Transformational Teaching in a Culturally Passive Environment in Higher Education: A Phenomenological Study of STEM Professors

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Transformational Teaching in a Culturally Passive Environment in Higher Education:

A Phenomenological Study of STEM Professors

by

Julie M. Kjeer

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Educational Doctorate in Educational Leadership

Minnesota State University, Mankato

Mankato, Minnesota

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Transformational Teaching in a Culturally Passive Environment in Higher Education:

A Phenomenological Study of STEM Professors

Julie M. Kjeer

This dissertation has been examined and approved by the following members of the student’s committee:

Dr. Ginger Zierdt, Advisor

Dr. Polly Browne, Committee Member

Dr. Jean Haar, Committee Member
Dedication

To my beloved husband, Pete, who left this earth too soon to see my goal come to fruition but inspired me through his intellect, sense of humor, work ethic, and deep love. You are the epitome of an inspirational professor.

To our daughters, Katherine and Emily, who are the most amazing women that I know. God truly blessed us when He gifted us with you. I could not have completed this challenge without your encouragement, love, and support.

As you wish.

4 Make me to know your ways, O Lord; teach me your paths.

5 Lead me in your truth and teach me, for you are the God of my salvation;

for you I wait all the day long.

Psalm 25: 4–5
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13 And now we thank you, our God, and praise your glorious name. 1 Chronicles 29:13
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Abstract

Science, technology, engineering, and mathematics (STEM) education in this country has come under increasing scrutiny as employers, government agencies, and postsecondary institutions point to the lack of prepared students in STEM-related fields. Evidence compels higher education institutions to improve the quality of teaching to better prepare students for lives of productive service. While such evidence has spurred multiple reform movements, little substantive change has actually occurred. Despite a culture of passive and transmissive learning in higher education STEM disciplines, inspirational STEM professors exist who dramatically impact students in positive and meaningful ways. The purpose of this qualitative phenomenological study was to describe the lived experiences of transformational STEM professors who negotiate their existence within the passive culture that is prevalent in STEM higher education. Inspirational professors were identified through teaching awards and student comments that reflected transformational leadership components. Semi-structured interviews of eight professors unveiled insights into their shared experiences. Coding revealed five themes: professorship, culture, pedagogy, inspiration and motivation, and future change. The words of the professors provided evidence for all four components of transformational leadership, but the most impactful element was individualized consideration. Inspirational professors in this study relied less on charisma and more on genuine care and concern for students. Rather than focusing on factual knowledge as the quintessential element of a course, the professors considered facts to be the foundation for solving problems in new and innovative ways. The interviewed STEM professors collectively pointed to a crack in the process of adopting learner-centered strategies: perspective. Without recognizing how fundamental core beliefs about teaching and learning affect pedagogy, change is unlikely to be sustainable. Thus, professional development opportunities should include more than teaching techniques. First, they must address the underlying teaching philosophies of faculty members. Active learning strategies developed organically within an established mentoring and caring framework may be more permanent and have a greater impact. Finally, higher education institutions should be more intentional in ways to support and promote a culture that values relationships between faculty and students.
CHAPTER 1

Introduction

Background of the Problem

America is in a science, technology, engineering and mathematics (STEM) crisis, and students are not prepared for STEM careers according to government agencies, universities, and academic organizations (Achieve, 2010; DeJarnette, 2012; Dorph et al., 2011; Drew, 2011; Tucker, 2012). In response to this crisis, STEM education is under close scrutiny in search of improvement (American Association for Advancement of Science [AAAS], 2011; Lechuga, 2016; President’s Council of Advisors on Science and Technology [PCAST], 2012). STEM courses, especially mathematics, “act as a ‘gatekeeper’ to economic success, to active citizenship, and to higher education in our society” (D’Ambrosio, 2012, p. 202). Serious economical disadvantages may result when fewer students opt for college majors that require mastery of mathematics (Geary, 1996; Philips et al., 2002; Stake & Mares, 2005). The National Science Board (2015) summarized, “Assessing, enabling, and strengthening workforce pathways is essential to the mutually reinforcing goals of individual and national prosperity and competitiveness” (p. 2). A PCAST report (2012) indicated the need to produce a million more college graduates in STEM fields by 2022. This report also noted that less than 40% of students who enter higher education intending to major in a STEM field complete a degree in STEM. Olson and Riordan, two presidential advisors, made five recommendations in the report:
Catalyze widespread adoption of empirically validated practices, advocate and provide support for replacing standard laboratory courses with discovery-based research courses, launch a national experiment in post-secondary mathematics education to address the math preparation gap, encourage partnerships among stakeholders to diversify pathways to STEM careers and create a Presidential Council on STEM Education. (PCAST, 2012, pp. ii-iii)

Unfortunately, high-achieving students often cite uninspiring introductory courses as an influential factor in their choice to switch majors (Green & Sanderson, 2018; Wright, 2011). According to the PCAST report, better teaching methods are needed by university faculty to make courses more inspiring. Despite the need and call for STEM educational reform, there has been very little actual change in the pedagogy used in STEM courses at the university level (Brownell & Tanner, 2012; Green & Sanderson, 2018; PCAST, 2012).

Shifts in faculty-student interaction and instructional methods have the potential to address the serious deficits in the number of STEM graduates. A study by Kim and Olson (2016) claimed, “effective university professors are those who not only possess expertise in their fields, but in addition are engaging, student-focused and able to build rapport with their students” (p. 123). According to the Carnegie Commission on Mathematics and Science Education (2009), it is vital to “increase the supply of teachers who have strong working knowledge of mathematics and science and the pedagogical techniques necessary to teach math and science effectively” (p. 35). The content knowledge of university professors is typically not in question, as professors have studied
their disciplines in great depth and are considered experts in their fields. However, professors face multiple challenges in applying learner-centered pedagogies and engaging students in deep learning.

Research indicates that high impact learning practices require more preparation, time, and effort to implement (Hanson & Moser, 2003; Miller & Metz, 2014; Pundak & Rozner, 2008). When there is little to no incentive for faculty to invest precious time and energy into these practices, faculty may be unwilling to change how they currently teach. This is especially true in a university setting where teaching in novel ways or introducing evidence-based strategies results in few to no rewards from the institution (Romano et al., 2004). The tenure process still relies primarily on research within the discipline. Thus, calls for change in teaching practice, even when supported by evidence, go unheeded since rewards dictate that time would be better spent on scientific research within a faculty member’s subject. Student reactions also inhibit professors’ willingness to change instructional practices. Engaging in deep learning is more difficult and time consuming for students. Several studies have reported that students often prefer traditional lectures over active learning (Covill, 2011; Herreid & Schiller, 2013; Tharayil et al., 2018).

Professors feel pressure to modify their classes to give students what they want, not necessarily what they need, in this consumer-driven culture to keep students satisfied and retention rates high. Initial changes in instructional practice can lead to negative teaching evaluations, again affecting progress toward tenure. Due to numerous institutional barriers, faculty may perceive that the additional preparation, time, and effort necessary
to change educational practice does not pay off. Incentivization may be a necessary, but not sufficient, means to increase the implementation of new learner-centered pedagogies.

Professors lack support and training in non-lecture pedagogies (Brownell & Tanner, 2012; Fornaciari & Kauanui, 2008; Mulryan-Kyne, 2010). According to Miller and Metz (2014), “active learning may not be an intuitive technique for professors who are accustomed to traditional didactic lectures, and sufficient training and feedback may be necessary” (p. 251). Unlike their K-12 counterparts, university professors do not receive any systematic preparation for their teaching roles. The result may be unfounded or incorrect beliefs about effective teaching. Ebert-May et al. (2011) reported that 75% of instructors who claimed to use learner-centered practices actually used a lecture-based, teacher-centered pedagogy. Professional development can attempt to repair the disconnect. However, most professional development programs come in the form of short-term training. Expecting one or two week development programs to address the substantial lack of pedagogical instruction may be short-sighted and is incongruent with the concept that true change takes serious commitment and requires multiple iterations to continuously analyze, assess, and revise. In fact, a study by Silverthorn et al. (2006) reported that instructors who were interested in active learning failed to apply these techniques even when active learning modules were provided without charge and professional development was available. Incentives and training may be steps in the right direction, but the higher education STEM infrastructure supports passive modes of teaching and learning that will be difficult to overhaul.
Professors face multiple individual struggles as well. The potential loss of professional identity for faculty may be a substantial barrier to implementing pedagogical change (Brownell & Tanner, 2012). Scientists’ professional identities include professional philosophy, passions, commitments, ways of acting and interacting, values, and morals (Luehmann, 2007). To access entrance into the scientific community, budding scientists need to learn how to adapt to the culture, which involves a commitment to research in the sciences as opposed to teaching. Harvard physics professor Dr. Eric Mazur has written multiple books and journal articles in the area of peer instruction and other active learning strategies. Yet his biography on Harvard’s faculty page only mentions his physics research, with no mention of any of his books or articles in education. Mazur (2009) reported that in science classes across the globe “you'll find lecture halls filled with students and, at the front, an instructor,” even though research revealed, “learning gains nearly triple with an approach that focuses on the student and on interactive learning” (p. 51). Most college classes in the sciences are still taught in lecture mode, so graduate students who aim to teach at a university will naturally equate teaching with lecturing. According to Gibbs and Coffey (2004), new university professors may experience peer pressure from scientific colleagues to conform to traditional teaching methods. Substantive educational reform in STEM higher education will likely require discovering ways in which teaching can become woven into the fabric of the discipline.

With all the barriers to progress, the outlook may appear dim. However, despite the strong culture of transmissive and passive learning in STEM higher education, some
Professors act as bright lights to inspire students and transform students’ educational journeys and careers. How are certain professors able to act contrary to their surrounding culture and become inspirational and transformational professors? Transformational leadership by educators has been associated with more positive student attitudes and beliefs, greater motivation, more enjoyment out of class, greater satisfaction with the class and teacher, and greater self-determined motivation, as well as with significant improvements in self-efficacy and intrinsic motivation (Beauchamp & Morton, 2011). Therefore, understanding how STEM professors become transformational educators in the classroom can provide important lessons that will benefit individual students and address the STEM crisis. Hesslebein (1999) noted, “culture does not change because we desire to change it. Culture changes when the organization is transformed; the culture reflects the realities of people working together every day” (p. 6). Transformational and inspirational educators can be an impetus to change the culture of STEM higher education.

The definition of an inspirational professor in this study will be one who demonstrates transformational leadership traits. Pounder et al. (2018) noted, “transformational classroom leadership… is a suitable vehicle for faculty development aimed at producing university teachers who display transformational classroom or inspiring professor qualities” (p. 335). According to Bass and Riggio (2006), transformational leadership involves “inspiring followers to commit to a shared vision and goals for an organization or unit, challenging them to be innovative problem solvers, and developing followers’ leadership capacity via coaching, mentoring, and provision of
Both challenge and support” (p. 4). They described four dimensions of transformational leadership: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Idealized influence provides modeling of moral and ethical behavior that engenders mutual trust and admiration. The leader offers support to overcome obstacles. Inspirational motivation is the articulation of a vision and the promotion of enthusiasm and optimism that seeks the collective success of a group. The leader articulates a compelling vision of the future. Intellectual stimulation is the focus on independent thinking and the challenge of accepted ideas. The leader encourages analysis from multiple and new angles. Individualized consideration refers to the extent that a leader acts as a mentor, paying close attention to the needs for achievement and growth (Antonakis & House, 2014; Northouse, 2018). In essence, a transformational leader motivates others to do more than they even expected to do. Bass (1999) identified inspiration as an essential characteristic of transformational leaders. While recent research has studied transformational leadership in the classroom (Bolkan & Goodboy, 2009; Browning, 2018; Pounder et al., 2018), there is very little research in how transformational leadership is applied in a STEM postsecondary classroom. When discussing transformational leadership, Bolkan and Goodboy (2009) indicated, “instructional researchers would be well advised to determine how to promote such leadership in the classroom” (p. 304). This study investigates how STEM professors are able to employ transformational leadership in the classroom to successfully inspire students despite a culture that promotes the transmission of factual content only.
Research has revealed that learner-centered and active learning strategies enhance deep learning and are considered effective methods (Angelo & Cross, 2012; Cornelius-White, 2007; Slunt & Giancarlo, 2004; Wright, 2011). Even though evidence has shown this for many years, teacher-centered classrooms that primarily use a lecture mode of transmitting content are still the norm in STEM higher education. As a consequence, too many students graduate without the necessary STEM skills that are valuable in securing a job in a competitive market. Multiple barriers to implementation of effective teaching strategies such as increased time, lack of support, and a culture that inhibits change have all been acknowledged in multiple scholarly articles. Despite the plethora of barriers, inspirational professors in STEM are changing lives. There is very limited research on how STEM professors become transformational leaders and truly inspire students in an environment that supports the opposite. Gaining insight from the lives of those STEM professors who are defying the odds may inspire other professors to overcome barriers and obstacles, ultimately changing the culture of passive learning and teacher-centered pedagogy in STEM higher education.

**Purpose of the Research**

The purpose of this qualitative phenomenological study will be to describe the lived experiences of transformational university STEM professors who negotiate their existence within the passive culture that exists in STEM higher education.

**Research Question**

Despite a common culture of passive and transmissive learning in higher education STEM courses, there exist inspirational and transformational STEM professors
who are able to dramatically influence students positively and inspire them to persevere. The calls to advance STEM education to respond to a nationwide crisis loom louder and louder since very little progress has been made at the college or university level (Brownell, & Tanner, 2012; Pundak & Rozner, 2008; PCAST, 2012). Yet little is known about how certain STEM professors manage in a culture that runs counter to their educational behavior in the classroom. This study intends to add to the existing research by exploring the following research question: How do transformational STEM professors inspire higher education students even in a culture of passive learning?

**Significance of the Research**

Clark (1997) reported that the public frequently hears the assertions, “deep interest in research entails low interest in teaching, and, notably, that when academics do research they abandon students” (p. 12). Yet, this generalization is not true of all professors. Certain STEM professors have a profound and long-lasting impact on the lives of students. The descriptions of the lived experiences of these transformational professors will contribute to the scholarship of teaching and learning in STEM higher education.

The need to engage in the scholarship of teaching in STEM education has been documented for the last decade, yet implementation has been limited, especially in higher education. Patterson (2009) stated, “little is known about the evidence on which educators base their teaching practice within the classroom” (p. 327). Professors have extensive knowledge of the curriculum, as they are considered experts in their respective disciplines. However, engaging students with the curriculum in such a way as to bring a
topic alive occurs less often than desired as evidenced by the lack of STEM graduates and the high rate of attrition in STEM majors. Inspiring students to persevere and complete a STEM major will begin to close the gap of the additional million STEM graduates needed to fill the growing number of positions expected (PCAST, 2012). By studying the experiences of transformational STEM professors, barriers that inhibit change and means by which to overcome these barriers may be illuminated. If common themes of teaching strategies are uncovered, this may provide an impetus for others to employ such strategies. Baldwin (2009) pointed out, "the lack of knowledge of the teaching and learning literature and the many types of instructional strategies places limits on what many STEM faculty do in their classrooms and laboratories to encourage undergraduate learning" (p. 12). Educators need to perceive an advantage in applying new teaching strategies before they will consider adoption.

Inspirational and transformational STEM professors impact students in ways that last far beyond the factual knowledge of the course. In addition to the lasting imprint on the students, the positive influence of these professors must be preserved for current and future educators. Philosophical founder of constructivism and educational reformer John Dewey (1929) listed one of the saddest things about American education:

The successes of [excellent teachers] tend to be born and die with them: beneficial consequences extend only to those pupils who have personal contact with the gifted teachers. No one can measure the waste and loss that have come from the fact that the contributions of such men and women in the past have been thus confined. (p. 10)
Collecting and recording the philosophies and insights from successful STEM professors in this study provides a method of decreasing the waste and loss of valuable knowledge that should be shared. Studying the methods of inspirational STEM professors in an environment filled with obstacles can add to the body of knowledge regarding the improvement of STEM higher education.

Assumptions

Since this qualitative study is designed to understand and share the lived experiences of impactful and transformational STEM professors, the researcher assumed that there would be multiple realities present. The assumption was made that the participants would be able to honestly assess and share their stories and respond openly to the interview questions. The researcher assumed that the live interviews would unveil information that would add to the body of knowledge in the education of college and university students within the STEM fields. Another assumption is that the researcher properly identified transformational educators. No single piece of evidence served to determine if a professor qualified for this study. Lists of top professors from various websites were consulted, including those individuals who received teaching awards. Comments from numerous students that indicated the STEM professor was valued for providing inspiration or transforming lives were considered, but these comments could not be the sole identifying factor. Snowball sampling also played a role in this study. More details can be found in the methodology section of this paper.

Teaching is a highly individualized craft. According to the National Research Council (1999), “good practice in teaching cannot be prescribed but must emerge from a
teacher's knowledge, judgment, and circumstances” (p. 45). Thus, the researcher never believed that this study would uncover a formula that all professors must follow. It is also not intended to be a list of best practices in pedagogy. As Duffy (1992) noted, inspired teaching “originates in the creativity of teachers” (p. 444). This study aimed to discern how certain STEM professors are able to apply a transformational leadership style to inspire students within a passive culture.

The researcher brings experience as a mathematics educator in higher education, primarily at small liberal arts institutions. Thus, the interpretation of data may be subject to assumptions developed through this past experience. However, awareness of these assumptions results in mindful efforts to bracket personal experience. The researcher acknowledges that the phenomenological research used in this study will affect the researcher. As van Manen (1990) wrote, “phenomenological research is often itself a form of deep learning, leading to a transformation of consciousness, heightened perceptiveness, increased thoughtfulness” (p. 163).

**Limitations**

As with all qualitative research, the findings should not be extended to a general population. There is no statistical test for significance, as the goal is to analyze inductively the information from the participants rather than to test a hypothesis. All of the participants work within the United States at a college or university as a faculty member who teaches undergraduate students within a STEM discipline. Further research could be done in other tertiary institutions outside the U.S. to consider how cultural differences play a role.
Summary

STEM education in this country has come under increasing scrutiny as employers, government agencies and postsecondary institutions bemoan the lack of prepared employees and students in STEM-related fields. One issue under attack is the pedagogy used within STEM courses. Yet, faculty have few incentives to change. Barriers include lack of time, lack of training, potential loss of professional identity, and a culture that supports the transmission of factual content knowledge in a teacher-centered environment. Even with these obstacles, some STEM professors manage to inspire students using transformational leadership methods in the classroom. How do such successful STEM professors manage within an environment that contradicts their behavior? This study aims to analyze and report the lived experiences of inspirational STEM professors.

The remainder of this paper is divided into four chapters that relate the previous research and findings in this area with the current study. Chapter two is a comprehensive review of the literature on transformative STEM education at the college and university level. The gap between the recent literature showing the effectiveness of active learning with the lack of its usage at tertiary institutions will be highlighted. The research design as well as details regarding the implementation of the study are located in chapter three. The last two chapters focus on the specific research conducted for this study. The research results are provided in chapter four, followed by an interpretation and discussion of the findings in chapter five.
CHAPTER 2

Literature Review

According to the National Science Board (2006), the highest education priority in the United States is to produce future generations of scientists and engineers. McFarland et al. (2017) reported through the National Center for Education Statistics that the U.S. test scores continued to rank near the bottom, especially in the area of mathematics, on both the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). The gap between what the country needs to grow its economy and stay at the forefront of technological advances and the current test scores of U.S. students in STEM topics creates cause for alarm. The lack of scientific literacy in undergraduate students does not only affect those in a STEM major but students from every path of study. In today’s complex and rapidly changing society, the skills taught in STEM courses offer benefits beyond future employment in a STEM field. Dr. Kevin Droegemeier in the introduction to a progress report on the federal implementation of the STEM education strategic plan developed by the National Science and Technology Council (2019) commented:

Students well equipped with STEM knowledge and skills not only provide a workforce prepared for meeting tomorrow’s challenges to ensure National security and economic strength, but also are able to function more effectively in our increasingly technologically sophisticated society irrespective of their chosen career (p. iii).
Regardless of the employment path, STEM courses create abilities and mindsets in undergraduate students with far-reaching advantages to society. The first section of this literature review explores the research that describes the current state of STEM higher education.

With the national recognition of a great divide between scientific priorities and academic results, there has been substantial research addressing possible changes in education that have the potential to bridge the gap. Empirical evidence on multiple learner-centered strategies has been shown to positively affect both the academic achievement of students in STEM courses as well as student attitude. The National Science Foundation (NSF) created an undergraduate education program to “strengthen STEM education at two- and four-year colleges and universities by improving curricula, instruction, laboratories infrastructure, assessment, diversity of students and faculty, and collaborations” (NSF, n.d.). These goals for improvement exemplify a recognition of the need for change. A summary of some of the recent efforts to improve STEM undergraduate education will be considered.

