THE INFLUENCE OF ACADEMIC PREPARATION AND SELF-EFFICACY
ON GRADUATES’ CHOICE OF AND PERSISTENCE TOWARD
STEM DEGREES

By
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A dissertation submitted in partial fulfillment of
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To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation of SARAH JANE POOLER find it satisfactory and recommend that it be accepted.

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Abstract

by Sarah Jane Pooler, Ph.D.
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As our schools, districts, and government seek to effectively prepare students for post-secondary education and careers in STEM fields, many communities have created stand-alone STEM focused schools. While these schools have garnered attention, not much is understood about inclusive project-based STEM programs within comprehensive high schools. This study utilized social cognitive career theory in a mixed methods format framed by sequential explanatory design to understand the impact of self-efficacy and academic preparation developed in an inclusive STEM high school program on graduates’ choice of and persistence toward a college degree in a STEM discipline.

The study involved fifty-two graduates of an inclusive project-based STEM program within an urban comprehensive high school. The academic preparation of the students in the STEM program included project-based learning and Advanced Placement classes. Survey results showed significant relationships between graduates’ number of Advanced Placement classes, their high school career goals, and their choice of and persistence toward a college degree in a STEM discipline. Interview results showed that self-efficacy was cultivated by learning through
projects within STEM program classes. Additionally, the self-efficacy developed in the project-based academic context influenced graduates’ choice of a STEM career and their persistence toward a STEM degree.

Since most of the children in the United States are educated in traditional comprehensive high schools, it is important to understand how these schools could increasingly promote self-efficacy and academic preparation, inspire students to pursue STEM majors, and build their capacity to persist towards STEM degrees. This study provided research findings that may inform comprehensive high school leaders of the potential student benefits of developing a project-based STEM program. Even if the implementation of a STEM program is not feasible, the study findings suggest other potential areas of application for schools.
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Dedication

This dissertation is dedicated to my husband Doug Pooler and my sons Isaac and Aaron Pooler. I could not have done this program without Doug’s support. He took care of our boys and things at home during years of night classes and while I wrote at nights and on weekends. A million thanks Doug. I love you. Thanks to Isaac and Aaron for understanding that even though I missed time with them that I still love them very much.
CHAPTER ONE: INTRODUCTION

In our increasingly technological, globally connected, and innovation driven economy, there is a growing emphasis from policy makers and industry leaders to increase the numbers of qualified individuals to contribute to the Science, Engineering, Technology and Math (STEM) workforce (Cappelli, 2014; National Science Board, 2016, United States Department of Labor, 2007). Many reports state the critical need for the United States workforce to increase the number of STEM professionals to maintain and enhance personal opportunity in addition to our national productivity and prosperity (National Science Foundation 2015, National Academy of Sciences, 2016; Rothwell, 2014). Since 95% of STEM workers have postsecondary education and training (Carnevale, Smith, & Strohl, 2014), students choosing to enter STEM degree pathways and retention in university STEM degree programs such as engineering, life science, computer science, chemistry, medicine, and physics, are essential to increasing the number of people in the STEM workforce. In order to increase the number of STEM professionals, K-12 students must be prepared before college in ways that enable them to choose, enter, and persist in necessary post-secondary education to attain college degrees in STEM disciplines.

A focus on persistence in STEM from high school to college has become a national priority (Xianglei & Matthew, 2014). Persistence, like effort and resilience, is necessary for students to overcome personal, social, and academic obstacles to achieve their goals (Wilson & Kittleson, 2013; Zeldin, Britner, & Pajares, 2008). Persistence is a salient concept related to student retention or attrition in STEM degree programs. The impact of high school experiences on undergraduate persistence in STEM majors has become a research focus as the United States continues to attempt to meet increasing STEM workforce demands (Chang, Sharkness, Hurtado & Newman, 2014).
Examination of national statistics provides a means to understand this timely research agenda. Out of every 100 ninth graders, only six graduate from college with STEM degrees (U.S. Department of Education, 2015a). Fewer than 40 percent of students who enter college intending to major in a STEM field complete college with a STEM degree (U.S. Department of Education, 2015a; Olson & Riordan, 2012). Many students who enter college with the goal of obtaining a STEM degree ultimately switch majors or leave higher education altogether (U.S. Department of Education, 2015a). Persistence related to undergraduate STEM retention in college is composed of a combination of factors such as academic preparation and psychological constructs such as self-efficacy. These psychological constructs are developed not only from students’ personal abilities and college experiences, but also from the quality of pre-college preparation the students receive (Chang, Eagan, Lin, & Hurtado, 2011; Espinosa, 2011; U.S. Department of Education, 2015b).

