college dropout decision. *Journal of Labor Economics*, *30*(4), 707-748.

Stitt-Gohdes, W. L. (2001). Business education students' preferred learning styles and their teachers' preferred instructional styles: Do they match? *Delta Pi Epsilon Journal*, *43*(3), 137-151.

Stoddard, H., & O'Dell, D. (2016). Would Socrates have actually used the Socratic Method for clinical teaching? *Journal of General Internal Medicine*, *31*(9), 1092-1096.

Stratton, L., O'Toole, D., & Wetzel, J. (2007). Are the factors affecting dropout behavior related to initial enrollment intensity for college undergraduates? *Research in Higher Education*, *48*, 453-485.

Stratton, L., O'Toole, D., & Wetzel, J. (2008). A multinomial logit model of college stopout and dropout behavior. *Economics of Education Review*, *27*(3), 319-331.

Strayhorn, T., & Saddler, T. (2009). Gender differences in the influence of faculty-student mentoring relationships on satisfaction with college among African Americans. *Journal of African American Studies*, *13*(476).

Strayhorn, T. L. (2012). *College students' sense of belonging: A key to educational success for all students*. New York: Routledge.

Svinicki, M. D. (2004). *Learning and motivation in the postsecondary classroom*. San Francisco, CA: Jossey-Bass.

Swail, W. S., Redd, K. E., & Perna, L. W. (2003). *Retaining minority students in higher education*. (ASHE-ERIC Higher Education Report, 30-2). Hoboken, NJ: Wiley.

Swenson-Goguen, L, Hiester, M., & Nordstrom, A. (2010). Associations among peer relationships, academic achievement, and persistence in college. *Journal of College Student Retention: Research, Theory, & Practice*, *12*(3), 319-337.

Terenzini, P., & Pascarella, E. (1977). Voluntary freshman attrition and patterns of social and academic integration in a university: A test of a conceptual model. *Research in Higher Education, 6*, 25-43.

Thielens Jr., W. (1987). *The disciplines and undergraduate lecturing.* Paper presented at the annual meeting of the American Educational Research Association, Washington, D.C. April 20-24. ERIC number: ED286436

Tierney, W. (2000). Power identity, and the dilemma of college student departure. In J. M. Braxton (Ed.), *Reworking the student departure puzzle* (pp. 213-234). Nashville, TN: Vanderbilt University Press.

Tijmstra, J. (2018). Why checking model assumptions using null hypothesis significance tests does not suffice: A plea for plausibility. *Psychonomic Bulletin and Review*, *25*, 548-559.

Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research, 45*(1), 89-125. http://dx.doi.org/10.3102/00346543045001089

Tinto, V. (1987). Leaving college: Rethinking the causes and cures of student attrition. Chicago, IL: University of Chicago Press.

Titus, M. (2004). An examination of the influence of institutional context on student persistence at 4-year colleges and universities: A multilevel approach. *Research in Higher Education*, *45*, 673-699.

Tracey, T., & Robbins, S. (2005). The interest-major congruence and college success relation: A longitudinal study. *Journal of Vocational Behavior*, *69*(1), 64-89.

Udovic, D., Morris, D., Dickman, A., Postlethwait, J., & Wetherwax, P. (2002). Workshop biology: Demonstrating the effectiveness of active learning in an introductory biology course. *BioScience*, *52*(3), 272-281.

Umbach, P., & Wawrzynski, M. (2005). Faculty do matter: The role of college faculty in student learning and engagement. *Research in Higher Education*, *46*(2), 153-184.

U.S. Census Bureau. (2012–2016). *American Community Survey (ACS) 5-Year Estimates*. Available at https://www.census.gov/content/dam/Census/library/working-papers/2019/demo/sehsd-wp2018-27.pdf

Van Dusen, B., Langdon, L., & Otero, V. (2015). *Learning assistant supported student outcomes (LASSO) study initial findings*. American Association of Physics Teachers. DOI:10,1119 perc.2015.pr081

Van Gennep, A. (1960). *The rites of passage.* M. Vizedine & G. Caffee (Trans.). Chicago, IL: Chicago University Press.

Von Glaserfeld, E. (1998). Why constructivism must be radical. In: M. Larochelle, N. Bednarz, & J. Garrison (Eds.), *Constructivism in education* (pp. 23-28). Cambridge, MA: Cambridge University Press.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wainer, H., & Robinson, D. (2003). Sharping up the practice of null hypothesis significance testing, *Educational Researcher, 32*(7), 22-30.

Walter, E. M., Henderson, C. R., Beach, A. L., & Williams, C. T. (2016). Introducing the Postsecondary Instructional Practices Survey (PIPS): A concise, interdisciplinary, and easy-to-score survey. *CBE-Life Sciences Education*, *15*(4), 1-11.

Walvoord, B. (2004). *Assessment clear and simple*. San Francisco, CA: Jossey-Bass.

Wang, X. (2009). Baccalaureate attainment and college persistence of community college transfer students at four-year institutions. *Research in Higher Education*, *50*(6), 570-588.

Wass, R., & Golding, C. (2014). Sharpening a tool for teaching: The zone of proximal development. *Teaching in Higher Education*, *19*(6), 671-684.

Weaver, G. C., Burgess, W. D., Childress, A. L., & Slakey, L. (Eds.). (2016)., *Transforming institutions: Undergraduate STEM education for the 21st century*. West Lafayette, IN: Purdue University Press.

Webb, O., Wyness, L., & Cotton, D. (2017). *Enhancing access, retention, attainment and progression in higher education: A review of the literature showing demonstrable impact*. Heslington, York, UK: Higher Education Academy.