Since reform efforts are in progress and potential strategies to improve STEM education do exist, the question remains as to why these changes have not been implemented on a broad scale. The reality is that STEM education in higher educational institutions has changed very little over the last decades (NRC, 2012; PCAST, 2012; Zappe et al., 2009). Green and Sanderson (2018) suggested, “even though the literature has shown a need for STEM education reform, there has not been enough change in STEM departments who ultimately act as the gatekeepers to STEM degrees” (p. 82).
There are multiple barriers that block the implementation of known advantageous pedagogies. Institutional barriers exist that involve the historical traditions and structure of higher education, student resistance, a lack of incentives in the existing advancement structure for faculty, and a lack of faculty training. In addition to institutional barriers, faculty may struggle with individual challenges that make the implementation of learner-centered strategies difficult.

Despite the necessity for change and the lack of any broad scale reform, certain STEM professors exhibit traits of transformational teaching in the classroom and are inspiring students. This research used the framework of transformational leadership by Bass and Riggio (2006) to identify key characteristics of transformational STEM professors. The research literature explains how a transformational teaching style can be applied to education in the classroom and the effect that such methods can have on student motivation, academic performance, and persistence.

As the existing literature demonstrates, there is a great need to improve STEM higher education. Kania and Kramer (2011) pointed out, “the heroic efforts of countless teachers, administrators, and nonprofits, together with billions of dollars in charitable contributions, may have led to important improvements in individual schools and classrooms, yet system-wide progress has seemed virtually unobtainable” (p. 36). Multiple studies show that research indicates promise in learner-centered strategies. Yet the barriers to widespread implementation are numerous. Both initiation and implementation of change are challenging, especially in the climate of the scientific community. Even with the transmissive and passive culture of STEM higher education,
certain motivating professors are navigating the existing system to break free and inspire students. The gap in the existing literature as to precisely how this phenomenon occurs is the focus of this research study.

**Current State of STEM Higher Education**

Improving undergraduate STEM higher education has been a goal for government offices, colleges, universities, and employers for over 50 years. Research has highlighted several issues in undergraduate STEM programs: courses are not supportive of students developing a meaningful understanding of the course content (Hake, 1998; Wandersee et al., 1994), courses do not immerse students in tasks normally done by practitioners in the real world (Halloun & Hestenes, 1985; de Jong & Ferguson-Hessler, 1986; National Academies of Science, 2007; PCAST, 2012; Reif, 1995), and students find the courses unwelcoming (National Science Foundation, 1996; Seymour & Hewitt, 1997; Tobias, 1990). Higher education institutions in the U.S. have failed to adequately prepare students for the fast-paced, global, technological society, which Friedman (2005) referred to as a “quiet crisis” (p. 253). The report *A Nation at Risk* (Gardner, 1983) brought an intense national spotlight on the decline in achievement in STEM areas by students in the U.S. compared to their counterparts elsewhere. In a 2007 report, the National Academies of Science issued a statement that urged quick action to bolster STEM education:

> If the United States is to retain its edge in the technology-based industries that generate innovation, quality jobs, and high wages, we must act to broker a new, collaborative understanding among the sectors that sustain our knowledge-based
Standardized testing by the Organization for Economic Co-operation and Development (OECD) group through the triennial PISA survey resulted in the U.S. being ranked 31st out of 35 industrialized nations in the area of mathematics in 2018. The news was not as dismal for science, where the mean score for the U.S. was about average (OECD, 2019). While this survey is for students aged 15 years, the results extend into higher education. Noel-Levitz (2016) indicated that 45% of incoming freshmen struggled significantly in mathematics. Scores in first-year mathematics courses are a strong predictor of graduation in STEM fields (Chen, 2013). Low international rankings combined with rapid growth in technological advances have led policymakers in many areas to raise an alarm and focus efforts on STEM education.

First-year STEM courses that typically include chemistry and calculus, referred to often as “gateway” or “gatekeeping” courses, are widely perceived as challenging for students. These courses are frequently cited as factors in the attrition of STEM students (Barr et al., 2008; Dienstag, 2008; Mervis, 2010; Tai et al., 2006; Thurmond & Cregler, 1999). In particular, the type of mathematics courses and performance in STEM courses the first year are predictors of the number of students that stay in a STEM major (Alting & Walsner, 2007; Chen, 2013). The high rate of attrition adds to the widening gap between the number of students who graduate with a STEM major and the number needed to fill all the STEM careers. Godfrey et al. (2010) noted that the substantial number of students who drop out of engineering programs represents an “excessive loss
to the qualified workforce” and “a loss of return on public investment” (p. 26). Retaining more of these students would help to alleviate the “leaky pipeline” of STEM students. Presidential advisors reported that retaining existing STEM majors is a cost-effective means to increase the number of professionals in STEM careers (PCAST, 2012). Through interviews with 335 students at multiple institutions, Seymour and Hewitt (1997) indicated that 90% of students who left STEM majors listed poor teaching by faculty as a concern. Thus, there has been substantial effort placed on improving the experience in the classroom for students enrolled in the gateway STEM courses.

When the door opens to a typical STEM classroom in higher education, there will likely be an instructor in the front of the classroom with students seated in rows facing the instructor. A common teaching style used in STEM courses at the postsecondary level is the lecture. Mazur (2009) noted that “this approach to education has not changed since before the Renaissance and the birth of scientific inquiry” (p. 50). He later added that “the traditional approach to teaching reduces education to a transfer of information” and “the lecture method was the only way to transfer information from one generation to the next” (p. 50). Stains et al. (2018) revealed that 55% of 709 STEM university courses were classified as “didactic,” which means that at least 80% of the class time was spent lecturing. Allison and Wurdinger (2005) indicated, “traditional education systems tend to consider knowledge transmission as the primary purpose” and “the great majority of systems involve the teacher as the ‘font of knowledge’ and the students as the recipients of that knowledge” (p. 386). Most college professors teach as they were taught, which usually involves the use of the lecture in order to transmit information to a passive group
of students (National Research Council [NRC], 2012; Stieha et al., 2016; Travis, 1997). A teacher-centered pedagogy has its foundation in the transmission of content from the expert (professor) to the passive student. Physicist Susan Wyckhoff (2001) commented, “teaching by lecture rather than interactive engagement may be among the significant factors limiting the quality of science education in this nation” (p. 206). Despite this observation, most STEM faculty base their teaching method on how they were taught as students, which perpetuates the lecture as a means of transmitting information (Bedgood, 2008; Oleson & Hora, 2014; Travis, 1997). The National Research Council (2012) reported that the majority of science educators primarily or exclusively use lectures in the classroom. By contrast, a student-centered approach has been shown to hold promise for increasing the achievement, attitudes, and persistence of STEM students.

A growing body of research indicates active engagement practices that are considered to be part of a student-centered approach can lead to higher levels of learning (Blanchard et al., 2010; Cromley et al., 2016; Freeman et al., 2014; Froyd, 2007; Knight & Wood, 2005; Kogan & Laursen, 2014; Lasry et al., 2008; Wang et al., 2017). Academic achievement is frequently measured through scores on final exams. If the exams focus primarily on recall of information, then there is a reasonable expectation that a teacher-centered approach would work well. However, Freeman et al. (2014) performed an analysis of 225 studies and found an increase in both exam scores and course pass rates that were statistically significant when the students engaged in active learning strategies. Other more conceptual exams have also been used to measure achievement, including the Force Concepts Inventory (FCI) developed by Hestenes, Halloun, Wells,
and Swackhamer. Administering this exam to his first-year physics students prompted Eric Mazur of Harvard to change his teaching pedagogy. While his course evaluations were quite positive, the poor scores on the FCI prompted him to rethink how he taught his course. He now employs peer instruction and the use of concept tests interspersed with short presentations on key points. Additional evidence-based instructional strategies could involve the implementation of technology, providing undergraduates with more research experiences, connecting the classroom with real-world problem-solving applications, or anything else intended to engage students. The research demonstrates that recall of content and conceptual understanding are enhanced with these techniques.

In addition to higher scores on exams with student-centered teaching, student motivation has also risen. Students who are more motivated to learn are more likely to process the information they acquire at a deeper level (Biggs & Tang, 2011; León et al., 2015). Previous research demonstrated that problem-based learning improves the intrinsic value for a subject (LaForce et al., 2017; Masek, 2015). When students are more interested and motivated, they are more likely to continue in a STEM major. Attrition is particularly high in introductory courses in STEM, and an understanding of how to structure a course to enhance motivation may lead to better student persistence (Simon et al., 2015). This may be why Fairweather (2008) wrote, “the key to improving STEM undergraduate education lies in getting the majority of STEM faculty members to use more effective pedagogical techniques than is now the norm” (p. 13). Since student-centered instruction increases motivation, retention improves and another hole in the leaky pipeline begins to shrink (Ellis et al., 2014; Hutcheson et al., 2011).
Active learning strategies have their roots in a constructivist theory of education. According to Brooks and Brooks (1993), constructivist teaching includes posing problems of relevance, structuring concepts from whole to part, acknowledging students’ suppositions, and assessing learning in context. This is not a recent notion. Reese (2013) quoted John Dewey: “If you have doubts about how learning happens, engage in sustained inquiry: study, ponder, consider alternative possibilities and arrive at your belief grounded in evidence” (p. 320). The notion that learners who engage in real-world problems authentically and must construct their own knowledge will display higher levels of understanding has been in existence for a long time. The recent emphasis on active learning in the higher education STEM classroom demonstrates that change has not been rapid or widespread. However, the scrutiny on the issue of inadequate numbers in the STEM workforce has brought the notion of improvement and attrition front and center.

Not all research points to the atmosphere of the STEM classroom as the strongest predictor of STEM graduation rates. In a study from 2003-2009, Chen (2013) several additional factors that influence attrition rates. Chen discovered that the graduation rate of the parents, the income level of the students, the highest level of mathematics taken during high school, and whether the student was a recipient of a Pell Grant all factored heavily into whether a student was likely to graduate with a degree in a STEM field. However, these factors are not controllable by higher education institutions. Therefore, it seems prudent to pay more attention to elements that actually are able to be changed yet will still have an impact on the experience of students within the STEM community.
Curricular changes in STEM should be keenly reflective of not only improving the experience to attract and retain more STEM students, but the changes should also reflect competencies that are required for today’s STEM careers. In addition to a shortage of applicants for STEM positions, the group of candidates often “lack basic personal professional skills such as teamwork, communication, and problem-solving” (Kramer et al., 2015, p. 4). Employers seek applicants who can “continue to learn over time and solve complex problems” (Belkin, 2015, p. 25). In a survey by Hart Research Associates (2015) commissioned through the American Association of Colleges and Universities, 90% of employers considered college graduates “poorly prepared” in the areas of problem-solving, critical thinking, and communications. Not only is there a need to increase the number of STEM graduates, but colleges must also recognize that many students are considered “unemployable due to the lack of soft skills” (Jackson & Mellors-Bourne, 2018, p. 8). One potential problem is that faculty are trained experts in the content of their discipline but not in the soft skills that employers desire (Drake & Reid, 2018). A sufficient and proficient workforce should be one aim of colleges and universities. Thus, reform should address both the quantity and quality of STEM graduates.

Reform movements in STEM education are often started with grants through the National Science Foundation and other similar government agencies. This comes at no small cost. Atkinson and Mayo (2010) reported, “the annual federal investment in STEM education programs, while difficult to estimate, is typically considered to be around $3 billion” (p. 2). While this is a considerable sum of money, the fear is that the real cost to
the nation of an ill-prepared citizenry is much higher. The alarm has been raised, research on possible ways to improve STEM undergraduate education has been done repeatedly, and large amounts of money are being spent. Therefore, the results of STEM reform should be widespread. However, this is not the case: “Little seems to change, despite the continued proliferation of reports to Congress raising the same alarm, identifying the same problems, and calling out for largely the same solutions” (Atkinson & Mayo, 2010, p. 7). Unfortunately, there is a long list of obstacles that appear to hinder forward progress.

**Barriers to Change**

Active learning techniques and a more student-centered teaching style have shown some promise in both achievement and retention of STEM students. The adoption of these techniques has increased over time (Eagan et al., 2014). Yet, student-centered pedagogies are still not mainstream. Multiple STEM-focused reform movements have emerged within the last decade (AAAS, 2011; Corbo et al., 2016; National Academy of Engineering & National Research Council, 2014; Shernoff, 2017). The shift in focus recently is the sustainability of such reform movements. The current method of spreading new ideas in STEM pedagogy starts with researchers developing new strategies and then making other instructors aware of the ideas through conferences or journal articles. The expectation is that instructors who become aware of new ideas will automatically make use of these changes in the classroom (Henderson et al., 2011). A scan of the funded NSF Transforming Undergraduate Education in STEM proposals over the last few years revealed that publishing a paper, speaking at conferences, and holding workshops were
the most common plans listed in the broader impact section of the proposal. According to the seminal work of Rogers (2003) on the diffusion of innovations, “getting a new idea adopted, even when it has obvious advantages, is difficult” (p. 1). Diffusing innovations in education has not produced sustainable change. Henderson et al. (2011) concluded there are four categories of change strategies for undergraduate instruction: disseminating curriculum and pedagogy, developing reflective teachers, developing policy, and developing a shared vision. Without attention to all four categories, sustained change will be difficult. Research demonstrates that a change is vital and necessary for STEM education, yet the classroom of today shows little effect of this research. For example, Borrego et al. (2010) reported that even when 82% of department chairs were cognizant of educational innovations, only 47% actually adopted any form of these ideas at their institution. Reinholz and Apkarian (2018) stated it succinctly when they wrote “change is notoriously difficult but also urgently needed in higher education” (p. 8). The barriers to change are numerous and will be considered in two broad categories: institutional and individual.

**Institutional Barriers to Change**

**Historical traditions.** As the scientific revolution led to the industrial revolution, the creation of knowledge focused on a means of controlling the world rather than investigating it. The transmission of this knowledge occurred among fellow scientists, keeping the circle small and often out of touch for the general public. Huxley (1880) observed, “neither the discipline nor the subject-matter of classical education is of such direct value to the student of physical science as to justify the expenditure of valuable
time on either” and “for the purpose of attaining real culture, an exclusively scientific education is at least as effectual as an exclusively literary education” (p. 12). A separation developed between those who studied literature and humanities versus those who studied science. Snow (1963) acknowledged this chasm in his speech addressing what he referred to as the two cultures of the physical scientists and the literary intellectuals. He commented, “the intellectual life of the whole of Western society is increasingly being split into two polar groups” (p. 3). This historical tradition of separation remains today. Referring to faculty at a university, Blackburn and Lawrence (1995) indicated, “competition has replaced collegiality” and “their training immerses them in a language all their own, one others cannot understand” (p. 3). The culture of STEM higher education, bred by the coveted autonomy of faculty, has resulted in isolation and elitism. Many of the reform movements are aimed at removing this elitism and its oft connected sexism and racism from STEM education, yet it permeates universities. Meanwhile, the research done in STEM education is often done by social scientists and educators. There is a notion that the work coming from academic developers might be rejected as “belonging to a regime of teaching and learning that resides in the Social Sciences and therefore inappropriate to … Science disciplines” (Trowler & Cooper, 2002, p. 231). If STEM faculty do not highly regard the results of research on education, then there is little motivation to make a change. There could be years upon years of research indicating that student-centered teaching is more effective, but if those doing the teaching do not respect or believe this research, there will be no sustained impact. Thus, the historical traditions and culture of science are a barrier to change in STEM higher education.
**Institutional structure.** Higher education institutions (HEIs) enjoy a bit of isolation from the corporate world. A college or university is often regarded as a city upon a hill. However, corporations benefit from both the research innovations of faculty as well as the flow of human capital in the form of graduating students. This is not all that corporations and colleges share. Kezar and Lester (2009) explained:

Colleges and universities developed complex administrative structures during the twentieth century. They followed the example of businesses and corporations of the time, which created increasingly vertical organizations shaped by command-and-control leadership and standard policies and procedures to dictate behavior and ensure uniformity of activities (p. 29).

The result of the new structure impacts the environment for faculty, which has negative consequences when it comes to change. Studies have demonstrated that bureaucratic and hierarchical organizations tend to support adherence to the status quo, even to the extent of being hostile to innovation (Barringer & Harrison, 2000; Rosenblatt, 2012). Similarly, Sikes et al. (1974) reiterated this idea when they wrote, “educational institutions have many blocks to innovation and creativity typical of bureaucracies. A key block is that schools prize order, rationality, predictability, and impersonal modes of operating” (p. 39). If colleges are structured in such a way as to value order and predictability, then change will be resisted. In his introduction to the book *Higher Education Reconsidered*, Lane wrote, “In order to move higher education toward a collective approach to addressing problems, we need to realize that our existing structures struggle against such an approach” (Zimpher, p. 10). Even when individual faculty members choose to
transform the classroom by adopting new techniques, the administrative structure of the institution can be a barrier to sustainable and widespread change.

The role of administrators in reform at an institution cannot be minimized. Smith (2012) highlighted that management is a key component of change when she indicated, “senior staff need to support an innovation for it to spread effectively” (p. 174). Similarly, Lašáková et al. (2017) mentioned, “in order to reach a real cultural shift at HEIs, consistent support from people in power structures is immensely important” (p. 70). Thus, establishing a supportive administrative structure that implements institutional policies favorably disposed to change and progress is an essential component in enabling the flow of innovation. Within the hierarchy of more and more administrative levels, new improvements can get lost and mired in an intricate structure that demands time at every level. Faculty would be more motivated to invest additional time and effort when these efforts are respected and positively received by administrators. Wergin (2003) explained, “people everywhere want to feel valued, to know that others see their work as worthwhile. Faculty are no different” (p. 17). The initial motivation may stem from a personal commitment to teaching, but long-term stability is aided by social support and encouragement, which should be part of the culture of the institution at all levels.

Higher education institutions will have to address the challenges of working with accreditation boards in order to make internal adjustments. If an adjustment in pedagogy causes temporary increases in student dissatisfaction, for example, then the reported results will be perceived negatively by accreditors. Even the possibility of adverse comments by an accreditation agency affects higher education institutions.
“Governmental decisions over accreditation criteria are, according to our study, viewed as strict and time-consuming, and as such, they protect the status quo in respect to innovation in education” (Lašáková et al., 2017, p. 76). In the U.S., public HEIs must lobby their state legislature for financial funding, including funding to support groundbreaking projects. Inflexible regulations along with time-consuming tiered management make the funding process restrictive to implementing new ideas.

The administrative organization of HEIs should acknowledge the autonomy of the faculty. When innovations are perceived as mandates rather than opportunities, then faculty may not be as receptive to spending additional time that is necessary for adoption. Gappa et al. (2007) noted, “faculty members choose an academic career because it offers autonomy, intellectual challenges, and freedom to pursue personal interests” (p. 105). Similarly, Wergin (2003) reported, “research on faculty motivation has found that those of us who enjoy vital faculty life are driven by a relatively small number of motives: autonomy, community, recognition, efficacy” (pp. 14-15). When a group tends to have these characteristics, then widespread change is not likely to occur through directed commands from administrators. In a study of 191 STEM change efforts from 1995-2008, Beach et al. (2012) concluded, “power alone, in the form of ‘top-down’ policy implementation, is insufficient to leverage change” (p. 56). Instead, they suggested, “a successful change strategy should allow for a mixture of emergent and prescribed outcomes and pay attention to multiple levels of context, from the individual faculty to the environments and structures within which faculty work” (p. 58).
**Student Resistance.** Multiple research studies reported students responded positively to active learning strategies (Armbruster et al., 2009; Borda et al., 2020; Carlson & Winquist, 2011; Corkin et al., 2017; Freeman et al., 2014; Graham et al. 2013; Nguyen et al., 2016; O’Brocta & Swigart, 2013). Other studies, however, demonstrated that students have a negative response (Lake, 2001; Seidel & Tanner, 2013; Shekhar et al., 2015; Yadav et al., 2011). In the two aforementioned studies, students perceived that they did not cover as much content and learn as much material as they would have in a more traditional classroom, even though the assessment of achievement did not support this. Fears of negative student reaction to active learning strategies inhibit faculty from making a change in instructional strategy (Finelli et al., 2013; Froyd et al., 2013; Henderson & Dancy, 2007). Weimer (2002) attributed negative attitudes toward active learning to the extra effort that is required on the part of students as well as anxiety that stemmed from being in a new, nontraditional environment. With the plethora of studies suggesting an increase in both student achievement and motivation when active learning strategies are used, the fear of negative student evaluations of teaching may be greater than the reality. Owens et al. (2017) reported, “faculty indicate that students censure them on evaluations after incorporating active learning in their classrooms, leading many to discontinue the pedagogical practice” (p. 1). Rather than eliminating all forms of progress, however, Tharayil et al. (2018) recommended the use of numerous strategies to mitigate student resistance, including clear and explanatory directions and scaffolding.