A focus of STEM education has historically centered on the assumption that increased academic preparation through math and science achievement will certify that high school graduates are “ready” for university academics in STEM (Holdren, Lander, Varmus, 2010; National Research Council, 2011; National Research Council, 2012). Unfortunately, many students are not effectively prepared for STEM focused college courses. According to the most recent Programme for International Student Assessment (PISA) exam, U.S. students ranked 31st out of 35 in math, below the average for Organization for Economic Co-operation and Development (OECD) countries (National Research Council, 2016). On the PISA exam for science, U.S. students ranked 19th out of 35 for OECD countries (National Research Council, 2016). In 2014, only 45 percent of U.S. high school graduates were ready for college work in math; 30 percent were ready in science (U.S. Department of Education, 2015b). This could be
due to the fact that not all U.S. students have access to STEM courses. Only 48% of U.S. high schools offer calculus, 78% offer algebra II, 60% offer physics, and only 72% offer chemistry (U.S. Department of Education Office for Civil Rights, 2016). According to the same 2016 report by the U.S. Department of Education Office for Civil Rights, of schools with the largest populations of black and Latino students only 33% offer calculus, 71% offer algebra II, 48% offer physics, and only 65% offer chemistry. The inequalities that exist limit students’ opportunity to enroll in STEM classes and therefore limit their ability to achieve at levels needed for success in STEM degree programs. Even some of the highest achieving students, those in the top quintile for SAT/ACT, are not furthering their STEM learning from high school into college (Lowell, Zalzman, Bernstein & Henderson, 2009). While academic preparation in high school is an influential component to graduates choosing STEM majors, it does not explain the whole picture of why some students choose STEM majors while some do not. Additionally, the President’s Council of Advisors on Science and Technology reported that achievement and academic preparation in STEM are not sufficient to ensure students continue their STEM learning from high school through choosing STEM majors and STEM careers (2010).

In addition to academic preparation, another predictor of students choosing STEM majors are affective psychological constructs developed in high school, such as self-efficacy. A student may or may not develop self-efficacy to believe he/she is able to succeed in STEM. There are varying degrees of personal will, aspirations, and beliefs that affect students’ abilities to achieve academic success in STEM courses. Affective constructs were predictive even for students who were high achievers in advanced high school STEM courses. Maltese and Tai (2011) documented that student’s beliefs about their abilities and career interests were more strongly
correlated to them pursuing a STEM degree major than enrollment and achievement in high school STEM courses.

**Purpose of this Study**

The purpose of this study was to understand if graduates’ reflections of teachers’ emphasis, in an inclusive high school STEM program, on self-efficacy and academic preparation influenced graduates’ choice of STEM degree pathways and their capacity to continue STEM focused learning in college. Qualitative and quantitative data were collected and analyzed to identify whether the two constructs of self-efficacy and academic preparation influenced graduates’ choice to pursue a STEM degree and their persistence in STEM majors. While academic preparation and self-efficacy are two separate constructs (independent variables), the concepts of graduates’ choice of a STEM major and the continuation of their STEM learning in college were one construct (dependent variable). The unit of analysis was the graduates from an inclusive high school STEM program.