Weidman, J. (1989). Undergraduate socialization: A conceptual approach. *Higher Education: Handbook of Theory and Research, 5*, 289-322.

Weimer, M. (2002). *Learner-centered teaching: Five key changes to practice*. San Francisco, CA: Jossey-Bass.

Weston, D. (2014). A positive constructivist: An internal debate on opposing educational philosophies. *Teaching & Learning*, *8*(1), 1-19.

Whitcomb, K., & Singh, C., (2020). Gender inequities throughout STEM: Women with higher grades drop STEM majors while men persist. arXiv.org, 1-24 [physics.ed-ph]. https://arxiv.org/abs/2004.00560

Worthen, B., & Spandel, V., (1991). Putting the standardized test debate in perspective. *Educational Leadership*, 48(5): 65-69.

White, J., Van Dusen, B., & Roualdes, E. (2016). *The impacts of learning assistants on student learning of physics*. (LAA Resources https://sites.google.com/view/laa-resources/assessment-research-and-results/papers).

Wieman, C. (2017). *Improving how universities teach science: Lessons from the science education initiative.* Cambridge, MA: Harvard University Press.

Williams, D. M., & Rhodes, R. E. (2016). The confounded self-efficacy construct: conceptual analysis and recommendations for future research. *Health Psychology Review*, *10*(2), 113-128. https://doi.org/10.1080/17437199.2014.941998

Wink, D. (2014) Constructivist frameworks in chemistry education and the problem of the "thumb in the eye". *Journal of Chemistry Education*, *91*(5), 617-622. https://doi.org/10.1021/ed400739b

Wohlgemuth, D., Whalen, D., Sullivan, J., Nading, C., Shelley, M., & Wang, Y. (2007). Financial, academic, and environmental influences on the retention and graduation of students. *Journal of College Student Retention*, *8*(4), 457-475.

Wolniak, G. C., Mayhew, M. J., & Engberg, M. E. (2012). Learning's weak link to persistence. *Journal of Higher Education*, *83*(6), 795-823.

Wood, W. (2004). Clickers: A teaching gimmick that works. *Developmental Cell*, *7*(6), 796-798.

Woosley, S. (2004). Stop-out or drop-out? An examination of college withdrawals and re-enrollments. *Journal of College Student Retention*, *5*(3), 293-303.

Wright, R., & Boggs, J. (2002). Learning cell biology as a team: A project-based approach to upper-division cell biology. *Cell Biology Education*, *1*(4), 145-153.

Xu, Y. (2016). Attention to retention: Exploring and addressing the needs of college students in STEM majors. *Journal of Education and Training Studies*, *4*(2), 67-76.

Xu, Y. (2018). The experience and persistence of college students in STEM majors. *Journal of College Student Retention: Research, Theory, & Practice*, *19*(4), 413-432.

Zumeta, W., Breneman, D. W., Callan, P. M., & Finney, J. E. (2015). *Financing American higher education in the era of globalization* (2nd ed.). Cambridge, MA: Harvard Education Press.

Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education*, *25*, 1081-1094.

**Appendix**

## Institutional Review Board (IRB)

720 4th Avenue South AS 210, St. Cloud, MN 56301-4498

**ST. CLOUD STATE**
U N I V E R S I T Y
EDUCATION FOR LIFE.

**Name:** Jodi Laudenbach

**Email:** jrlaudenbach@go.stcloudstate.edu

## IRB PROTOCOL DETERMINATION:
### Exempt Review

**Project Title:** Teaching Methods Matter: Comparison of Learning Outcomes and Persistence in STEM Between Traditional Lecture and Active Learning Using Undergraduate Learning Assistants in Introductory Chemistry

**Advisor** Rachel Friedensen

The Institutional Review Board has reviewed your protocol to conduct research involving human subjects. Your project has been: **APPROVED**

Please note the following important information concerning IRB projects:

- The principal investigator assumes the responsibilities for the protection of participants in this project. Any adverse events must be reported to the IRB as soon as possible (ex. research related injuries, harmful outcomes, significant withdrawal of subject population, etc.).

- For expedited or full board review, the principal investigator must submit a Continuing Review/Final Report form in advance of the expiration date indicated on this letter to report conclusion of the research or request an extension.

- Exempt review only requires the submission of a Continuing Review/Final Report form in advance of the expiration date indicated in this letter if an extension of time is needed.

- Approved consent forms display the official IRB stamp which documents approval and expiration dates. If a renewal is requested and approved, new consent forms will be officially stamped and reflect the new approval and expiration dates.

- The principal investigator must seek approval for any changes to the study (ex. research design, consent process, survey/interview instruments, funding source, etc.). The IRB reserves the right to review the research at any time.

If we can be of further assistance, feel free to contact the IRB at 320-308-4932 or email ResearchNow@stcloudstate.edu and please reference the SCSU IRB number when corresponding.

**IRB Chair:**

Dr. Benjamin Witts
Associate Professor- Applied Behavior Analysis
Department of Community Psychology,Counseling, and Family Therapy

**IRB Institutional Official:**

Dr. Latha Ramakrishnan
Interim Associate Provost for Research
Dean of Graduate Studies

**OFFICE USE ONLY**

| SCSU IRB# 1968 - 2544 | Type: Exempt Review | Today's Date: 5/29/2020 |
|---|---|---|
| 1st Year Approval Date: 5/29/2020 | 2nd Year Approval Date: | 3rd Year Approval Date: |
| 1st Year Expiration Date: | 2nd Year Expiration Date: | 3rd Year Expiration Date: |