Student evaluations of teaching (SETs) have long been questioned as accurate reflections of truly effective education (Centra, 1977; Marsh & Roche, 1997; Pounder,
2007; Shevlin et al., 2000). In an article for the *Chronicle of Higher Education*, Wilson (1998) commented on the dramatic increase in usage of SETs:

Only about 30 percent of colleges and universities asked students to evaluate professors in 1973, but it is hard to find an institution that doesn’t today. Such evaluations are now the most important, and sometimes the sole, measure of a teacher’s teaching ability (p. A12).

Since these evaluations are used frequently in hiring and promotion criteria, faculty justifiably have concerns about engaging in any reform efforts that may lower their scores. Students should clearly have a voice and faculty should be evaluated on their teaching. However, the convenience and relative simplicity of relying solely on student evaluations of teaching are problematic. When the institutional policy of judging a professor’s teaching ability involves more than SETs, then another barrier to change is diminished.

**Lack of Incentives.** Academicians, especially those in 4-year institutions, are very familiar with the aphorism publish or perish. Especially in the current era of financial challenges, tenure decisions are primarily determined by research publications and the funding that follows. Typically, the three categories of tenure include research, teaching, and service to the institution and community. Stated more casually, Wasburn-Moses (2018) claimed tenure is actually based upon the following: “(1) the amount of research we produce that nobody will ever read, (2) the extent to which our students like us, and (3) the number of committees we chair that will never do anything” (para. 1). If a faculty member is denied tenure, there is a one-year grace period, during which time the
faculty member seeks out a new position. There is an expectation that denial of tenure means that the individual is not a good fit for the HEI and should seek employment elsewhere. In one sense, it is akin to an extended firing. Thus, there is a great deal of pressure to be granted tenure. This system, with such a substantial weight associated with it, acts as a major incentive for faculty. Tenure-track faculty work tirelessly to make certain the work that is done contributes positively toward the outcome of tenure. STEM faculty devote more time to research and less time to developing their teaching practices (Austin, 2003; Fairweather, 2008; Suchman, 2014; Walczyk et al., 2007). Published research and funding advance, in a very public way, the HEI and its reputation. If there is a risk associated with implementing new strategies that could jeopardize tenure, then faculty are not likely to take that risk. The competition between highly-rewarded research and teaching serves as another barrier to change (Chasteen et al., 2015; Parker et al., 2015; Porter et al., 2006). The existing reward structure emphasizes individual achievements, which is contrary to developing a collaborative atmosphere that focuses on student learning.

Professors are expected to bring in funding through research grants, but the institution should be dedicated to internally funding teaching reform. Change is time-consuming (Darling-Hammond et al., 2009; Elrod & Kezar, 2016; Wilson & Berne, 1999), and sustained change should not be expected when it is not supported. In 2005, the Science Education Initiative was launched in an effort to improve science education at two institutions: University of Colorado at Boulder (CU) and University of British Columbia (UBC) (Chasteen et al., 2015). The ten-year project involved $5 million
(US) at CU and $12 million (CAD) at UBC. The money was primarily used to hire postdoctoral fellows to support course transformation. Chasteen et al. reported that the initiative was “generally effective in impacting courses and faculty across the institution” (p. 1). However, Reinholz and Apkarian (2018) provided updated information that “despite this success, when resources were removed, sustainability became an issue, and course transformations did not necessarily persist” (p. 2). If colleges and universities want to refocus on one of their main missions of helping students to learn, then the old adage of “put your money where your mouth is” states the obvious.

**Lack of Training.** STEM faculty are lacking the support, incentive, and training necessary to learn and implement instructional improvement (Fairweather, 2008; Seymour, 2002; Suchman, 2014; Walczyk et al., 2007). In response, HEIs often have campus teaching centers or professional development programs, although these tend to provide more generic and less discipline-specific training (Henderson et al., 2011). For these centers to have sustained impact, however, there needs to be more than brief exposure through outside speakers. Faculty may leave short workshops energized, with the best intentions of implementing what they heard. Then, as time moves on and the professor works in isolation, good intentions fade away in the fog of everyday tasks (Dancy & Henderson, 2010). Training that focuses solely on disseminating a list of best practices is not likely to have sustained impact, as the mindsets and underlying beliefs of faculty need to be addressed prior to substantive change (Hashweh, 1996; Luft & Roehrig, 2007; Tsai, 2002). According to Herman et al. (2018), “even if such a lone-ranger approach succeeds, the reform is owned by the individual who designed it and is
unlikely to be adopted by those who follow” (p. 36). Changing instructional approaches is difficult, especially when a professor has not experienced a new approach (Anderson, 2002; Bain, 2004; Brown, 2014; Ramsden et al., 2007). The low self-efficacy due to a lack of experience inhibits change. Increasing self-efficacy will open the door to learning and implementing new instructional strategies (Rowbotham, 2015). As a group of individuals who value autonomy, faculty do not care to be told what to do. Thus, any professional development programs should address teaching more holistically to first shift attitudes so that there is a recognized need to change, rather than mandating a list of best practices. Simultaneously, professional development must recognize the discipline-specific challenges that emanate from teaching STEM. Winberg et al. (2019) highlighted, “the professional development of STEM university teachers has over-emphasised generic forms of teaching practice and neglected discipline-specific teaching practice” (p. 940). The result of ignoring STEM disciplinary logic in pedagogical training is “to deny the importance of ‘epistemological access’ to disciplinary knowledge” (Muller, 2014, p. 260).

According to the NRC (2012), the majority of STEM faculty do not have any organized training on effective pedagogical methods prior to becoming professors. A report from the Association of American Colleges (1985) stated, “if the professional preparation of doctors was as minimal as that of college teachers, the United States would have more funeral directors than lawyers.” STEM graduate students are trained to be research scientists and not teaching faculty. Many STEM GTAs enter graduate school with the goal of employment in higher education, but the graduate programs in STEM are
focused more on developing scientists than educators (Braxton & Del Favero, 2000). New faculty frequently report being underprepared for the teaching responsibilities in tenure-track positions, in part due to lack of any training or support in graduate school (Feldon et al., 2011; Golde & Dore, 2001). Due to the focus on discipline-specific research, GTAs in STEM are more likely to move out of the classroom as they progress in their programs (Nyquist et al., 1999). As with faculty, any offered training is typically in the form of brief workshops (Luft et al., 2004). Love-Stowell et al. (2015) indicated, “empowering TAs through the development of their teaching skills transforms the TA experience from an obligation to an intellectually engaging activity that will benefit not only graduate students but also their undergraduate students” (p. 318). Graduate programs should be revamped to acknowledge the potential instructional role in the future of many GTAs. “A balanced research and teaching apprenticeship as a regular part of departmental practice could generate a new generation of faculty with professional identities as teachers and scholars” (Kendall et al., 2013, p. 316). One concern is that this balance could involve more time and distract GTAs away from their research. Recent studies indicated GTAs with teaching responsibilities reported higher satisfaction and motivation to complete their programs and also improved research skills such as the ability to hypothesize and create valid experiments (Feldon et al., 2011; Trautmann & Krasny, 2006). If GTAs are exposed to student-centered learning strategies, then self-efficacy will improve and another barrier to change is diminished.

At an institutional level, there are multiple barriers to change. The historical traditions of science higher education create an atmosphere where change is slow at best.
The administrative structure of HEIs adds to the difficulties, especially when key positions do not set a tone that supports the importance of undergraduate teaching. The students in the classroom may resist a change in instructional practices if they perceive it adds more time or work, and shifting the status quo makes some students uncomfortable. HEIs can do more to incentivize student-centered teaching by allowing faculty more time and by emphasizing the teaching component of tenure. Through centers for teaching or professional development programs, colleges and universities have an opportunity to train and continuously support faculty in their efforts. These are all challenges that can be addressed by institutions. In addition to these global barriers, there are also individual barriers to consider.

**Individual Barriers to Change**

The decision to make a change in a classroom occurs at an individual level (Andrews & Lemons, 2015; Bouwma-Gearhart, 2012; Dormant, 2011). A top-down approach is unlikely to succeed over a long period of time. Therefore, any sustained change must have faculty support and buy-in. Multiple barriers affect individual change.

**Time.** Several studies have indicated that faculty consider a lack of time to be a significant barrier to change (Andrews & Lemons, 2015; Brownell & Tanner, 2012; Elrod & Kezar, 2016; Foote et al., 2016; Parker et al., 2015; Shadle et al., 2017; Turpen et al., 2016). Walder (2015) asserted faculty must be provided sufficient time just to think about their current beliefs and experiences and then compare these to the research on evidence-based instructional strategies. The time to actually implement any significant change must be diverted from the time that could be spent on research activities that will
improve the chances of promotion. To assume that faculty must increase time on the job to be involved in efforts to reform pedagogy will decrease the likelihood of participation. Gandhi-Lee et al. (2017) reported, “even faculty who were motivated to improve their classroom practice often lacked the time and resources to do so” (p. 8). Focusing strictly on awareness of innovative strategies greatly limits the potential sustained use. Sending a professor to a conference or offering a workshop checks a box that STEM educators have been informed, but this does not imply long-term changes in the classroom will occur. In a survey of engineering departments, Borrego et al. (2010) discovered that 82% of those surveyed were aware of student-centered teaching strategies, but only 47% indicated that these strategies had been implemented. Raising awareness is only one part of the picture. Sustained use is an even larger issue. Henderson et al. (2011) pointed to “coordinated and focused efforts lasting over a period of time” (p. 972) as an essential element required for adoption of evidence-based instructional practices. Without the time necessary for faculty to reflect upon beliefs and implement change, widespread and sustained change cannot be expected. Prior to exposure to new ideas, literature demonstrates that change agents should first establish a sense of dissatisfaction with current practices (Gess-Newsome et al., 2003; Thompson & Zeuli, 1999). Dealing with this sense of dissonance takes time. When educators are expected to add an additional component to the already busy curriculum, this will hinder educational innovations (Kunnari & Ilomäki, 2016). Not only are faculty expected to increase the amount of time spent to question beliefs, learn new techniques, and adjust pedagogy, but the amount of time that it takes to actually use some student-centered teaching methods in the classroom is a challenge.
The acquisition of scientific knowledge is a lengthy and intensive process that requires time and effort. In STEM disciplines, most courses are expected to include a prescribed subject matter with a well-defined syllabus that is packed with content. Since much of the advanced coursework builds on previous information, instructors feel a strong sense of obligation to cover the content that is expected. Otherwise, the student will have major holes and gaps in their discipline-specific knowledge that will prove to be a stumbling block. Coil et al. (2010) noted, “the expectation that faculty will cover a certain amount of content…is systemic and communal,” and there is “a collegial obligation to provide students with a certain amount of content knowledge before they enter more advanced courses” (p. 533). With the pressure to use every ounce of class time to teach content, a teacher-centered and lecture-based approach is not surprising. There does not appear to be a spare moment to engage in more time-consuming strategies. However, the irony is that while STEM faculty feel the need to teach content, the students are not necessarily learning and understanding the material. Exley and Dennick (2004) quoted an unknown source as stating, “lecturing is the transference of the notes of the lecturer to the notes of the student without passing through the brains of either” (p. 3). Faculty may be overestimating the level of understanding that students achieve from lectures. Professor of Physics Eric Mazur at Harvard University tested student understanding of Newtonian mechanics using the Force Concepts Inventory. Expecting that his students would easily pass, Mazur (2009) commented, “to my dismay, students had great difficulty with the conceptual questions. That was when it began to dawn on me that something was amiss” (p. 50). Ironically, there is a fear that the time
spent engaged in student-centered teaching will encroach on time needed to learn content. The literature in STEM education, however, indicates that time spent using active learning strategies is time well-spent since conceptual understanding increases when these strategies are used (Carmel, Jessa, & Yezierski, 2015; Freeman et al., 2011; Kogan & Laursen, 2014; Pakala & Bose, 2015; Ruiz-Primo et al., 2011; Watkins & Mazur, 2013). Lack of time to explore and adjust beliefs, lack of time to fully explore and learn new evidence-based practices, and lack of time (or perceived lack of time) to fully implement innovations in the classroom are all barriers to pedagogical change. What if faculty were given more time to engage in scholarly teaching? What if more time could be incorporated into the class schedule? Would this be enough?

**Professional Identity.** For STEM faculty, professional identity tension can be another obstacle. Ewan (1988) defined professional identity as a “self-image which permits feelings of personal adequacy and satisfaction in the performance of the expected role” (p. 85). Identity in academia constantly develops over time and is affected by the social norms of the department as well as the institution. Thus, the professional identity of STEM faculty will be different from those in other disciplines. Faculty must be able to associate with both the educator profession and the research profession. These two identities can be in tension due to the different values that individuals, departments, and institutions place on each (e.g., Brownell & Tanner, 2012; Fairweather, 2008; Robert & Carlsen, 2017). For example, Walczyk et al. (2007) determined that when an institution places value on teaching as part of the process for tenure, then faculty are more apt to include teaching in their professional identity. Also, a study by Fairweather (2002) found
that faculty who have not yet achieved tenure were the least likely to be considered productive in both teaching and research. If the culture of a department is such that research is highly valued and teacher-centered instruction is the norm, this will influence the professional identity of a faculty member, especially newer faculty. While professional identity is individualized, it is developed within a social context and guides external actions. Brownell and Tanner (2012) described that the “professional culture of science considers teaching to be lower status than research and positions scientists to have to choose between research and teaching” (p. 341). If a STEM faculty chooses to spend time on scholarly teaching, this choice may be misconstrued as an inability to be successful in scientific research. Thus, there can be a sense of embarrassment or shame for a faculty member in the sciences to pay attention to any innovations in pedagogy.

The lack of time available to think about educational practices and beliefs, the lack of time available to learn and understand new evidence-based teaching strategies, the lack of preparation time available needed to implement active learning techniques, and the lack of classroom time available to spend using alternative techniques all combine to make it a serious challenge to move away from the more traditional teacher-centered teaching. Even with more time, widespread change is still inhibited by the culture and professional identities of STEM faculty. Until excellence in teaching is highly valued, faculty will be more apt to spend their limited time behaving in a way that is standard in their discipline.

With all the institutional and individual barriers to change, it is expected that the reform movements that call for a change in STEM higher education have not become
systemic. Research has provided insight into methods that can improve student achievement and motivation in STEM. But techniques alone are not sufficient. A shift in attitude and values are also necessary. Kezar et al. (2015) highlighted:

If you want to help change a faculty member’s view of teaching, then you need to help them make new sense, moving from considering an organized lecture as good teaching to instead viewing the integration of the scholarship of teaching and learning, assessment, and technology as component parts of good teaching (p. 481).

Breaking down all of these substantial barriers may appear to be an insurmountable task, as evidence by the fact that sustained and widespread change has not occurred. Yet, there are individual STEM faculty members who are inspiring students and providing a bright ray of hope that change is possible. Why haven’t these professors abandoned their nontraditional ways? How is it possible to continue in a culture that does not value or reward a focus on teaching? If research can provide insight into how certain STEM professors can balance their professional identities as educators and researchers in disciplines and institutions that are not supportive of such behavior, then perhaps more professors can join the isolated few until eventually the entire culture shifts.

**Transformational Teaching**

In the introduction to his book *The Skillful Teacher*, author Stephen Brookfield (1990) wrote, “on the inspirational plane, I wanted to rekindle the sense of the importance and purpose of college teaching—the belief that college teachers can and do make a difference to their students and to society outside the classroom” (p. xiii). The prevalent
approach in the STEM classroom has been to view students as passive recipients of content knowledge transmitted through lectures (Boaler, 2000; Bedgood, 2008; Herman et al., 2018). In the last 30 years, research has focused on the effectiveness of several philosophies of learning as well as new methods of teaching. The foundation for these learning strategies is not new. Active learning, student-centered learning, collaborative learning, experiential learning, and problem-based learning have all been shown to increase conceptual understanding, persistence, and motivation (Deslauriers et al., 2011; Freeman et al., 2011; Haak et al., 2011; Preszler, 2009; Prince, 2004; Ueckert et al., 2011). While slightly different, all five of these methods share a common thread stemming from a constructivist theory of learning. Teaching styles based on constructivist theory move away from transmitting information, as the belief is students must construct their own knowledge from experiences to truly learn. As such, constructivist theory is necessarily centered on the learner and not the teacher. Students must engage in activities that create dissonance, examine previous knowledge, and construct new knowledge to be able to solve problems. Due to their common theoretical foundation, Slavich and Zimbardo (2012) considered active learning, student-centered learning, collaborative learning, experiential learning, and problem-based learning to be “synergistically related and, when used together, maximize students’ potential for intellectual and personal growth” (p. 569). They wrote, “these theoretical perspectives and methods share several fundamental characteristics and that they can thus be viewed as part of a broader approach to classroom instruction called transformational teaching” (p. 570). Similarly, Roberts et al. (2018) indicated, “transformational teaching approaches
include a variety of active learning strategies that are interactive and participatory, as opposed to more passive learning strategies such as a traditional classroom lecture” (p. 561). Thus, transformational teaching is not a specific teaching method in and of itself but can be considered an overarching framework. Slavich and Zimbardo defined transformational teaching as “the expressed or unexpressed goal to increase students’ mastery of key course concepts while transforming their learning-related attitudes, values, beliefs, and skills” (p. 576). With this goal in mind, professors employing transformational teaching frequently design activities that not only guide students in self-discovery of concepts but also have the potential to transform habits of mind.

Transformational teaching is connected to the concept of transformational leadership. According to Bass and Riggio (2006), transformational leadership involves “inspiring followers to commit to a shared vision and goals for an organization or unit, challenging them to be innovative problem solvers, and developing followers’ leadership capacity via coaching, mentoring, and provision of both challenge and support” (p. 4). The four dimensions of transformational leadership identified by Bass and Avolio (1994) are idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. While these were developed for organizations, they have direct correlations in an educational context. Idealized influence stems from a leader acting as a role model who looks out for the interests of others first. Transformational leaders with idealized influence behave ethically and with integrity such that the followers desire to emulate such behavior. A leader with this type of influence is often considered charismatic and inspiring. In the classroom, a transformational teacher would
place the needs of the students first and create learning experiences in the best interest of the students. Passion for the discipline combined with care for the student can be infectious. A leader with inspirational motivation will be able to inspire confidence and a sense of purpose for the followers. In order for this to be accomplished, strong communication skills to assist followers in understanding the big picture are necessary. Transformational teachers communicate how the course content fits into the big picture of the student’s educational journey. They offer up a compelling vision of the future. The optimism and enthusiasm of the educator motivate students to excel. When leaders support the efforts of followers to independently and creatively solve problems, then there is intellectual stimulation. The leader will guide without unnecessary criticism and encourage followers to question assumptions, think critically, and overcome obstacles. Transformational teaching aims to increase students’ mastery of concepts and transform students’ attitudes and skills. Thus, applying the component of intellectual stimulation is absolutely vital. Finally, transformational leaders act as coaches and mentors who recognize the needs of the individual. A leader who engages in individual consideration taps into the potential of each follower and directs them on a path to maximize their output. In order to satisfy the goal of transformational teaching, individual consideration must be used to ensure that each student is mastering concepts and adjusting internal attitudes. The four components of transformational leadership, when applied to the classroom, will assist educators in fulfilling the goals of transformational teaching.

While transformational teaching is not a specific technique, Slavich and Zimbardo (2012) argued that there are six core methods used in transformational teaching:
(1) establishing a shared vision for a course; (2) providing modeling and mastery experiences; (3) intellectually challenging and encouraging students; (4) personalizing attention and feedback; (5) creating experiential lessons that transcend the boundaries of the classroom; and (6) promoting ample opportunities for reflection and reflection. (p. 585)

The four components of transformational leadership are used in the six methods of transformational teaching. Idealized influence is the element that establishes a rapport by inspiring through mutual respect. An educator with idealized influence will honor students by including them in determining the goals and outcomes of the course. The behavior of a transformational professor will encourage students to model the expert problem-solving skills, which brings the student from a novice approach to a more sophisticated line of thinking within the discipline. A passion for the subject and an enthusiasm for the course are part of the inspirational and charismatic behaviors of a transformational leader with idealized influence. The classroom becomes a positive working environment where the students are more apt to respond well to intellectual challenges. A leader with inspirational motivation communicates high expectations within the shared vision and inspires the followers to extend and reach those high standards. A motivator such as this would create experiences for the students to be challenging yet within reach. An educator who operates with inspirational motivation will want to see students succeed at more than memorized and formulaic facts. Hence, experiential learning would be a natural outgrowth in an effort to motivate students to engage in deep learning that applies to real-work situations beyond the academic
classroom. Inspirational motivation, intellectual stimulation, and individualized consideration are all components of transformational leadership that are utilized in experiential learning. By active involvement with the content of the course through a meaningful experience, the student becomes more engaged and inspired to think critically about the issues and internalizes the learning at a deeper level. Wurdinger (2005) argued, “educators should remember that students do not need to leave the classroom to test out their ideas; they can be engaged in the pattern of inquiry in the classroom” (p. 55). Every educator should be adept at intellectual stimulation, as that is a necessary component of higher education. Intellectual stimulation can be used to encourage students to analyze problems and think independently (Bass & Riggio, 2006). Finally, when a professor applies individualized consideration, this will involve personal feedback and assessment. An educator with individualized consideration becomes a personal mentor to students. Zacharatos et al. (2000) noted, “with their use of individualized consideration, transformational leaders play an especially important role in followers’ growth and development” (p. 212). Transformational leadership aims to inspire and challenge individuals to reach their full potential (Beauchamp and Morton, 2011). The components of transformational leadership are all used in the methods of transformational teaching. Since transformational leadership is foundational for transformational teaching, professors who exhibit components of transformational leadership in the classroom as they pertain to the six core methods of transformational teaching will be classified as transformational educators for the purpose of this study.
The effects of transformational leadership have primarily been studied in occupational settings. These studies indicate improved outcomes in elevated self-efficacy beliefs (Kark et al., 2003), motivation (Piccolo & Colquitt, 2006), well-being (Arnold et al., 2007), and performance (Barling et al., 2000). Since teachers can be viewed as leaders within a classroom, it is reasonable that the positive outcomes from transformational leadership could extend to students. Chory and McCroskey (1999) stated, “applying organizational concepts to the classroom setting seems plausible” (p. 2).

Beauchamp and Morton (2011) conducted a five-month randomized intervention that trained teachers in transformational leadership. The results demonstrated an improvement in students’ motivation and self-efficacy. Another study by Pounder (2008) reported additional effort by students and a higher level of satisfaction when teachers used transformational teaching. Two components of transformational leadership, individualized consideration and intellectual stimulation, were the largest predictors of student engagement in a university setting (Harvey et al., 2003). Bolkan and Goodboy (2009) found that transformational leadership has a positive association with motivation, participation, satisfaction, and promotes both cognitive and affective learning. They hypothesized, “transformational leadership, then, may foster learning outcomes, participation, and teacher credibility because students perceive these educational practices as ‘personalized’ through the individual consideration of each student” (p. 303).

In their meta-analysis of 79 studies, Leithwood and Sun (2012) found that transformational leadership practices, especially building collaborative structures and providing individualized support, have positive effects on student achievement. Harrison
(2011) studied the effects of transformational leadership behaviors in a university classroom using the Multifactor Leadership questionnaire, developed by Bass and Avolio. Multiple regression analyses showed that 37% of the variance in cognitive learning and 65% of the variance in instructor credibility were associated with transformational leadership behaviors. Transformational teaching using transformational leadership components has positive benefits, both in achievement and attitudes, for students. Fortunately, Pounder et al. (2018) reported, “there is substantial evidence that transformational leadership can be effectively taught, and this suggests that there is also tremendous scope for establishing a professional development framework for teaching academics that is grounded on the notion of transformational classroom leadership” (p. 340). This offers hope for improvement in STEM education.

Conclusion

The pipeline that guides students into STEM areas has major leaks. One of the areas of leakage garnering considerable attention recently is STEM higher education. As Knight and Novoselich (2017) wrote, “With increasingly more complex problems embedded within an expanding technology-driven environment, there is a greater need for individuals who have technical expertise and who are capable of developing sustainable, workable solutions to serve in leadership positions” (p. 44). Due to the critical impact on our nation’s workforce, research has focused on attrition of STEM students and possible options to increase retention.

Student-centered approaches, including active learning, collaborative learning, project-based learning, experiential learning, and other high-impact practices have all
shown promise in enhancing both cognitive achievement and attitude of STEM students. Despite the research advocating for a renewed focus on the student rather than the instructor, most higher education STEM courses are still teacher-centric and employ a lecture style. The existing culture in STEM higher education embodies the acquisition of knowledge as a transmission from the professor to the passive student. Institutional and individual barriers hinder the widespread adoption of methods that improve students’ conceptual understanding and satisfaction level in STEM. These barriers are substantial and ingrained into the system of higher education, making change difficult.

Within this culture resides a number of transformational professors inspiring their students. These professors have discovered ways to overcome the barriers and survive in an environment that is in opposition to their teaching style. The STEM professors in this study exhibit transformational leadership qualities in the classroom. These qualities are evident in the transformational teaching methods used. According to Bolkan and Goodboy (2011), “students reported that they believed their instructors were behaving in a transformational fashion when they personalized the content of their courses and made their lessons relevant to students’ realms of experience” (p. 15). This study analyzes the work of transformational STEM educators. As reform movements have been slow to assimilate into the current STEM culture, it may be necessary to change the culture from within, one faculty member at a time.
CHAPTER 3

Methodology

A phenomenological approach is appropriate for this study since the goal is to describe a lived experience that is shared by transformational STEM professors in similar environments. A qualitative method offers an emphasis on discovery and description, centering on interpreting meanings of an experience (Bloomberg & Volpe, 2008). The purpose of a phenomenological study is to “understand an experience from the participants’ point of view” (Leedy & Ormrod, 2001, p. 157). The focus is not on the participants or the higher educational institutions but rather the essence of the interaction of the participants with their educational culture. Gabriel (2004) indicated, “stories could reveal how people make sense of organizational events or fail to do so; they can give us useful insights into organizational politics and culture” (p. 23). By telling the stories of inspirational STEM professors, it may be possible to gain insight into how the passive culture of STEM higher education courses can be challenged by transformational leadership in the classroom.

A phenomenological qualitative research study was performed to explore the lived experiences of higher education professors who are teaching STEM courses at the postsecondary level. This research method was selected because examining the lived experiences of these professors can aid in understanding the factors that influence how these professors can sustain a transformational leadership style within an environment that historically supports a teacher-centered transmissive educational model. Since qualitative research is open-ended, data collection contains themes and interpretations of
the experiences of individuals who have been affected by a common phenomenon (Creswell, 2014). Phenomenological research analyzes noteworthy statements made by participants and develops shared common themes to tease out the essence of the shared experiences (Moustakas, 1994). Logue et al. (2005) mentioned that a phenomenological approach intends to “freely present information regarding personal perspectives of the experiences, and potentially, to reveal percepts that have not emerged in traditional theory and hypothesis testing methodology” (p. 395). The detailed descriptions of transformative STEM professors living in a passive culture would not be possible using a quantitative method.

Due to the quantitative nature of the researcher’s mathematical background, the expectation was that the study would be quantitative rather than qualitative. However, the type of study should be not dictated by the desire or familiarity of the researcher. Rather, the intention of the research and the questions raised should point to a method that will best answer the question. In this case, the researcher investigated a particular phenomenon of a focused subset of the STEM educator population. Getting at the essence of the nature of these lived experiences required a qualitative rather than quantitative study.

Theoretical Framework

According to Greenbank (2003), “When researchers are deciding what research methods to adopt, they will inevitably be influenced by their underlying ontological and epistemological position. This in turn will be influenced by their values” (p. 792). Constructivism lies at the heart of this study, both construction of knowledge as well as
the construction of a person’s identity. Colleges are more than places to transmit or exchange information. As places of social interaction, they help form attitudes and character along with the mind. This view opens up the possibility for a classroom to become a place of transformation. Advancing ideas by philosopher John Locke, John Dewey (1910) wrote:

> While it is not the business of education to prove every statement made, any more than to teach every possible item of information, it is its business to cultivate deep-seated and effective habits of discriminating tested beliefs from mere assertions, guesses, and opinions; to develop a lively, sincere, and open-minded preference for conclusions that are properly grounded, and to ingrain into the individual’s working habits methods of inquiry and reasoning appropriate to the various problems that present themselves (pp. 27-28)

Within this framework, higher education institutions need to move away from limitations of transmission of information and engage more fully in the responsibility to equip students with “intellectual tools, efficacy beliefs, and intrinsic interests needed to educate themselves in a variety of pursuits throughout their lifetime” (Bandura, 1997, p. 214). With this responsibility comes the possibility of deeply impacting students in meaningful ways.

Since knowledge is constructed, an effective learning environment can be created by the instructor who designs and structures the classroom for both cognitive and social outcomes. The social interactions within the class affect the rates of learning within the students (Kalina & Powell, 2009). Thus, focusing on more than the content of the course
impacts the development of the student. A constructive environment includes opportunities for meaningful practice and application. According to Hussain (2012), “a university teacher should involve students in a learning process through activities aiming to inculcate academic and social skills among them” (p. 179). Students at this level already have life experience and enter the classroom with diverse backgrounds. A constructivist classroom includes activities that enable the student to build upon these previous experiences in order to enhance critical thinking, problem-solving and analytical skills. A constructivist approach involves students as participants rather than recipients, which leads to more active learning strategies in the classroom. The researcher’s lens of constructivism shaped the study by viewing the classroom as potentially transformative. Constructivist research assumes that "through intense interaction and dialogue, both the participant and researcher will reach deeper insights" (Ponterotto, 2005, p. 131). In this study, those insights were gained through the lived experiences of the participants into the phenomenon under investigation.

**Participants**

This study used purposive sampling to produce a sample that is representative of inspirational professors. Hermeneutical phenomenological researchers recommend purposive sampling due to the subjective nature of participants’ perspectives that stem from individualized and unique experiences that are difficult to duplicate (Bloomberg & Volpe, 2008). Creswell (2014) suggested the importance of acquiring participants who will be willing to openly and honestly share information. Since phenomenological qualitative research seeks to provide a detailed analysis of a particular phenomenon,
purposive sampling is important to ensure that the participants can offer knowledge about the phenomenon they experienced.

The professors involved in this study represent chemistry, mathematics, computer science, engineering, and biology at large, medium, and small colleges across the country. All of the STEM professors involved were selected based on the demonstration of characteristics of transformational leaders. The first set of participants identified as recipients of teaching awards. The awards were narrowed to those that included student input. If the student comments involved components of transformational leadership, then the professor was contacted and asked to participate in the study. Awareness of additional potential participants was created using the snowball method. Each time a potential participant was contacted, the researcher asked for recommendations of colleagues who are also transformational educators within STEM to participate in the research. Snowball sampling works well in phenomenological studies since the educators uncovered in this process may not have been considered prior to the research (Goel & Salganik, 2010). A total of eight professors were interviewed, seven through videoconferencing and one through the phone.

Each participant was provided with an overview of the study and the expectations involved in participation. They were then provided with the option of proceeding with an interview or declining participation. The informed consent form highlighted that the recorded interviews would be stored securely without names and the researcher had no intent to deceive in any way when conducting the proposed research (Bryman & Bell, 2011). Participants were free to withdraw at any time in the process.
Data Collection

Phenomenological research focuses on information gained through rich descriptions that allow for understanding of the essence of experience (Moustakas, 1994). The primary means of gathering information to create rich descriptions involved semi-structured in-person interviews at the location of the participant or via videoconferencing. For a phenomenological study, Moustakas suggested researchers conduct face-to-face interviews that include open-ended questions to essentialize a detailed and descriptive representation of lived experiences. The researcher intended to travel to the home institution of each participant for the interview. Participants could then also be observed in the classroom. These classroom observations could add to the description of how the professors applied transformational leadership. However, a pandemic that resulted from the coronavirus prohibited such travel. Therefore, the participants were interviewed using videoconferences, which were recorded with permission. During the interview, the questions were open-ended to enable the participant to provide more in-depth information, which provided tentative explanations for the prevalence of phenomena (Miller & Travers, 2005). The interviews were recorded for later transcription, with notes written by the researcher at the time. Any follow-up questions were asked either through written communication, such as email, or a brief videoconference. All participants signed an informed consent. This ensured that the researcher explained all the aspects of the study, including any potential risks. All participants acknowledged that they participated voluntarily and permitted recording of the interview. Materials, including notes and
interview transcriptions, are kept confidential on a password-protected computer, free of all identifiable data.

**Interviews**

Literature recommends the use of an open or semi-structured interview in phenomenological research (Marshall & Rossman, 2016; Smith et al., 2009). According to Kvale and Brinkman (2009), “A semi-structured life world interview attempts to understand themes of the lived everyday world from the subjects’ own perspectives” (p. 27). The semi-structured interview provides focus on the phenomenon while leaving space open to explore emerging threads. This format “ensures that the questions elicit open responses by the participants that enable lines of conversation to be developed in situ in ways that could not have been anticipated when the interview schedule was being planned” (Brown & Danaher, 2019, p. 77). While there are multiple advantages to using interviews for qualitative research, there are also challenges that should be acknowledged by the researcher to help mitigate any negative effect.

In any interview, there is a power differential between the interviewer and the interviewee. Seidman (2013) stated, “an interviewing relationship is fraught with issues of power — who controls the direction of the interview, who controls the results, and who benefits” (p. 99). A researcher takes the initiative for the interview, sets the parameters for the interview, and takes responsibility for analyzing the results. The participant, however, is the source of the information and controls how much of the experience is shared with the researcher. To help develop rapport, the background of the researcher was used to connect with the participants, although little personal information
was shared in order to not influence the responses. The researcher explained the purpose of the study both in the informed consent as well as during introductory remarks so that the interviewee was fully aware of how the stories would be used. The researcher also engaged in active listening by reflecting back to the interviewee and asking probing questions for clarification. “The researcher has total responsibility toward the participants, the research project, and the institution” (Karnieli-Miller et al., 2009, p. 283). This responsibility cannot be taken lightly. When an interview is done well, the results reveal how participants “construct reality and think about situations, not just to provide the answers to a researcher’s specific questions and own implicit construction of reality” (Yell, 2012, p. 12). The professors interviewed in this study were forthcoming and engaged in thoughtful conversations that offered multiple insights into their experiences.

**Interview Questions**

The use of a semi-structured interview permitted a combination of planned open-ended questions along with additional impromptu questions designed for clarity or to probe an idea during the interview. Probing allowed for clarification of relevant issues raised by the respondents (Hutchinson & Skodal-Wilson, 1992). A completely unstructured interview, without any prepared questions, creates the possibility of becoming side-tracked by concerns outside the scope of the study. “The focus of the phenomenological interview is not only to understand the experience of the interviewee, but more importantly to understand the invariant phenomenological structures of this experience” (Hoffding & Martiny, 2016, p. 550). To understand the structures of the
shared experiences of the participants, the following questions were asked in each interview:

1. Briefly summarize your path to becoming a STEM professor.
2. Describe your educational philosophies.
3. What pedagogies do you use that you consider to be effective? How did you become aware of the methods that you use?
4. What words would you use to describe the culture of your department?
5. What words would you use to describe the culture of your scientific profession?
6. Former students have described your influence in the classroom as inspirational and/or transformational. What do you believe are the contributing factors as to why your teaching is described this way?
7. Traditionally, teaching in a STEM discipline at the college level has been primarily focused on transmitting factual knowledge. Describe your experience working in such an environment.

Since the interviews were semi-structured, the questions did not all follow an exact format. This allowed for flexibility and greater depth to explore the experiences of the participant. Depending upon the responses of a participant, follow-up questions that probed for deeper meaning and a better understanding of the experience were asked.

Rubin and Rubin (2005) stated the interview is a structured conversation. The structure kept the focus on exploring the participant’s experience, while the conversation allowed for revelations beyond responses to specific questions. The interviews ranged between 30
to 90 minutes, depending on the stories shared by the participants and the number of probing questions asked.

**Data Analysis**

Upon verbatim transcription of all the interviews, the researcher was fully immersed in the descriptive data and used the process of coding to categorize and organize the text. “Coding is the process of analyzing qualitative text data by taking them apart to see what they yield before putting the data back together in a meaningful way” (Creswell, 2015, p. 156). Themes were developed to describe the perspective of transformational STEM professors who live in a culturally passive educational environment. Coding followed the three-stage process of Strauss and Corbin (1990) that entails open, axial, and selective coding to arrive at summative categories and themes. Open-ended interview questions allowed participants to contribute as much detailed information as desired and fully express their viewpoints. The researcher sifted through these narrative responses to accurately and properly code the data, reflecting the true meaning and intent of the participants. Data were analyzed through coding, interpreting the data, reflecting on the interpretation of the data as significant to the extant literature, and then ensuring validation.

Coding in qualitative research is the analytical process of organizing raw data into themes that assist in interpreting the data. Qualitative coding is inherently more interpretive. To assist in this coding, the researcher used the software program NVivo. The researcher kept a coding journal during the process to record coding decisions and reflections, making the coding process more transparent. Corbin and Strauss (2008)
defined open coding as “breaking data apart and delineating concepts to stand for blocks of raw data … one is qualifying those concepts in terms of their properties and dimensions” (p. 195). Each transcription was analyzed multiple times, with open coding done soon after the interview occurred. This process yielded phrases directly from participants to describe their experience. Once open coding was completed on all the interviews, axial coding grouped these codes. During axial coding “categories are related to their subcategories to form more precise and complete explanations” (Strauss & Corbin, 1998, p. 24). Finally, the categories from axial coding were organized around central themes during selective coding. This allowed patterns and connections to emerge. “Coding gives the researcher a condensed, abstract view with scope and dimension that encompasses otherwise seemingly disparate phenomena” (Bryant & Charmaz, 2007, p. 266). Ultimately, the coding process developed a description of the essence of the phenomenon through the lived experiences of the participants.

**Validity**

Creswell and Poth (2018) considered “validation in the qualitative research to be an attempt to assess the accuracy of the findings, as best described by the researcher, the participants, and the readers” (p. 259). Internal validity or credibility in qualitative research is “the extent to which the study and its findings are accurate and truthful” (Lankshear & Knobel, 2004, p. 67). Recording the interviews ensured that the statements made by the participants were accurate. The researcher’s responsibility is to “interpret [participant’s] experiences, how they construct their worlds, and what meaning they attribute to their experiences” (Merriam, 2009, p. 5). The process of analysis involved
interpretation and thus is subject to potential bias. Creswell and Poth (2018) stated they “view validation as a distinct strength of qualitative research in that the account made through extensive time spent in the field, the detailed thick description, and the closeness of the researcher to participants in the study all add to the value or accuracy of a study” (p. 259). To assist with credibility, participants were invited to check the transcriptions as well as the summary themes to make certain that the results reflected the intent of the participants. According to Maxwell (2005), member-checking is “the single most important way of ruling out the possibility of misinterpreting the meaning of what participants say and do and the perspective they have on what is going on” (p. 111). However, misinterpretation is always a possibility since the researcher is analyzing the transcriptions. Moustakas (1994) indicated, “hermeneutic science involves the art of reading a text so that the intention and meaning behind appearances are fully understood” (p. 9). The researcher became part of the process. Therefore, the researcher analyzed her own position throughout the study.

Mortari (2015) indicated that reflexivity is a practice that “a researcher should carry out to make the politics of research transparent,” which is “essential in research” (p. 2). The researcher carefully reflected upon her own experience as an educator to become aware of any potential bias that could affect the interpretation of the data. “The researcher who places him or herself within the qualitative paradigm must set aside all preconceptions, judgments or prejudices towards a particular topic in order to make an objective analysis of the information participants bring to an investigation” (Padilla-Diaz, 2015, p. 103). The researcher in this study has many years of experience in mathematics
higher education and uses multiple active learning strategies in her classes. She believes every student is capable of improving mathematical skills, with a focus on critical thinking and problem solving rather than working with formulae and memorization. Complete objectivity may not be possible, and it may not even be desirable as the researcher brings skills and expertise to the process. Biases and assumptions are involved, but they should be identified and monitored to see how they shape interpretation of the data. The aim is to develop “a careful description of the structure of the lived experience of that phenomenon in a particular type of situation” (Giorgi, 2008, p. 41), and the researcher’s subjectivity cannot stand in the way. The voices of the participants were filtered through the researcher but speak loudly and clearly in this study.

Reliability

Creswell (2014) referred to reliability in qualitative research as the “stability of responses to multiple coders of data sets” (p. 253). The transcriptions of all interviews were coded by both the researcher and an additional coder with experience in higher education to enhance reliability. The researcher established a platform for coding and developed an initial code list. The second coder read through all the transcripts and created a separate set of axial codes. Then the two codebooks were compared, with a high degree of similarity. Guest et al. (2012) noted, “reliability is of greater concern with thematic analysis than with word-based analyses because more interpretation goes into defining the data items (i.e., codes) as well as applying the codes to chunks of text.” (pp. 10-11). Despite these concerns, they indicated, “a thematic analysis is still the most useful in capturing the complexities of meaning within a textual data set” (p. 11).
Thematic analysis was used in this study to provide a rich, detailed, and complex description of the data. The researcher ensured that the research process was logical, traceable, and well-documented.

A phenomenological approach was appropriate for this study since the researcher was seeking to learn more about the experiences of transformational STEM professors who are working in a passive environment. Semi-structured interviews were used to gather data about this shared phenomenon. The interviews were audio-recorded and transcribed verbatim. The transcriptions were then analyzed carefully by the researcher using open, axial, and selective coding. The resulting themes, supported by quotes of the participants, provide insight into how these individuals negotiate the culture of STEM higher education yet manage to inspire students.
CHAPTER 4
Research Findings

This phenomenological research study examined the how STEM professors inspire students within a culturally transmissive and passive environment by analyzing the lives of transformational professors in this environment. The STEM professors involved in the study received an award for teaching or appeared on a list of top STEM educators. Publicly recorded student comments provided evidence of at least one aspect of transformational teaching for each STEM professor invited to participate in the study. A total of eight STEM professors were interviewed. The lived experiences shared by these professors are the basis for this chapter.

In the view of the researcher, STEM higher education is enshrouded in a grey abstrusity that makes the path to a STEM degree confounding for students. Even amid this dark cloud, a few shining lights in the form of inspirational professors appear. How do these lights manage to stay lit in the surrounding darkness? One method to begin to discover the answer to this question is straightforward: ask. Ask the transformational STEM professors who are highly praised by their students what they think is the reason for their lasting positive impact on students’ lives. This chapter provides portions of the conversations with STEM professors who discussed their experiences teaching and working with students.

A Gallup-Purdue survey (2014) of 30,000 postsecondary graduates in the U.S. indicated that inspiring professors, as defined by Bidwell (2014), positively and significantly impacted their students’ workplace engagement after graduation. A follow-
up study at Lingnan University in Hong Kong created a University Experience +10 instrument by combining three characteristics of inspiring professors with seven transformational classroom leadership traits. According to Pounder, Stoffel, and Choi (2018), “the transformational classroom leadership experienced by Lingnan alumni during their studies at the University may account, at least in part, for their higher level of workplace engagement” (p. 339). If further research continues to support the connection between transformational professors and high levels of workplace engagement, employers may push institutions of higher learning to use this type of leadership in the classroom. Numerous studies (Bass & Avolio, 1994; Kelloway et al., 2000; Warrick, 2011) suggest that transformational leadership can be effectively taught, which could thus impact faculty development efforts.

The purpose of this qualitative phenomenological study was to describe the lived experiences of transformational university STEM professors who negotiate their presence within the passive culture that exists in STEM higher education. Semi-structured interviews with inspirational professors from biology, chemistry, computer science, engineering, and mathematics aimed to uncover more about how professors inspire and transform students. This chapter provides an analysis of the interviews. The goal during the analysis was for the resulting themes to represent “the essences at a particular time and place from the vantage point of an individual researcher following an exhaustive imaginative and reflective study of the phenomenon” (Moustakas, 1994, p. 100). The professors told their stories openly and honestly, such that the researcher was able to
reflect upon the comments and find multiple common threads running through the experiences shared.

**Data Collection**

Since this study required professors who met particular criteria, purposive sampling was necessary. Internet searches for awards in teaching at higher education institutions started the process. Only those professors who teach in a STEM field were considered. Recommendations were also requested so that the net was cast wider. Each professor in the study engaged in transformational teaching, based upon ideas from transformational leadership. Student comments were used to demonstrate evidence of a component of transformational leadership. These comments were found in one of two locations: the student comment section of the teaching award or a publicly accessible website where students can make comments on a college professor. The four elements of transformational leadership include idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Based on the description of each of these components discussed by Bass and Riggio (2006), a list of associated words was developed, as shown in table 1.
Table 1

*Keywords as evidence of transformational leadership*

<table>
<thead>
<tr>
<th>Transformational Leadership Component</th>
<th>Keywords as Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idealized influence</td>
<td>Admired, respected, trusted</td>
</tr>
<tr>
<td>Inspirational motivation</td>
<td>Passion, energetic, enthusiastic, inspirational</td>
</tr>
<tr>
<td>Intellectual stimulation</td>
<td>Learned, challenged, comprehensible, examples</td>
</tr>
<tr>
<td>Individualized consideration</td>
<td>Caring, focused on students, responsive, personal</td>
</tr>
</tbody>
</table>

The original list of 31 professors was narrowed to those who had a current webpage with an email address on the home institution’s website. A total of 27 emails were sent out, explaining the study and requesting an interview (Appendix B). Nine professors responded with a willingness to be interviewed. One of these was unable to fulfill the commitment, so a total of eight STEM professors were interviewed using a semi-structured format via the electronic video conference platform Zoom. The length of the interviews ranged between 30-90 minutes. Each interview was recorded and transcribed. Axial coding was applied to the transcriptions to develop themes.

Initially, the researcher intended to visit the professor at each person’s home institution and observe a class. However, the coronavirus pandemic produced stay-at-home orders and prevented travel. Classes at most institutions moved to an online format. As a result, there were no physical courses to attend. The rapid shift from face-to-face teaching to completely online learning resulted in additional work and stress for most instructors. Thus, the researcher is exceptionally grateful for the time so graciously given.
by the participants to engage in conversations around teaching, learning, and the culture of STEM.

**Participant Demographics**

The general population for this study was professors who teach at a college or university within the U.S. in a STEM field. While there was no effort made to assure a gender balance, three of the eight interviewed identified as female and the remaining five identified as male. The number of years of experience as a STEM professor varied between a minimum of five years to a professor emeritus who taught for 56 years. The mean number of years of teaching was 27.3 years while the median number of years of experience was 22. These higher numbers are expected, as teaching awards generally require an established pattern of excellence in the classroom. The distribution of the scientific disciplines within STEM for the eight professors is shown in Table 2.

**Table 2**

*Scientific Discipline of Interviewed STEM Professors*

<table>
<thead>
<tr>
<th></th>
<th>Biology</th>
<th>Chemistry</th>
<th>Computer Science</th>
<th>Engineering</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Participants</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The disciplines had varied responses regarding professional culture, so this is an important distinction that will be referenced later in this chapter.

An interesting pattern was uncovered when analyzing the categories of home institutions of the participants. Each college or university was categorized according to the classification provided by the education section of U.S. News and World Reports. As part of their ranking system, they classify each accredited college and university in the
United States based upon the Carnegie Classification of Institutions of Higher Education. The first chart in Figure 1 groups the home institution of each potential participant. These are the STEM professors who were sent an email requesting an interview. The second graph provides the same data for the actual participants who completed an interview. The noticeably absent slice from the second graph is a participant from any institution categorized as a national university. These schools “offer a full range of undergraduate majors, plus master's and doctoral programs. These colleges also are committed to producing groundbreaking research” (U.S. News & World Report, 2020). The Carnegie classification of these institutions is “Research I Universities,” often referred to as simply R1 schools due to their intensive focus on research. While 37% of the award-winning STEM professors are employed at a national university, no professors from this category agreed to an interview.

**Figure 1**

*Type of Institution for Potential vs. Actual Participants*
The majority of the STEM professors who participated in an interview hailed from a national liberal arts college. While half of the professors commented on their circuitous route into the professoriate, all five who worked at a liberal arts college indicated a good fit due to the balance between teaching and research that is found at such colleges.

The informed consent indicated that all identifiable information would be removed so that the participants would feel more comfortable during the interviews to share any information desired. Thus, the home institution for each participant will not be listed, and actual names will not be used. A random name generator was used to create a list of names. Each participant was assigned a name from the list of random names. Table 3 lists the pseudonyms, type of institution, and a range for the number of years of experience for each participant.

**Table 3**

**Participant Description**

<table>
<thead>
<tr>
<th>Participant Pseudonym</th>
<th>Discipline</th>
<th>Type of Institution</th>
<th>Years of Experience (Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam</td>
<td>Biology</td>
<td>National Liberal Arts College</td>
<td>30 &lt; Y</td>
</tr>
<tr>
<td>Ben</td>
<td>Mathematics</td>
<td>Regional University</td>
<td>10 &lt; Y ≤ 20</td>
</tr>
<tr>
<td>Chloe</td>
<td>Computer Science</td>
<td>National Liberal Arts College</td>
<td>0 &lt; Y ≤ 10</td>
</tr>
<tr>
<td>Daniel</td>
<td>Engineering</td>
<td>Engineering School</td>
<td>20 &lt; Y ≤ 30</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>Computer Science</td>
<td>National Liberal Arts College</td>
<td>10 &lt; Y ≤ 20</td>
</tr>
<tr>
<td>Felix</td>
<td>Chemistry</td>
<td>National Liberal Arts College</td>
<td>20 &lt; Y ≤ 30</td>
</tr>
<tr>
<td>Gideon</td>
<td>Biology</td>
<td>Regional University</td>
<td>30 &lt; Y</td>
</tr>
<tr>
<td>Hannah</td>
<td>Biology</td>
<td>National Liberal Arts College</td>
<td>30 &lt; Y</td>
</tr>
</tbody>
</table>
Data Analysis

Before the interviews, the researcher created interview questions (Appendix A), an email recruitment template (Appendix B), and an informed consent form that included the details and methodology of the research (Appendix C). A submission to the institutional review board was approved (Appendix D), and informed consent was signed for each participant. As part of informed consent, each participant verbally agreed to have the interview recorded. Seven of the interviews were recorded through video conferencing software. One interview occurred via phone, so the recording is only audio. After each recording, the researcher transcribed the interview by writing down verbatim what was stated. During member checking, no interviewees requested any changes to the transcriptions. Writing all the conversations verbatim allowed the researcher to become immersed in the data.

After all the transcriptions were completed, the researcher applied inductive reasoning by starting with open coding of data and developing categories and themes. Each transcript was uploaded to the software NVivo to organize and structure the coding process. The transcripts were coded manually within NVivo. The transcripts were read multiple times to see if any initial codes needed to be slightly adjusted or new ones added. When a new code was added, all the transcripts were reread. This iterative process was time-consuming, but the intent was to allow the participants’ voices to speak without being filtered through preconceived notions by the researcher. Charmaz (2006) indicated that coding “generates the bones of your analysis. Integration will assemble those bones into a working skeleton” (p. 45). Thus, the open coding process provided a pile of initial
bones. Upon completion of all the open coding, the codes were connected during the process of axial coding. According to Strauss and Corbin (1990), axial coding is “a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories” (p. 96). The researcher used mapping to uncover connections between the open codes and the logical ways that the open codes formulated groups of similar ideas. At this point, another colleague also coded the anonymous data. For verification, member checking and peer review were used. Having a second coder helped to reduce cognitive biases. The codebooks were compared, with a high degree of similarity noted. Often the difference was simply a matter of phrasing: “teaching methods and styles” as a code compared to “pedagogy.” The coding results were blended in NVivo. After agreeing with the axial codes, the two coders analyzed and discussed how these codes grouped and formed themes.

Findings

Phenomenological research is situated to discover themes not restricted to the research question. By exploring the experiences of the participants, the five themes emerged, as shown in Figure 2. A discussion of these five themes, along with supporting evidence through the voices of the participants, is the focus of this section.
**Professorship**

Professorship includes those things related to holding the position of professor. All participants hold a doctoral degree as part of their path to becoming a professor, yet few anticipated academia for their future. The first interview question asked each participant to briefly describe their career path. The intention was to see if there were any influential factors during this background that affected how the professor acts in the classroom today. Unexpectedly, the participants shared a common theme of circuitous paths on the road to a professorship.

**Serendipitous Beginnings.** Out of the eight participants, only one had a background that foreshadowed any aspect of teaching. Chloe indicated, “My story is very weird, but I’m going to try to make it as brief as possible. I didn’t even think I would go into teaching at all.” Even though she stated that her story was “weird,” it was actually common. Adam also declared, “So it’s a very circuitous route. I’m sorry to tell you such
a long story, but it’s to show you it’s a nontraditional way.” Similarly, Felix described his entrance into the professoriate as “a sort of twisted, tortuous path.” The reflection caused by the question produced some revelations by the participants. After telling her story of becoming a professor, Hannah stated, “It’s kind of funny when I think about that now.”

For the majority within this group, a professorship was never an intended plan. Thus, it appears that intentionality was not an influential or motivating factor. They are not inspirational professors as a result of a long dream. They did not enter into this profession fully prepared with a strong desire to educate adults. As typical with higher education educators, these participants were not trained in the field of education. Oddly, the paths to becoming professors were all unique, yet they had a commonality in being serendipitous.

**Balance between Teaching and Research.** As previously mentioned, no participants worked at national universities. These universities focus on research and offer several doctoral programs. Participants would refer to these as “R1” universities. Four of the five participants that work at national liberal arts colleges found their institutions to be compatible with their desire to have a balance of teaching and research.

Chloe aimed to teach at an institution that included a balance due to her experience in graduate school at a national university:

My problem with R1 universities was that I did notice that all my advisors and professors would just focus on research, all the time. All they cared about was funding, funding, getting money, grants, funding, funding. That’s all they talked about. And getting graduate students so that they can keep the cycle going. I just
couldn’t live through the stress. I thought it was extremely stressful, not sustainable, no work-life balance.

Chloe was not alone in her desire to get away from the research demands at some universities. A professor at an engineering college, Daniel, noted his shift to a college that enabled him to focus on teaching: “I decided to become an engineering professor who was focusing on education as opposed to an engineering professor doing research.” In his case, he specifically sought a different type of institution than he attended. Felix also opposed a strong tilt in one direction: “I think it’s really rare to find research active people who are serious about their teaching. I did a post-doc at a really research active R1 university, and the faculty barely taught. They weren’t really interested.” The liberal arts colleges appear to provide a space for both teaching and research. However, this can come with its downsides as well. Despite the fact that he was awarded a prestigious teaching award, Felix noted, “There are so many awards for research, and there are so few rewards for teaching.” The demands of balancing both teaching and research simultaneously at extremely high levels can take a toll on the professors dedicated to both.

Sources and Experiences of Stress. For those who consider the role of professor to be easy, a conversation with any of the interviewed professors should challenge this notion. All of the professors indicated satisfaction and enjoyment with their work. Nevertheless, this leadership position entails demands from multiple directions: students, administrators, parents, the general public, and the government. Hannah succinctly stated, “It was patently clear to me that the world didn’t actually realize what it was like in the
trenches.” She later repeated this idea: “You ought to see me on an ordinary day. It’s very exhausting. It’s very exhausting.” This exhaustion may stem from perfectionist tendencies to serve students well while also keeping up with the demands of research. Not enough time to do both was a common theme.

The balance between teaching and research was acceptable for the participants whether located at a national liberal arts college, regional university, or engineering college. The disadvantage of engaging in both teaching and research as part of the job is finding the time to do both. All the participants are inspirational professors. Inspirational teaching does not happen magically. It takes valuable time. Ben noted that time was needed within the class to make personal connections with students. However, finding time within the classroom requires additional time to prepare in advance:

That’s the biggest challenge, I think, is time. But also setting up a lesson plan that allows you to have that time. There’s definitely some planning. Even though I’m talking about a lot of instinct that we have as inspirational teachers, you still have to plan for it.

When Ben was questioned about how to find this time, he acknowledged, “I am definitely one of those teachers that has no boundary for time. If I can’t sleep, I’ll go downstairs and start writing a lesson. Sometimes you just have to do it. Just make time.” The time involved in preparing for class is substantial. For example, Hannah noted, “I work my ass off, and they know that. I never give the same lecture twice. I spend ten hours on every lecture. When I come to class, I’m prepared. I have never winged a lecture.” The fact that she never gives the same lecture twice may not surprise her students who know her, but it
would likely surprise people less familiar with higher education. The notion that a professor simply walks into a classroom and spouts the same information from last year is not accurate for this group of inspirational professors. The question then arises as to whether this time-consuming dedication plays a role in the student perception of the professor as a positive role model. If time is the only factor, then this has a very negative consequence.Demanding college professors simply allocate more time to their work is unrealistic. Since there is a limit of 24 hours in a day, devoting more time to work can come at a cost. For Gideon, this cost included his family:

I had a brief period where I had a little bit of disillusionment and burnout about it, because my wife and I had 5 kids and as you know, educators don’t pull in a lot of income. I felt a little guilty because I said I’m making my family sacrifice so that I can be indulged in my passion.

Gideon considers his career to be his passion. Passion is often evident to the students and contagious in the classroom. The notion of burnout, however, is real and problematic. When reflecting on some of her colleagues, Elizabeth noted the following:

The faculty will say, “You know, I really want to learn all their names, but there’s just too many of them, and I have so many other things to do.” I mean, for most people in their jobs, you just don’t have enough time. Something has to give.

The question arises as to what exactly is going to give. The mental health of the professors should not be on the list of options.

The majority of interviewees entered the professoriate via a winding path, without initial intentionality to pursue this career. They appreciated and specifically sought out an
institution that values both teaching and research. Nevertheless, this choice may be associated with a struggle to find the time to address both aspects successfully. Despite the challenges and stressors of the professorship, most of the interviewed professors spoke highly of their departments. In the next section, the professors discuss the culture of their departments, their scientific profession, and the culture of education as a whole.

*Culture*

This study included only inspirational STEM professors in higher education in the United States. As such, the researcher asked the professors to describe the culture of the department and the discipline to better understand the working environment of the professors. For most of the interviewees, these cultures are experienced very differently.

**Department Culture.** All but one of the interviewees belonged to a department within the institution that included members of the faculty teaching the same subject material. Since this is typically the smallest unit of faculty structure, the attitudes, beliefs, and norms of these departments can have substantial impact on the atmosphere in which the professors are immersed. The professors spoke highly of their individual department cultures. Elizabeth commented, “Our department is cohesive and supportive.” Ben also spoke positively about the interactions between the faculty members of his department: “We all get along really well! We are the one school that seems to be heading in the positive direction in terms of enrollment and faculty morale.” This collegiality plays an essential role in the retention of faculty members. In a study of faculty attrition, Burnett et al. (2012) concluded that faculty who resigned were less satisfied in the areas of
climate, culture, and collegiality. Other professors commented on the interaction of their departments with the students. Chloe described the reputation of her department:

If [students] come and talk with any CS professor, you’re never going to be judged for what you’re saying. You’re never going to be penalized for what you’re saying. And even if whatever you’re saying is going to be spread to the rest of the department, the name is never going to be associated… They trust us. I mean, I’m new to the department, so I’m happy that that was the culture when I came in. They already trust the department. It’s there. It’s known about the CS department. It’s the department you can go to if you want to talk.

Her department worked to create special bonds with the students that enabled them to share concerns and openly discuss issues. She benefitted from this relationship with the students and fit right into the existing faculty culture. Later in the conversation, Chloe noted that the trust that the students had with her department led students to feel secure in being able to address some campus concerns with the faculty. The department took these concerns seriously and addressed issues of racism and inclusivity based upon these student comments. Establishing a culture of openness led to improvements for the entire student body. The departmental attitudes and beliefs aligned with Chloe’s personal values. This led to a higher degree of job satisfaction and a sense of belonging.

One professor works at an institution without departments. Daniel found the lack of typical faculty structure to be a positive aspect of his college:

We don’t have departments, which I think is actually quite important. We are a faculty-whole, so whether it’s a math person or an arts and biology person or an
engineer, we’re all sort of the same team. So, I think, certainly, interdisciplinary is one of the things that I would use. I think focused on human development would be something that would be in there. Trusting of students. Fun is a pretty important word.

Once again, the issue of trust with the students was mentioned. Thus, there is a sense that the professors and the students have established a sense of openness with communication and strong rapport. There seems to be a level of respect that goes both ways between students and professors. The interviewees noted this level of trust and communication as a significant and positive aspect of their department culture. For all but one professor, the comments regarding the culture of the department teemed with pride. This satisfaction makes it easier to try new things in the classroom and still feel a level of safety and support since the department is focused on students. Only one professor was more reserved when speaking of the culture of the department. Felix noted that his department was not necessarily all on the same page:

We have two or three faculty who live for research and come in and work incredibly hard, but the research is the number one goal. And the secondary goal is to educate students in their own image. And then we have a couple of people for whom teaching is their priority and research is secondary.

This distinction between the different aims of the professors within his department led Felix to use the term “bifurcated” when describing his department culture. This may not be surprising at a liberal arts college, where both teaching and research are expected. While this allows professors to be involved in both, it can also put pressure on faculty to
be excellent in both arenas. As mentioned in the section on professional stress, this takes time. Therefore, some professors may be inclined by either pressure or desire to put a strong emphasis on either research or teaching but not both. Felix noted many rewards for research, but the same cannot be said for teaching. He saw this as a point of frustration that needs to be improved. He placed his stance as “in the middle.” Felix enjoys both teaching and research. He has published multiple books and articles, yet he has also received teaching awards and is respected by his students. This takes quite a bit of energy, but Felix mentioned that teaching keeps him young, and he feeds off the energy that comes from working with young people. The bifurcation of Felix’s department extended to his scientific profession as well.

**Culture of the Scientific Profession.** The professors in this study are experts in biology, chemistry, computer science, engineering, and mathematics. These STEM disciplines each have active and robust professional organizations that aim to advance and disseminate research in their respective fields. Often, these organizations also publish journals with articles related to educational reforms of the discipline. These articles may be the result of work done under grants aimed at changing higher educational practices toward more evidence-based teaching (Tagg, 2012). As part of engaging in the scientific profession, STEM professors are accustomed to solving problems with the scientific method, including seeking evidence to support conclusions. Despite this, Brownell and Tanner (2012) reported:

> The general perception is that while there are pockets of change driven by individual faculty, there is little evidence that the majority of our faculty members
are reconsidering their approach to teaching, despite dozens of formal policy documents calling for reform (p. 339).

Frequently cited barriers to change include time, lack of training, and lack of incentive. Brownell and Tanner suggested another addition to this list: a scientist’s professional identity. They suggested that this identity might interfere with a willingness to participate in pedagogical change. Understanding how the inspirational STEM professors interviewed perceived their scientific disciplines provided a window into how their professional identity impacted their role in teaching.

While all but one professor had positive comments about the culture of their departments, the mood changed when discussing their scientific cultures. The comments were much less flattering. Felix, the professor who referred to his department as “bifurcated,” extended this same notion to his discipline:

I think what I just said is true for chemists as a whole too. Even more so at an R1 university. I think it’s really rare to find really research-active people who are serious about their teaching. I did a postdoc at a really research-active R1 university, and the faculty barely taught. They weren’t really interested.

From Felix’s point of view, focusing on teaching contradicts the status quo in his field. The pressure that currently exists includes spending time, attention, and resources solely on research rather than on teaching. The group norms dictate that scientists are “less than” if they focus on the education of their disciplines. Changing professional cultures to become more inclusive of teaching rather than solely research within the field may make the path easier for those STEM professors who seek to push significant reform in
education. Until that happens, the culture of specific scientific disciplines prohibits some STEM professors from engaging in the discourse around the teaching component of higher education due to a desire to advance professional identity.

The culture of a scientific profession discourages attention to the education of students by professors in these fields, but this is not the only negative impact mentioned in the interviews. Daniel, an engineering professor, pointed out how his scientific discipline tends not to engage in the affective or emotional domains of the interactions of people, which is a necessary piece of the puzzle when working effectively with students.

The culture of engineering has impeded changes in engineering education. A large part of the reason the culture of engineering has impeded changes in engineering education is that engineering assumes that people are rational, assumes that emotion doesn’t matter, and assumes that if you build a better mousetrap, people will come. If you look at the NSF coalition’s work, for example, there’s a classic case of, “we’re going to build a bunch of better mousetraps, and it’s all going to be good, right?” Like, they spend a shitload of money and nothing happened because engineers don’t pay attention to culture. Engineers pay attention to artifacts. They don’t ask questions about “what are the assumptions about those artifacts?” I think as we’ve moved ahead from that, engineering has started to pay more attention to culture, and I think that’s part of why we’ve been able to start to make changes.

Daniel teaches at a progressive engineering school, where professors are encouraged to focus on engineering education. He claimed that engineering professors “certainly are
marginalized at lots of other institutions because of what the culture of engineering is. Education is about people and that’s all squishy, and that’s not real stuff.” His institution has had success moving away from the dominant expert and content framework toward a system that is intentional about personal development of students. Part of that may be because his school deliberately chose to work together to create a counterculture very different from the traditional engineering culture. Acknowledging the ripple effect of how the current culture of engineering disturbs the engineering classroom was the starting point for substantive change at the college.

Existing culture of a discipline can also impact how the STEM professors prepare their students for the future. Chloe is a professor at a college of all women students, which presents unique challenges when white men dominate her field. Recognizing the current culture of her computer science field changes how she teaches at her institution. “I keep reminding them that when you go, and you graduate, you’re going to be in a very different culture. It’s not all women. You’re not going to feel safe.” She encourages her students to not be intimidated when they go into industry.

If you know what you’re saying - if you’re confident, and you keep that confidence, you’re going to be fine. And you don’t need to just lower your voice. You can speak up if you know what you’re saying is true. It’s okay to speak up… I try and teach them little tidbits here and there to whoever comes and asks for advice or whoever I see who is not confident enough. I tell them. I try and encourage them. And that’s my way of trying to fix the current culture in industry and in academia.
Chloe sees her opportunity for change by encouraging and developing powerful students who will then move forward to make meaningful advancements within the scientific profession. She uses her classes and advising time to prepare students for what lies ahead. The current culture of her field impacts how she teaches by shifting the focus from strictly content to taking the time and effort to prepare her students to disrupt the existing norms.

The professors in the fields of chemistry, computer science, and engineering all had concerns over how the culture of their disciplines may negatively impact the progress of education. The biology professors, on the other hand, did not have the same negative complaints. For example, when Adam was asked about the culture of this professional field, he responded with information about the national biology conferences that he attended. These conferences included sessions on teaching biology and motivating students to learn. The sample size is too small to make any overarching conclusion in this area, but there was still a marked difference between the different disciplines.

**Culture of Education.** The issues in STEM higher education may need to include conversations with educators in elementary and secondary schools. Several of the professors noted that students tend to enter their classrooms with a negative attitude. Chloe stated, “I started tutoring high school students. And I noticed that they come in with that, ‘I don’t like math. I’m not good at math.’ That’s the first thing they say.” Similarly, Gideon also would volunteer time at his local schools and mentioned the following about his young students:
They’re so enthusiastic, and I really think the foundation and the thing that we build off of with education and with individuals in education, it starts right there in the elementary school. If we can nurture that enthusiasm and keep that going, we’re going to have a well-educated society. However, it’s sometimes discouraging - that’s the word I’m looking for - to see what happens to that enthusiasm between, say, the third and fourth grade and where they are as college freshmen.

These professors are questioning whether changes in education can be made so more students enter college classrooms with a willingness to learn and explore the sciences. Daniel eloquently analyzed the philosophical foundations of our current educational system and explored how the process might be different if the framework of education shifts away from an emphasis of content procurement to secure a job:

If you think about education purely as acquisition of content knowledge so you can subsequently do something, so this very kind of prerequisite framing of education, you end up with an education system that looks a lot like the one we have, where students learn a bunch of stuff so they can go do something afterwards. I think that the reality, though, is that students actually learn the most stuff by doing something.

These words bring to mind the notion of experience as defined by John Dewey. Experience “recognizes in its primary integrity no division between act and material, subject and object, but contains them both in an unanalyzed totality” (Dewey, 1929, p. 8). Daniel refers to education as being a “thing that happens in the process of doing stuff in
the world.” From this perspective, the notion of lifelong learning, which many higher educational institutions list as one of their objectives, should be rooted in students’ interactions and experiences with the world rather than the transmission of discipline canons. The educators in this study showed concern about more than just the instruction and design of their individual courses. It was clear from their comments and behavior that they contemplated the state of education as a whole.

**Pedagogy**

Rapid advances in technology during this complex information age increased demand for STEM employees. America lags behind other countries in basic STEM skills (National Science Board, 2019). The result has been increased attention on STEM undergraduate education. Much of that focus has been on the use of evidence-based practices and active learning strategies. There is an abundance of evidence demonstrating that the use of these practices improves student learning outcomes (Freeman et al., 2014). However, research also demonstrates that these pedagogical techniques are infrequently used in the higher education classroom (Stains et al., 2018). The next sections describe the teaching philosophies and practices of the interviewed professors.

**Philosophies.** Not surprisingly, the inspirational professors kept the focus of their teaching on student learning. When asked what he taught, Gideon answered, “I teach people.” When pushed to answer what precisely he taught to people, Gideon would respond, “I teach people how to use the brain.” Thus, the emphasis is not only on the students but specifically on raising the level of critical thinking. Hannah spoke of the many hours she spent crafting every lecture carefully, paying attention to proper usage of
each word. When asked why she does this, Hannah responded, “because my job with students is to train them.” Note that she did not indicate that her job was to teach content. Chloe also emphasized the reasoning aspect of her courses when she indicated, “It’s important for them to know why. What are they doing? Why are they doing it?” Similarly, Adam viewed the content of the discipline as just the beginning. Regarding the facts and vocabulary that he teaches, Adam stated to his students, “you’re going to use this to get a deeper understanding of how we are.” Elizabeth’s teaching philosophy keeps a relationship with the student as a vital component of student learning. She said, “if I can make people feel welcome or like they belong, then I feel like that’s the foundation upon which learning can occur. But if they don’t have that, then everything becomes a lot harder.” Student learning starts with the development of a personal connection. One professor noticed how his teaching philosophy has changed. Daniel stated, “during the time I’ve been at [college name], I have shifted from being someone who has, to a greater or lesser extent, viewed education as being about learning specific stuff and much more in the direction of personal growth.” Due to the very distinct and universally accepted canon within most STEM courses, an emphasis on personal growth over detailed factual knowledge is unexpected.

Besides being focused on student learning, the STEM professors identified teaching facts as only one part of a bigger goal. In a Boyer Commission Report, Kenny et al. (1998) indicated, “the experience of most undergraduates at most research universities is that of receiving what is served out to them. In one course after another they listen, transcribe, absorb, and repeat, essentially as undergraduates have done for centuries” (p.
In STEM fields, this process often implies absorbing and repeating factual knowledge. All of the professors interviewed acknowledged the importance of understanding facts critical to the discipline. However, these facts are not the full extent of the goals of these educators. Rather, facts are viewed as one component of a larger vision. Adam pointed out, “the facts then also integrate into doing problem-solving.” As a biologist, he taught courses that included a fair amount of memorization. However, he noted that understanding the underlying concepts that connected the facts was more valuable than memorizing facts independent of a unifying theme. Adam also summarized, “it’s not only facts. Science is not facts. Science is a collection of observations to explain the world: the natural world, the physical world, the world of numbers.” Adam’s teaching philosophy reflected a vision of content within his field as a larger piece of understanding science. Similarly, Felix reflected on how his teaching was different from other peers in his department:

In comparison to my colleagues, I might be more likely to give my students more open access to lots of things and be more interested in them being able to find the technique they need to be able to solve the problem rather than remembering the equation and the constants. The concept was more important than the facts.

Once again, there is a teaching philosophy that emphasizes the role of factual knowledge as part of a grander picture. This group of STEM professors focused on advancing student learning through conceptual knowledge and applying facts to solve problems.

Practices. Research indicates that active learning can engage students and improve learning outcomes, as demonstrated by higher examination scores and higher
passing rates (Cavanagh et al. 2018, Freeman et al. 2014). A recent study focused on narrowing the achievement gap in STEM urged educators to “replace traditional lecturing with evidence-based, active-learning course designs across the STEM disciplines” (Theobald et al., 2020, p. 6476). With the heavy emphasis in the last decade to enhance student learning by switching to active learning strategies, it would not be surprising to discover that one of the distinctive common traits of the inspirational professors is their use of active learning in the classroom. However, this was not the case.

“What pedagogies do you use that you consider being effective? How did you become aware of the methods that you use?” When asked these questions, the STEM professors paused longer compared to other responses. The researcher developed the impression that most interviewees needed time to reflect before providing an answer. Despite the additional time, some professors still had difficulty describing methods. Chloe observed, “I realized that my style has evolved and grown, and it’s ever-changing.” Many professors did not name particular practices but referred back to philosophies, indicating that perhaps they did not focus on specific methods. Instead, they will try multiple approaches that make sense within their overarching framework. Felix indicated, “I’m not going to present anything in class without showing relevance. Numerous techniques like that. I don’t use one technique or one method.” The emphasis remains on his philosophy of using the content of his discipline as a way to enhance student problem-solving skills. Felix mentioned having his students create blogs and using a class Tweet with a specific hashtag as examples of the diverse methods that he employs. When asked how he learned about these ideas, he responded, “when I see things that I like, that I find
interesting, I try to adopt them. I think a lot of it is just seeing and copying.” Felix’s response indicates an attitude of continuous adaptation. There is no indication from his words that he has a set and defined practice that he always uses. Ben pointed out that his teaching style deliberately includes the ability to pivot: “I think I’m a great observer as a teacher. I can tell almost exactly when I’ve lost a class by going down the wrong path, and I quickly turn the ship around.” Thus, one of Ben’s strengths involves the ability to respond to the students that are present in class. Reading the room in this fashion was also used by Elizabeth. She stated, “so I might cover something one way, and then say, ‘okay if that didn’t mesh for you, here’s another way to think about it.’” Her words indicated a desire for student comprehension by shifting the approach to accommodate multiple learning styles. The closest mention by any professor of a specific teaching practice occurred when Elizabeth stated, “we try to make the classroom as interactive as possible.” No professor mentioned the phrases “active-learning” or “evidence-based practices.” However, a student-centered foundation was still evident when they discussed pedagogies.

**Inspiration and Motivation**

The STEM professors in this research study were selected to participate based upon student comments. Statements indicated that these professors inspired and transformed students. The researcher readily acknowledges that this is not magic but takes hard work and dedication. What motivates the professors to engage in this hard work and continue to spend the necessary time to impact students? The interviews
uncovered evidence of student connection, personal fulfillment, and a nonconformist attitude.

**Student Connection.** The interviewed STEM professors transformed students’ lives. When speaking with these professors, it became clear that the relationships between students and professors are mutually beneficial and not a one-way path. Hannah is nearing retirement, but she easily described her motivation for staying in the classroom:

I couldn’t pursue this job if I didn’t do anything that I didn’t enjoy. I mean, it’s my salvation. I really enjoy it. I like the interaction that you get with students. That’s a reward that is beyond anything; the emotional satisfaction. You know when you’re teaching a class, and you see a student who is indifferent and glassy-eyed, and not really there, and then two or three weeks later, you see that kid engaging. That is the best.

Her eyes would light up when she discussed her students and the progress that they made in her classes. The relationship between student and professor was a vital part of Hannah’s work as a professor. One professor emeritus, Adam, felt the loss of working with his students in retirement. He stated, “That’s the only thing about retiring is not having that interaction with students.” Felix also relied on this personal relationship. When talking about his students, he indicated, “I enjoy them, and I think that’s equally as important as being in class. I think that the students feel that I am concerned about how they’re doing in class.” He also stated, “I think teaching keeps me young, because I’m always with students. I like being with students.” When Felix commented on his teaching philosophy, it was clear that he gained just as much from his students as they did from
him. He seemed to be inspired and motivated by his students. He commented on “that joy of doing something and being able to do it when it works out after struggling to do it. That is something that is really worth teaching and doing.” There is a sense that Felix feels that all the sacrifices and efforts that he puts into his teaching pay off when his students experience success on a challenging problem.

There is a reciprocal relationship between the students and the professors. Gideon thrived from his connection with his students. He commented, “I love my students. Last year they asked me in a news article for the school why I kept teaching. Because I love it. I love teaching. I love the students. Why would I want to do anything else?” Gideon had earlier spoken about a time in his life where he suffered from disillusionment and burnout. Yet his relationships with his students kept him going. Elizabeth became invested in her students. She stated, “the message I want to send is, ‘I care about you, and I’m glad that you’re here. And so I’m investing time, and I hope you’ll do the same, right, in terms of this class.’” Chloe also noted, “So now I include my students. I like them as partners.” These professors are interested in doing the work that they do because of the relationship that they develop with their students. It becomes more than just a job at that stage.

**Personal Fulfillment.** While many of the professors entered into the professoriate through circuitous paths, once they arrived, it became a deeply personal commitment. For some, the path led to a liberal arts college. Elizabeth mentioned, “I think one of the selling points of a liberal arts college is the small faculty to student ratio, and that there is an expectation of a closer relationship between faculty and students at liberal arts
colleges.” She originally started her career in Silicon Valley, but teaching filled a hole in her previous work. Elizabeth described her impetus for teaching:

I went to work for a year in Silicon Valley, and it was fine. It was interesting. But after a year, it was also a little bit boring. So, I spent a lot of time working in front of a computer, but not a lot of time interfacing with people, and then it became clear to me that I wanted to do something more people-facing.

Teaching at a liberal arts college likely does not provide the same level of pay as her previous job at a technology company in Silicon Valley. However, in college teaching, Elizabeth gains a sense of satisfaction that was missing in her higher-paying position. Hence, the intrinsic motivation fueled by a personal sense of satisfaction outweighed the extrinsic motivating factor of monetary compensation. Chloe noted. “I really enjoyed my time being there, teaching and helping others.” When Felix was asked why he thought his teaching was inspirational, he succinctly stated. “I think it’s a personal interest.” The satisfaction that comes from making a difference in the lives of others is a source of motivation to continue to educate students.

**Nonconforming.** A surprising characteristic of the inspirational STEM professors interviewed is an underlying trait of rebellion. Often, these professors experienced a course in their own background that served to point them in an opposite direction. For Adam, much of his desire to provide high-quality teaching stemmed from his own experiences. These experiences were not all positive, but the negative ones were just as important to determining how Adam teaches today. Adam explained how one professor in particular affected his teaching:
I had a differential equations professor who said, “I’m not going to learn your name because I want to be totally objective in a grade.” And I said, “I’m not going to be like these people” because you want to be able to motivate.

In Adam’s case, it was past educational experiences that affected his teaching style. For Gideon, his interactions with others pointed out his uniqueness. He stood firm in his own convictions:

One thing I wanted to mention - because I am different. That’s different.
Whenever you’re different, there are going to be people around you that don’t like you because you’re different. [Laughs]. And I found out that I have people that don’t like me and people that do like me in the religion department and in the science department. The ones that don’t like me, I go, “I’m not going to apologize. That’s just who I am.”

When discussing pedagogy with Gideon, he maintained the same individualism: “Well, let me tell you what I think about pedagogy, okay? I’m a little bit rebellious against the best practices concept.” He later stated, “I don’t care if people said this is a good thing to do. If it’s not working in that situation, it’s not a good thing to do!” Gideon has a strong sense of what he is trying to accomplish, and it became obvious through his comments that he learned to weather outside storms and stand firm in his own ideas. Daniel’s form of rebellion came more from the culture of his discipline. He analyzed how the traits of people in his field of engineering prevented progress in engineering education:

Engineering assumes that people are rational, assumes that emotion doesn’t matter, and assumes that if you build a better mousetrap, people will come….
There is a great deal of hubris to engineering. Engineers think that “give me a problem and I can solve that. Anything that you can identify, we can engineer a way to make that better.” So, the fact that we talk about reengineering engineering education is like, just think about it for a second: Everything is a nail when you’ve got a hammer, and engineers have a pretty big hammer.

The conversation made it clear that acknowledging these factors developed an even more personal desire for Daniel to strive forward and make changes. Since most of his professional culture made it difficult to shift focus in higher education, someone needed to push harder to make the changes happen. And that someone, Daniel determined, included himself.

STEM professors have an uphill battle to climb to make substantive and meaningful improvements in the content, purpose, style, and outcomes of STEM higher education. Numerous students have already benefitted from the inspirational style of the professors interviewed in this research study. These professors stay motivated by their students. They find personal fulfillment and satisfaction in their work. They remain firm in their determination to prevent their own negative experiences from continuing forth and in their desire for positive growth and change moving forward.

**Future Change**

Since these STEM professors have already made a positive impact, it would be a missed opportunity not to ask them about future desirable changes in STEM higher education. Thinking more globally, what changes would these leaders like to see? The
two most common areas of discussion involved issues of diversity and a shift in higher education toward more personal development of students.

**Diversity.** Almost all of the professors agreed that STEM professions are dominated by white men (Makarova et al., 2019; OECD, 2012). Chloe acknowledged challenges at her own institution, which “had, to an extent, been reinforcing the message that society gives our students in general; that tech is not for people of color. So now we’re trying to make small changes to shift that culture, but it’s hard.” While many noted some recent improvements in the level of diversity, more work needs to be done. Felix observed that in his discipline, “I think we all have a lot of problems, in chemistry specifically, maybe, with gender and teaching, that typically the professors are all white males, and that needs to change.” The female professors in this study noted their own lack of experience with any female instructors. Elizabeth mentioned, “It wasn’t until grad school that I finally started to have female professors.” Since she did not have any role models in her field, she indicated it is essential for her to inspire young women in her classes. This is not an easy problem to solve. Elizabeth noted:

There’s a lot of things I would like to see happen in terms of gender balance and inclusivity, but I don’t know. I don’t know how to make those things happen easily. There’s a lot of efforts that have been directed at trying to equalize those issues, but I haven’t seen a lot of success.

Success is not widespread, but Chloe observed that steps can still be taken at individual institutions. She said, “I know society, in general, doesn’t tell black and brown girls that they belong in tech - messages that they get from a young age. So, I’m trying to work to
make my department be more aware of that also.” This awareness ultimately developed into a group of faculty and students who formed a committee to work on issues of diversity and inclusion of women. Chloe was particularly excited that students instigated this idea and brought it to the faculty in her department. That act demonstrated that her department was open to suggestions and trusted by the students. Another female professor, Hannah, grew up in an area where gender disparity was not as substantial. She described her background:

Of course, I knew I was going to be a scientist when I was in the second grade. It never occurred to me to have to explain why… Until I came to [name of graduate school], it never occurred to me that I had to defend my sex when I was talking about my academic interests.

Hannah worked to improve the conditions at her institution. Through various programs, she would “try to equip students who come from disadvantaged backgrounds to figure out how the hell to deal with what they’ve got now.” Frustrated with an inability to support disadvantaged students sufficiently, Hannah indicated, “I’m not so sure that educational institutions should be masquerading as social laboratories without articulating it to themselves, in terms of what can we do and what can’t we do.” Much more needs to be done, but progress is slow, and the path is unclear.

**Personal Student Growth.** Since this group of professors seems heavily focused on student learning, it is not surprising that a shift toward the personal growth of students in STEM higher education across the board also arose as an issue. Those interviewed would like to see individual course shifts and complete curricular changes to better
prepare students for the future. Many of these changes revolve around altering perspective. Higher education instructors might want to think differently about the students in their classes: how to engage them more deeply and whether the existing mechanisms allow students to construct knowledge and apply it to new problems. Fundamentally, STEM education may need to question existing assumptions in how students are served by the existing courses. As Daniel stated, “there’s a space around rethinking education generally to try to break down some of the barriers between disciplines around sort of underlying assumptions about how the world works and how things ought to be.”

Professors desire a change in student learning outcomes to be more focused on preparation for life and less about the details of the existing content. For Ben, the confusion regarding information about the coronavirus increased his attention to the lack of numeracy that exists even in STEM students. He bemoaned, “I would like to think that those in STEM would have a little bit better understanding of budgeting and how numbers work, but that doesn’t necessarily mean they do.” Despite courses in advanced mathematics, Ben was concerned that STEM majors may still not be able to analyze qualitative data critically. Therefore, he would like to see the intense focus on textbook content expanded to include more practical skills necessary for life. Similarly, Felix also noted a need to alter the current content in his field. “Nothing comes from nothing, so we have to talk about this. The way that we teach chemistry, to keep on harking back to those old German organic chemists, needs to change as well.” He would like to see
relevant issues such as climate change, energy, and proper treatment of waste become part of the chemistry curriculum.

In addition to changes in specific courses or fields, interviewees also spoke about bigger picture issues within STEM higher education. Despite the historical and current emphasis on the subject matter, some professors expressed an aspiration for education to transform away from an industrial, factory model toward a place of personal growth and development. Since a pandemic during spring semester required a shift to online education for all of the professors, Adam had the opportunity to reflect upon the difference between how courses are delivered:

I think it's still going to be faculty members who are motivated that are going to help students learn how science is done. Not only the what about science, but how science is done to use what they’ve learned to become a problem solver. It’s going to require people. Education is people. It’s not machinery.

Adam’s comments serve as a reminder that it will require faculty can teach the extension of scientific facts into applications and investigations for education to become more valuable for the learner. Daniel painted a picture of broad, sweeping change in STEM higher education:

The idea that education is a prerequisite for doing meaningful things is something that we should really be questioning. I think, in fact, that education is a lot more powerful if you actually think about learning and value creation or learning and authentic engagement in the world as being things that are happening at the same time in reinforcing ways. I think questioning the sort of idea that education is a
sort of prerequisite and is a product as opposed to education being a thing that happens in the process of doing stuff in the world, that’s another direction.

Rather than treating higher education as a time to absorb content that a student might need in a future career, Daniel instead equates learning with “authentic engagement in the world.” Certainly, this is not a new notion but connects with the experiential learning work of John Dewey and David Kolb. Unfortunately, very little substantive change has occurred over the decades. This does not prevent the inspirational professors from hanging onto hope for the future. As Gideon mentioned, “we’re all on the road to change. I’m still becoming something different every day.” The students are changing, the faculty are changing, and with intentional efforts, STEM higher education will change.

Summary

This chapter provides evidence for the coded analysis of eight interviewed STEM professors. The researcher used open, axial, and selective coding to analyze the transcripts. A second coder independently engaged in the same process, and the result was a surprising level of agreement. The following categories emerged: professorship, culture, pedagogy, inspiration and motivation, and future change. The professors were selected for the study due to evidence of inspirational and transformational teaching. Their thoughtful words in responses to interview questions provided the substance for this chapter to tell their experiences. The themes emerged from the data rather than being imposed by the questions from the outside. The following chapter discusses the results of the research within the framework of transformational teaching, as well as implications for future practice and study limitations.
CHAPTER 5

Discussion

During this era when rapid advances in technologies affect many aspects of the economy and everyday life, STEM higher education needs to focus on problem-solving and lifelong learning capacities to prepare students thoroughly. The complex problems present in a globalized society demand creative and technical solutions. Higher education must accept its role in preparing students not only to succeed in careers but to apply technology to grow a peaceful and more equitable civilization. The interviewed STEM professors welcomed this responsibility. They inspire future generations. While this is a desirable outcome, it is rare. To better understand how this is possible in a culture of passive learning, this research aimed to investigate the mechanisms by which transformational STEM professors inspire higher education students. In this chapter, the results are discussed through the lens of transformational leadership. Implications for STEM teaching in higher education, limitations, and future research directions are considered.

Transformational leadership framework

In chapter four, the results were presented according to themes developed through open, axial, and selective coding. The professors’ words were put forth as evidence of the various unifying concepts that emerged. In this chapter, the results are considered through the framework of transformational leadership. The four dimensions of transformational leadership as defined by Bass and Avolio (1994) are idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. Although written
for organizations, the core concept of each dimension also supports a cornerstone of transformational teaching, as seen through the responses of the interviewed STEM professors.

**Idealized influence**

A leader exhibiting idealized influence articulates a vision and serves as a positive example, worthy of respect. Educators with idealized influence are role models who are trusted by their students. Bass and Avolio (1990) indicated:

> Inspirational leaders can articulate, in simple ways, shared goals and mutual understanding of what is right and important. They can provide visions of what is possible and how to attain it. They can enhance meaning and promote expectations about what needs to be done. (p. 15)

Within transformational teaching, the professor’s ability to articulate goals, provide vision, and enhance meaning encourages students to interact with classroom material more potently and productively. Professors who embody these qualities can draw higher levels of student engagement by presenting content as part of a more profound journey to understanding and long-term success. In Chloe’s male-dominated field, she offered a vision for her female students to stand firm. Instead of teaching only programming skills, Chloe prepared her students for the realities of the industry environment. She did so by encouraging them to be confident and speak up in a workplace that may not take them seriously. She permitted her students to be bold:

> When you go and you graduate, you’re going to be in a very different culture….You’re not going to feel safe. But if you know what you’re saying - if
you’re confident, and you keep that confidence, you’re going to be fine. And you don’t need to just lower your voice. You can speak up if you know what you’re saying is true. It’s okay to speak up. Because her students trusted and respected her, they heeded her words and became valued employees and leaders in their fields. Chloe also reported a level of trust that the students have with the entire department. This trust means that her department is “the department you can go to if you want to talk.” The idealized influence behaviors of the faculty members resulted in students who were more willing to follow. Adam considered this level of trust to be necessary for his teaching:

A personal relationship should be full of integrity, and it should be full of trust. It has to be something that’s solid, that’s complete. It’s whole. It’s a good foundation. And then it has to be so solid that a student feels they can trust it. If the students do not have faith and trust in the professor, they are less likely to do the hard work necessary to engage in deep learning. When professors outline their vision, and the students can trust the professors to guide them toward that vision, they become inspired.

While idealized influence was evident in the words of the professors, it was not the most critical component of transformational leadership noted. Bass (1985) initially labeled idealized influence as “charisma” (p. 27). This was renamed in subsequent articles to eliminate any connotation of idolization. Professors in STEM who do not consider themselves to be charismatic may be relieved that even though idealized
influence remains a dimension of transformational leadership, it is not the sole component of becoming an inspirational professor.

**Inspirational motivation**

Motivation is key in students’ experiences of processing and absorbing deep levels of information (Biggs & Tang, 2011; León et al., 2015). Atkinson (2012) reported, “all too often, teachers (and administrators) in disciplines such as engineering and physics go out of their way to make the first year difficult, boring, and painful” (p. 35). The participants in this study do not reduce the difficulty of the material, but they reduce the pain of learning. Transformational teachers inspire students to challenge themselves to grow as both learners and individuals and invest the necessary time and effort to understand and apply the course material. The interviewed professors indicated that they motivate students through a deep and personal commitment to their teaching and a deliberate effort to encourage their students both in and out of the classroom.

The importance of creating an inspiring and motivating environment in the classroom cannot be understated. Rosebrough and Leverett (2011) argued, “education should be more about inspiration than information” (p. 28). Throughout his interview, Daniel consistently pointed to his drive to reshape engineering education toward personal growth as the underlying source of his ability to inspire students. He acknowledged that engineering suffers from “a kind of exceptionalism that fails to recognize the value that other ways of thinking, that other disciplines, can bring to the table.” He indicated a desire to push back against an engineering culture that believes “people are rational…emotion doesn’t matter.” Daniel chose instead to focus on the holistic
development of students. Daniel resisted the idea that the sole purpose of education is to obtain a job:

If you think about education purely as acquisition of content knowledge so you can subsequently do something, so this very kind of prerequisite framing of education, you end up with an education system that looks a lot like the one we have.

There is a clear thread throughout Daniel’s comments that he strives to impart more than course content. His goal is to inspire students to reach their full potential by bringing the world into the classroom instead of acting like the class is preparation for the world. He noted, “the idea that education is a prerequisite for doing meaningful things is something that we should really be questioning.” Daniel created a motivational classroom by presenting factual knowledge as the key to unlocking creative solutions to real-world problems. When students can connect the content to an application, they are motivated to learn new ways of thinking. Gardner (1999) indicated, “leaders don’t invent motivation in their followers, they unlock it” (p. 145). By enrolling in an engineering program, the students have already indicated a desire to use their talents to design and build working solutions to technical problems. When mathematics and science discussed in the classroom do not appear to connect with their goals, the students lose interest.

Transformational educators practice inspirational motivation and keep the classroom a dynamic learning environment.

Burke and Nierenberg (1998) reported three aspects that students identified in inspirational professors: caring toward students, positive attitudes, and dedication toward
the job. When the leader demonstrates high levels of dedication, the followers build commitment to the shared vision. Adam described his method of motivation: “You project yourself to them.” His students experience inspirational motivation through the passion that Adam displays in the classroom. Elizabeth motivates her students by spending time structuring and preparing the course. She tells her students, “I’m investing time, and I hope you’ll do the same.” To inspire and motivate, instructors should approach their courses with optimism, enthusiasm, positivity, and dedication.

The qualities of an inspirational teacher, especially dedication, do not come freely. Professors who maintain high levels of enthusiasm in their courses and successfully involve their students do so as a result of many hours of work. Time is invested in both course preparation and student engagement. Hannah indicated in her interview that her life as a teacher was “very exhausting” and “the world didn’t actually realize what it was like in the trenches.” This theme was repeated across all the interviewed professors. Hannah further specified she spends “ten hours on every lecture” to meet her own standards. This careful investment of time exemplifies the dedication that students recognize in class. The time professors take to thoroughly prepare their courses with student learning outcomes in mind can foster a stronger connection between the instructor and the students. It goes a long way towards increasing “cognitive learning, affective learning, student motivation, student communication satisfaction, student participation, and perceived instructor credibility” (Bolkan & Goodboy, 2009). There is a risk in investing so much time. Ben admitted that he had “no boundary for time,” and several interviewees expressed frustration with burnout due to overextending themselves.
Gideon experienced “a brief period where I had a little bit of disillusionment and burnout…I felt a little guilty.” The toll on professors who regularly spend an overabundance of time working can quickly spiral out of control. Despite the rewards that come from devoting extensive hours towards class preparation and working with students, professors should be encouraged to maintain their own mental health and be supported in these efforts. It is irresponsible for institutions to demand that instructors devote inordinate hours to educating students while also working on research. The ultimate result of burnout will not be beneficial to anyone. Since institutions cannot create more time in a day, they should be aware of what they incentivize and how that impacts behaviors. If schools aim to truly prepare students to be productive members of society, then faculty need time to create meaningful experiences.

The impetus for acting with inspirational motivation came from multiple sources. Professors commented on motivation through connections with their students. These connections are mutually beneficial and inspirational to both the students and the faculty. The interviewed professors are also motivated through personal fulfillment in their work. Students sense the personal dedication that these professors give to their jobs. This motivates the students to do their part in the educational process, as they feel respected by their professors. As Felix indicated, “my strength is that my students like me and like what I do. Hopefully, that then shows up in their ability to do the work.” A unique motivating factor that emerged from the interviewed professors was a rebellious and defiant attitude. This pushed them to continuously seek new paths to contradict how they were taught. The poor educational experiences that they endured during their schooling
spurred them to teach differently and to approach their courses from a new perspective. Chloe initially planned to go directly into the corporate world after graduate school. She reported to her advisor, “I like teaching, and I like research, but I don’t like this.” Chloe attended a graduate school at a national university where the professors only cared about “funding, funding, getting money, grants, funding, funding. That’s all they talked about.” This experience almost prevented her from becoming a professor. Instead, she used this negative experience as motivation to teach in a way that demonstrates care and concern for each student instead of focusing on funding. Students now benefit from this approach that differs so much from Chloe’s own experience. Rather than continuing to teach how she was taught, Chloe managed to change direction and go against historical traditions in her discipline. Bias is formed through personal experience, and for most of these STEM professors, the negative experiences of their schooling laid the groundwork for oppositional defiance. Fortunately for the students, defiance opened the door for a teaching philosophy focused on student growth.

**Intellectual stimulation**

Intellectual stimulation occurs when the “leader arouses followers to think in new ways and emphasizes problem solving and the use of reasoning before taking action” (Hater & Bass, 1988, p. 696). Employers note a lack of soft skills, including the ability to “continue to learn over time and solve complex problems” (Belkin, 2015). Being able to ask focused and nuanced questions, think critically on an issue, and understand the big picture are skills foundational to many STEM fields yet often overlooked in favor of required curricula. According to Arum and Roska (2011), this results in many college
students graduating with “gains in critical thinking, complex reasoning, and writing skills (i.e., general collegiate skills) [that] are either exceedingly small or empirically non-existent for a large proportion of students” (p. 204). Transformational professors continuously question how to advance the students from memorization and recall to application and synthesis.

The interviewed professors did not dismiss the value of knowing facts. However, this type of understanding was not considered the sole purpose of the course. Instead, content knowledge was viewed as only one aspect of learning. As Gideon indicated, “the educated person is able to apply logical reasoning to those facts.” For these inspirational professors, facts serve a greater purpose. Adam’s discipline often focuses primarily on memorization. However, his philosophy is that “facts then also integrate into doing problem-solving.” In traditional STEM courses, knowledge of facts is the primary purpose of the course, which often implies a lecture-oriented method to transmit information efficiently. The interviewed professors considered factual knowledge to be one step in advancing critical thinking skills and solving complex problems. Educators focusing on content and memorized facts are less likely to support independent critical thinking that encourages students to pursue deep levels of knowledge at the expense of time devoted to required curricula. Eyler (2009) succinctly stated, “transfer of knowledge requires deep understanding. Recall and reproduction of material taught in the classroom do not constitute understanding” (p. 27). The inspirational STEM professors structured their teaching with a student-centered foundation rather than a formula for acquiring content.
Since the leaders in this study are college professors, intellectual stimulation is almost a certainty. Solving problems is a standard procedure in STEM courses. However, the strategies used in the classroom can substantially affect students’ level of engagement with reasoning skills. Active learning intrinsically emphasizes a comprehensive effort to engage students with the material through a critical thinking lens (Carmel et al., 2015; Freeman et al., 2011; Kogan & Laursen, 2014; Pakala & Bose, 2015; Ruiz-Primo et al., 2011; Watkins & Mazur, 2013). Since the inspirational professors sought to include problem-solving and deep learning, one might expect a common thread of active learning strategies. However, that was not the case. Each professor was explicitly asked, “what pedagogies do you use that you consider to be effective?” Surprisingly, a theme of active learning methods did not arise in the coding process.

The interviewed professors did not have a consensus on teaching methods used. Elizabeth’s plan involved trying to “make the classroom as interactive as possible.” She then noted her frustration with the switch to online teaching during the semester. She bemoaned, “We really miss the student contact.” Instead of describing different methods of teaching, her comments reverted to a focus on the connection with students. Adam also referred to an overarching idea rather than specific techniques. His goal was to “introduce [students] to a world of critical thinking, being able to express themselves with better writing and verbal arguments.” The rebellious nature of one professor was displayed in his response. Gideon stated, “Well, let me tell you what I think about pedagogy, okay? I’m a little bit rebellious against the best practices concept.” Rather than offering up any ideas about what pedagogies he used, he described in detail why he does not follow best
practices. He indicated, “the best thing to do depends on the teacher and the students that are involved.” Once again, he showed his consideration for the individual student. Ben provided more detail than others regarding his teaching methods:

I know some teachers have different ways of showing visual and other types of things, but that’s my approach: just show them the big picture, break it down, and continue to scaffold. In the meantime, let them know that you actually care, that this is a safe learning environment, and that you can say whatever you want in the classroom. And don’t be afraid of being wrong. And that’s pretty much served me well over the years. It’s a pretty simple answer, and I don’t know if you wanted anything more complicated. But that’s my approach.

Embedded in the description of pedagogy lies the heart of the matter: caring. The participants used intellectual stimulation to inspire students successfully. However, this component of transformational leadership was not the most influential one. Repeatedly, the pedagogies and student-centered outcomes stemmed from a desire to address the personal growth and development of the students.

**Individualized consideration**

Bass (1985) stated that a leader who uses individualized consideration would give “individualized attention and a developmental or mentoring orientation” to followers (p. 83). According to Leithwood and Sun (2012), individualized support positively impacts student achievement. Bolkan and Goodboy (2009) hypothesized, “transformational leadership, then, may foster learning outcomes, participation, and teacher credibility because students perceive these educational practices as ‘personalized’ through the
individual consideration of each student” (p. 303). They found that transformational leadership promotes cognitive and affective learning. Students demonstrate increased motivation and engagement when instructors lead with a style that involves individualized consideration. In a study of mathematics teaching, Boaler (2000) indicated that students placed “their relationships with others and the interactions they experienced as central to their learning of mathematics” (p 389). The interviewed professors provided strong evidence of the usage of individualized consideration.

The participants in this study all practiced transformational leadership in their classrooms. Nowhere is this more evident than in the component of individualized consideration. When speaking about her students, Elizabeth indicated, “the message I want to send is that I care about you, and I’m glad that you’re here.” All students should feel welcomed so that they desire to join in the process of learning. Ben stated, “I think the most important thing is to let every person in your classroom actually feel like they’re one-on-one with you.” This aligns with previous research by Cranton (2006): “Fostering transformative learning in the classroom depends to a large extent on establishing meaningful, genuine relationships with students” (p. 5). This relationship does more than make the class enjoyable. Ben pointed out, “if the students know you believe in them, they will learn better.” This improved learning results in students who are fully prepared for the challenges of a technological society. Price (2005) elaborated, “teaching and learning are relational processes, involving co-creating knowledge through relationships among students, between students and teachers, and through the environment in which
these relationships operate” (p. 6). The individualized consideration displayed by the participants punctuated a goal of innovative STEM graduates.

When Gideon looked ahead at the future of STEM higher education, he desired “that it be as personal as possible. Because I really believe in the personal angle on education.” He practiced what he preached. Gideon told his students, “you’re more than a human being, you’re a human becoming. We’re all on the road to change. I’m still becoming something different every day.” By acknowledging his own vulnerabilities, he acknowledged the process of learning as a deeply personal endeavor. Wenger (1999) wrote:

Because learning transforms who we are and what we can do, it is an experience of identity. It is not just an accumulation of skills and information, but a process of becoming – to become a certain person or, conversely, to avoid becoming a certain person….We accumulate skills and information, not in the abstract as ends in themselves, but in the service of an identity. (p. 215)

Participants engaged in individualized consideration by establishing relationships with their students as the foundation of an environment where students can begin to explore and grow. The interviewed STEM professors inspire their students by prioritizing the transformational leadership component of individualized consideration.

Individualized consideration can be considered a necessary, but not sufficient, component of transformational teaching. Professors need to extend care into addressing learning outcomes that value the application and integration of knowledge over memorization, such that students are engaged in deep learning. This becomes an impetus
to adapt new active learning strategies in the classroom. Intellectual stimulation should be utilized to improve students’ abilities to conditionalize knowledge rather than recall material. Students can then see the big picture and solve new problems. The relationships with students combined with core beliefs in developing these students into critically thinking STEM professionals enable the inspirational professors to press forward in a culture that still focuses on the passive transmission of factual knowledge.

**Implications**

Albert Einstein famously said, “a society’s competitive advantage will come not from how well its schools teach the multiplication and periodic tables, but from how well they stimulate imagination and creativity” (as cited in Isaacson, 2007, p. 7). The STEM professors in this study might adjust the phrase to read, “a society’s competitive advantage will come not only from…” They still support teaching factual knowledge. The distinction is how such knowledge is both disseminated and perceived. In most STEM courses, the transmission of facts from the expert to the novice is the sole purpose. The inspirational professors use factual knowledge as a stepping stone to solving complex problems. Su (2011) expanded on this notion:

> Learning is not an administrative mechanism in pursuit of the construction of “disciplined knowledge” for its own sake, which accounts for closure; instead, learning unfolds the relationship of the learner and the world to the generation (creation) of knowledge for oneself. (p. 58)

Undergraduate STEM courses would benefit from a renewed focus on how factual knowledge becomes relevant to the whole student. Even though changes in attitude are
difficult to quantify and measure, STEM instructors should not dismiss a positive shift in disposition as unimportant.

Despite the numerous studies demonstrating increases in student achievement associated with active learning, many faculty in STEM are very canon focused and orient teaching toward the transmission of factual knowledge. Research has repeatedly pointed to the value of implementing learner-centered strategies that transform the lecture-oriented classroom into an engaging and active space for students (Blanchard et al., 2010; Knight & Wood, 2005; Lasry et al., 2008; Prince, 2004). Rogers (1969) indicated, “placing the student in direct experiential confrontation with practical problems, social problems, ethical and philosophical problems, personal issues, and research problems, is one of the most effective modes of promoting learning” (p. 162). The question arises as to why these strategies fail to be sustained by professors who frequently revert to the teacher-centric strategies more familiar to them. The interviewed STEM professors collectively pointed to a crack in the process of adopting learner-centered strategies: perspective. A typical process of reshaping STEM classrooms involves the professor attending a workshop or seminar that introduces learner-centered strategies and subsequently encourages faculty to adopt such practices. The professor may initially champion the new methods with enthusiasm, but over time recedes into more comfortable, traditional lecture styles. Without recognizing why new strategies are necessary, change is unlikely to be sustainable. Henderson et al. (2011) argued for taking several steps in improving STEM education: “First, effective change strategies must be aligned with or seek to change the beliefs of the individuals involved. Second, change
strategies need to involve long-term interventions, lasting a semester, a year, and longer” (p. 978). Professors must be willing to acknowledge the current hurdles in their classroom and their department culture to foster an internal motivation for change. Thus, sustained change in higher education may be more likely to occur when the necessity for change is addressed first, not specific active learning strategies.

The learner-centered strategies recommended by research do have their place in the classroom, as indicated by the studied positive outcomes of such methods. Continuing to educate, encourage, and train faculty in the practices of active learning may lead to increasing student outcomes in STEM higher education. However, these strategies should be seen as organic products of a professor’s philosophy rather than the direct path to change. Jumping on the bandwagon of various new teaching techniques is problematic when such methods are not aligned with the educator’s philosophies. In a review of the literature, Henderson et al. (2011) claimed:

One thing that is clear from the articles within this category that presented at least adequate evidence to support their claims is that the common change strategy of developing and testing “best practice” curricular materials and then making these materials available to other faculty does not work. (p. 971)

If the underlying reason to adopt learner-centered strategies is based primarily on directives, there may be a weakness in the lasting determination of the professor. Arum and Roksa (2011) argued:

One cannot mandate learning through the imposition of increased regulation; rather, for change to occur, various entities and actors will have to demonstrate in
their behaviors and actions a deep commitment to these goals and a willingness to take personal and institutional responsibility for their successful achievement. (p. 206)

Professors who recognize the need for change in higher education should be provided support for critical engagement with their philosophies to examine the alignment of current ideologies with desired future outcomes. An ongoing process of self-reflection is key to adjusting classroom practices to provide a transformational experience to students consistently. Sustainability is improved by this change emanating from faculty, rooted in a clear motivation to improve STEM higher education. Self-reflection can be embedded in understanding transformational leadership components as they pertain to teaching. Thus, professional development programs focused first upon transformational leadership components before specific classroom teaching techniques hold the possibility of sustained improvement of student outcomes in STEM higher education.

**Recommendations**

Despite recent reform movements, STEM higher education remains focused on transmitting factual knowledge from professors to students. High hopes for improvement in STEM education have been pinned on active learning strategies. These teaching methods are infiltrating some classrooms, but most spaces are still teacher-centered and lecture oriented. Participants in this study did not shed light on particular strategies that work. Instead, the transformational leadership component of individualized consideration, coupled with intellectual stimulation, served as foundational aspects of their teaching. Faculty conceptions need to change before learning new active learning
strategies. A foundation of care and concern for the students, combined with mutual respect and trust, must be achieved to encourage students to engage in deep learning. Herman et al. (2018) stated, “approaches are likely ineffective because they fail to address the implicit beliefs that drive instructional decisions” (p. 32). The descriptions from the experiences of the interviewed STEM professors echo these sentiments.

*Recommendation: Professional development opportunities should include more than teaching techniques. First, they must address the teaching philosophies of faculty members.*

Understanding is incomplete when students fail to transfer what they know. The acquisition of knowledge is not enough. Students must be able to take transfer knowledge and apply it to new situations. Courses in STEM higher education should be designed to interact with the world rather than pretending to prepare students for the world. Rather than accumulating factual knowledge, STEM courses must transform problem-solving and critical thinking to be the curriculum. Faculty need time and resources to transform their courses where this type of learning can occur. Reflecting on the current state of STEM education, aligning teaching philosophies with the desired program and learning outcomes, and keeping current with the latest advances in technology to bring relevant applications into the classroom all take time. When this is combined with the time professors spend developing mentoring relationships with students, burnout is a real possibility. Higher educational institutions should be sensitive to the time necessary to produce an outstanding education and rethink their culture to reward excellent teaching.
Recommendation: Universities and colleges need to respect and reward the time professors spend mentoring students. Professors should be supported in the hard work that is required to transform the classroom into a place that authentically engages with the world. They should provide support and offer mechanisms to change the culture of STEM departments and encourage high-quality teaching, including incentives for such work.

Limitations

To gather information about the experiences, values, and beliefs of a small subset of a population required qualitative rather than quantitative research. The comments provided by STEM professors provided detailed and thick descriptions of their lives as inspirational educators in disciplines known for passive learning. Coding allowed for themes to emerge, but the results cannot be extended to all STEM professors. Generalizability was not the intent of the study. While the researcher faithfully allowed the words of the participants to describe the phenomenon, the results of this study cannot be generalized to similar populations.

Purposive sampling was necessary to focus on only inspirational STEM professors. During the selection process, there was no knowledge in advance of the type of institution that housed each professor. After investigation, it turned out that 37% of the professors in the initial group hailed from national universities, otherwise known as R1 universities. Unfortunately, no professors from a national university responded to the email request for an interview. With incentives often tied to research, the experiences of this set of professors could be vastly different from their peers at liberal arts colleges.
Including professors from these institutions would help to add to the stories of inspirational STEM professors, especially in the descriptions of the culture of their departments.

Limitations can occur from items that are completely outside the scope of control. The original study was designed to observe the behaviors and pedagogies implemented in the classes of inspirational professors. However, the SARS-Cov-2 virus upended teaching, learning, and the entire way that people across the world interact with each other. The themes emerged from the interviews of the professors without any classroom observations. The researcher gratefully acknowledges the STEM professors who took time during a pandemic to engage in a conversation on teaching and learning.

**Future Research**

Transformational teaching increases both affective and cognitive learning in the classroom. This year, distance learning has replaced face-to-face environments for many schools due to the pandemic. Future research is needed to determine if the results can be replicated in online learning. The nature of online learning, whether synchronous or asynchronous, creates a different learning atmosphere. The participants in this study prioritized individualized consideration and intellectual stimulation, although all components of transformational leadership were displayed. More studies should be undertaken to determine if the components of transformational leadership have the same effects in a distance-learning environment.

Future research should include STEM professors in highly intensive research institutions. According to Gray and Drew (2012), these universities “achieve status
almost entirely through scholarly publications (or football teams), not through effective teaching” (p. 40). This atmosphere creates different expectations and culture than other institutions. The phrase “publish or perish” refers to the strict tenure process that professors at R1 universities must endure. “Promotion and tenure requirements at R1 schools center more on high-quality research output than on effective teaching” (Irons & Buskist, 2009, p. 118). When advancement is dependent on research and not teaching, it stands to reason that professors will allocate most of their time in the areas that are valued by the institution. The experiences of professors at national universities would likely be very different from those at teaching institutions. The heavy emphasis on research affects the department culture. Participants in this study had mostly positive comments and felt generally supported by their departments. This may not be the case for professors at national universities. Inspirational professors at R1 universities should be questioned specifically regarding the mental fortitude required to defy the standard traditions that exist in STEM education.

**Summary**

Students who are more academically engaged in a course tend to have higher performance levels, more motivation, and persist longer (Nelson Laird et al., 2008; Pascarella and Terenzini, 2005; Pike & Kuh, 2005). Active learning strategies promote student engagement (Tagg, 2003; Wang et al., 2017). Thus, these strategies have been regarded as a panacea for the ills that plague STEM higher education. Despite the promise shown, research indicates that implementation of active learning techniques in the STEM classroom has been slow and lecturing remains the primary method of
transmitting information (Shekhar et al., 2020; Stains et al., 2018). Preparing students to navigate the increasing complexities of our global society demands higher levels of critical thinking and problem-solving skills. Certain professors rebel against tradition to inspire and motivate students to engage in the work necessary to apply knowledge to new applications. This study aimed to better understand the experiences of inspiring STEM professors who flourish in a predominately passive culture. They motivate their students to apply scientific methodologies to new applications in a lecture-oriented environment that focuses on the transmission of factual knowledge.

Interviews collected data from transformational STEM professors who share the experience of inspiring students. The researcher developed “a composite description of the essence of the experience for all the individuals—what they experienced and how they experienced it” (Creswell et al., 2007, pp. 252–253). The transcripts were coded and themes emerged to “reduce individual experiences with a phenomenon to a description of the universal essence” (Creswell, 2007, p. 58). The universal essence was not an element of active learning strategies. Instead, the inspirational professors shared an underlying philosophy of care and concern for both student learning and the personal development of students as individuals. Before professional development programs train faculty in teaching techniques, they should first address beliefs about teaching and learning.

“If I can make people feel welcome or like they belong, then I feel like that’s the foundation upon which learning can occur. But if they don’t have that, then everything becomes a lot harder.” Elizabeth
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Appendix A

Interview Questions

Semi-structured Interview questions:

1. Briefly summarize your path to becoming a STEM professor.
2. Describe your educational philosophies.
3. What pedagogies do you use that you consider to be effective? How did you become aware of the methods that you use?
4. What words would you use to describe the culture of your department?
5. What words would you use to describe the culture of your scientific profession?
6. Former students have described your influence in the classroom as inspirational and/or transformational. What do you believe are the contributing factors as to why your teaching is described this way?
7. Traditionally, teaching in a STEM discipline at the college level has been primarily focused on transmitting factual knowledge. Describe your experience working in such an environment.
8. What changes would you like to see in STEM higher education moving forward?
Appendix B

Email Template

Dear [Professor’s name],

You have been identified as an inspiring STEM educator by your former students. As a doctoral candidate of the Educational Leadership department at Minnesota State University, Mankato, I am performing a research study under the guidance of my advisor, Dr. Ginger Zierdt, on how STEM professors inspire students in a culturally passive environment. As a part of this study, my goal is to interview transformational STEM professors. The results will be analyzed and written as part of a dissertation. I hope that you will be willing to participate in this study.

If you agree to participate, then my goal is to interview you. Since this cannot happen in person during these times, I am happy to use a format that is comfortable for you (videoconference using Zoom or through the telephone). During the interview, you will be asked questions about your working environment and what factors may be responsible for the positive impact that you have on your students. This interview will likely take around 30 minutes.

Attached to this email is a letter of informed consent that provides more details. If you agree to participate, then I would need a signed copy of the informed consent prior to the interview.

If you are willing to participate in an interview, then please respond to this email indicating that you agree to participate. I will then contact you regarding the letter of informed consent and finding a time that works in your schedule. If you have any questions at all about the research study or what will be expected of you, please do not hesitate to ask through a response to this email (Julie.kjeer@mnsu.edu) or by phone at (507) 995-0091. You may also contact the principal investigator, Dr. Ginger Zierdt, at Ginger.Zierdt@mnsu.edu or (507) 389-5433. Many thanks for your consideration.

Julie Kjeer
Department of Educational Leadership, Doctoral Candidate
Minnesota State University, Mankato

IRBnet ID: 15826841
Attachment: Letter of Informed Consent
Appendix C

Informed Consent

Transformational Teaching in a Culturally Passive Environment in Higher Education:
A Phenomenological Study of STEM Professors

Principal Investigator:
Dr. Ginger Zierdt
Armstrong Hall 114B, Mankato, MN 56001
Ginger.Zierdt@mnsu.edu
(507) 389-5433

Graduate Student Researcher:
Julie Kjeer
Dept. of Educational Leadership
Julie.Kjeer@mnsu.edu
(507) 995-0091

This research is being conducted by Julie Kjeer as a doctoral student under the guidance of Dr. Ginger Zierdt in the Department of Educational Leadership. The goal of this research study is to be able to learn more about the lived experiences of approximately 10 inspirational and transformational science, technology, engineering, and mathematics (STEM) professors who have been recognized by their students as having a positive impact. This will be done through interviews. The resulting transcripts will be coded and analyzed for themes, leading to a deeper understanding of this shared experience.

You are invited to participate in a research study of STEM professors who have been recognized as inspirational educators. I hope to learn how you are managing to have such a positive effect on students. You were selected for this study since you have either won a teaching award or your name has appeared on a public list of top professors. In addition, student comments that relate to your teaching indicate that you have displayed characteristics of transformational leadership in the classroom. For these reasons, I would like to ask you questions about your teaching and learn about your educational philosophies and methods to gain a deeper understanding about how you inspire students. For background information and context, I may ask about the culture of your department and discipline.

If you choose to participate, I will set up a time convenient to you within the next few weeks for a videoconference or telephone interview due to travel being inadvisable at this
time. The videoconferencing will occur using the online application Zoom, which is completely free to use. You would need access to a computer or a mobile phone and internet connection. I expect that the interview will last approximately 30 minutes. The video interview will be recorded using the record feature of Zoom and downloaded only on the researcher’s password-protected computer. Only the audio of the interview will be used and transcribed. If you prefer a telephone interview, the interview will be audio recorded in order for your responses to be transcribed. You may choose to not have the interview recorded. In this case, the student researcher will take notes on the conversation. These notes will be sent to you to confirm that your statements have been recorded accurately. The student researcher will transcribe the voice-recorded data collected in this study. Any identifiable private information, such as the name of the higher education institution where you work, will be removed from the transcript. Your name will not be associated with the research findings in any way, and only the researchers will know your identity as a participant. Anything that you discuss will only be used in such a way that you cannot be recognized. After removal of identifiable information, the remaining information could potentially be used for future research studies without additional informed consent from you. After the interview is transcribed and identifiable information is removed, you will have the opportunity to read through the transcript. The transcripts, with private information removed, will be stored on One Drive cloud storage and password protected. Only the student researcher and the faculty principal investigator will have access to the original transcripts. These files stored on One Drive will be deleted after three years from the completion of the research. There will not be any monetary compensation for participation; however, there will be my gratitude and appreciation.

A potential risk in this study includes being uncomfortable as I ask you to share information about your teaching philosophies and the impact of your methods on your students. Additional risks you will encounter as a participant in this research are not more than experienced in your everyday life. You may possibly find that reflecting about why your students find your teaching inspirational may be a positive experience and benefit your future teaching. You may also feel that you are contributing to a body of knowledge that could help current and future STEM professors become better educators.

Your decision whether or not to participate will not affect your relationship with Minnesota State University, Mankato, and refusal to participate will involve no penalty or loss of benefits. You are not required to answer all the questions during the interview and may discontinue the interview at any time desired. If you agree to participate at this time, you can still withdraw at any future time during the interview or refuse to answer any
question without penalty. You can also withdraw permission to use data from the interview within one week after the interview, in which case the material will be deleted and never used. Contact the student researcher via email (Julie.Kjeer@mnsu.edu) to withdraw from the study.

If you would like more information about the specific privacy and anonymity risks posed by online storage, please contact the Minnesota State University, Mankato IT Solutions Center (507-389-6654) and ask to speak to the Information Security Manager.

If you have any questions about this research study, contact the principal investigator Ginger Zierdt at (507) 389-5433 or Ginger.Zierdt@mnsu.edu. If you have any questions about participants’ rights and for research-related injuries, please contact the Administrator of the Institutional Review Board, at (507) 389-1242.

“I have read the informed consent document. I agree to participate in the research study conducted by Julie Kjeer in the Department of Educational Leadership at Minnesota State University, Mankato regarding inspirational STEM professors. I am free to ask questions and withdraw at any time without penalty. I agree to be interviewed and recorded. I am at least 18 years of age.”

Name of Participant (printed/typed)

____________________________________

Signature of Participant Date

____________________________________  __________________________
Appendix D

Institutional Review Board Approval Letters

April 29, 2020

Dear Scott Wurdinger:


Review Level: Level [II]

The reviewers commented, "We appreciate the investigators' diligence in addressing prior concerns."

Your IRB Proposal has been approved as of April 29, 2020. On behalf of the Minnesota State University, Mankato IRB, we wish you success with your study. Remember that you must seek approval for any changes in your study, its design, funding source, consent process, or any part of the study that may affect participants in the study (see https://grad.mnsu.edu/irb/revision.html). Should any of the participants in your study suffer a research-related injury or other harmful outcomes, you are required to report them to the Associate Vice-President of Research and Dean of Graduate Studies immediately at 507-389-1242.

When you complete your data collection or should you discontinue your study, you must submit a Closure request (see https://grad.mnsu.edu/irb/closure.html). All documents related to this research must be stored for a minimum of three years following the date on your Closure request. Please include your IRBNet ID number with any correspondence with the IRB.

The Principal Investigator (PI) is responsible for maintaining signed consent forms in a secure location at the university for 3 years following the submission of a Closure request. If the PI leaves the university before the end of the 3-year timeline, he/she is responsible for following "Consent Form Maintenance" procedures posted online (see http://grad.mnsu.edu/irb/storingconsentforms.pdf).

Cordially,

Bonnie Berg, Ph.D.
IRB Co-Chair

Jeffrey Buchanan, Ph.D.
IRB Co-Chair

Mary Hadley, FACN, Ph.D.
IRB Director

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Minnesota State University, Mankato IRB's records.
May 6, 2020

Dear Ginger Zierdt:

Your proposed changes to your Minnesota State University, Mankato Institutional Review Board (IRB) approved research ([Centered} Transformational Teaching in a Culturally Passive Environment in Higher Education: A Phenomenological Study of STEM Professors]) have been accepted as of May 6, 2020.

Thank you for remembering to seek approval for changes in your study.

If you make additional changes in the research design, funding source, consent process, or any part of the study that may affect participants in the study, you will have to reapply for approval (see https://grad.mnsu.edu/irb/revision.html). Should any of the participants in your study suffer a research-related injury or other harmful outcomes, you are required to report them to the Associate Vice-President of Research and Dean of Graduate Studies immediately at 507-389-1242.

Please bear in mind that your research activities must comply with all federal, state, and Minnesota State system guidelines and directives related to the COVID-19 health crisis. Since circumstances may change, you are responsible for monitoring developments that may affect your ability to conduct your research.

The letter approving your changes is attached to your original proposal; therefore, the original approval date has not changed. When you complete your data collection or should you discontinue your study, you must submit a Closure request (see https://grad.mnsu.edu/irb/closure.html). If you will be collecting data for one calendar year or longer, please submit a Continuation (https://grad.mnsu.edu/irb/continuations.html). Please include your IRBNet ID number with any correspondence with the IRB.

We wish you success in your research. If you have any questions, feel free to contact Mary Hadley at irb@mnsu.edu or 507-389-5102.

Cordially,

Bonnie Berg, Ph.D.
IRB Co-Chair

Jeffrey Buchanan, Ph.D.
IRB Co-Chair

Mary Hadley, FACN, Ph.D.
IRB Director

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Minnesota State University, Mankato IRB's records.