**Research Question**

My study was guided by the following research question:

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

My study utilized a mixed methods approach by analyzing qualitative and quantitative data from students who graduated from a specialized inclusive STEM program. The mixed methods design included an initial survey followed by semi-structured interviews. STEM program graduates responded to survey items related to self-efficacy and academic preparation as well as items related to their post-high school academic choices. The survey data was
analyzed to inform participant selection for the interviews. The participants of the study were men and women who graduated from the inclusive high school STEM program between the years of 2010 and 2016.

**Potential Impact**

The results of my study illuminate whether a comprehensive high school STEM program’s emphasis on self-efficacy and academic preparation affected graduates’ choice of and pursuit of a college degree in a STEM discipline. While Inclusive STEM High Schools (ISHS) have captured some research spotlight (LaForce, Noble, King, Century, Blackwell, Holt, Ibrahim, Loo, 2016; Lynch, Peters–Burton, Behrend, House, Ford, Spillane, Matray, Han, & Means, 2017; Means, Wang, Young, Peters, & Lynch, 2016; Weis, Eisenhart, Cipollone, Stich, Nikischer, Hanson, & Dominguez, 2015) comparatively little is known about STEM programs situated in urban comprehensive high schools. This study provides findings that may inform whether or not leaders of STEM programs may choose to emphasize self-efficacy and/or academic preparation. These results may yield valuable insights for school leaders and teachers in high school STEM programs as they select areas of emphasis to increase the capacity of graduates to choose and persist in STEM degree pathways. Eventually, the impact of my study resides in whether the reader determines my findings are informative to their particular context and life experiences (Morse, 1991; Morgan, 2007).

**Epistemological and Theoretical Framework**

“The theoretical framework, therefore, has implications for every decision made in the research process” (Mertens, 2003). Theories are developed to explain, predict, and understand experiences and, in many instances, to challenge and evolve prevailing knowledge (Mertens, 2003). The purpose of the theoretical framework is to contain or support the theory that
undergirds a research study. The purpose of the theoretical framework is to introduce the research study and describe how the theory provides context to the existence of the research problem (Swanson, 2013).

My study is founded on certain assumptions about knowledge claims. These claims might be called paradigms or theoretical frameworks (Creswell, Clark, Gutmann & Hanson, 2003; Lincoln & Guba, 2011; Mertens, 2003), or philosophical assumptions, epistemologies, or ontologies (Crotty, 2012). In my study, I make claims about what kind of data/evidence/claims I accept as contributing to new knowledge (epistemology), what philosophical position drives my study (theoretical perspective) and my process for studying it (methodology) (Creswell, 1994).

In the following sections, I make claims about the epistemological beliefs that are foundational to my study and the theoretical framework I utilize to frame my study. My research methodology is further discussed in Chapter 3.

Epistemological Framework

Post-positivism. The design of a study, including methodology, is determined by the research question, the epistemology of the researcher, and the theoretical framework related to the study topics (Marra & Palmer, 2008). The epistemological position that drives the methodology in my study is pragmatic post-positivism. Post-positivism accepts that data, evidence and rational contemplations form knowledge (Phillips & Burbules, 2000). Research conducted with a post-positivist worldview “seeks to develop relevant, true statements, ones that can serve to explain the situation of concern or that describe causal relationships of interest” (Creswell, 2013, p. 8). While post-positivism employs a deterministic perspective or framework where causes probably determine outcomes or effects (Creswell et al., 2003; Phillips & Burbules, 2000), I acknowledge that “objective reality can never be captured” (Lincoln, Lynham, & Guba,
and that research is “not ever truly objective” (Hughes, King, Rodden & Andersen, 1994). In aiming to understand causes and effects, my study will not claim to be definitive by any measure. My post-positivist position harmonizes with Richardson and St. Pierre’s (2008) perspective to “doubt that any discourse has a privileged place, any method or theory a universal and general claim to authoritative knowledge” p. 473. In agreement with Eisner (1992) and Thomas and James (2006), I accept that we experience reality through a combination of our personal frames and lived conditions. Each individual creates her/his version of reality through the lenses of personal “skill, point of view, focus, language, and framework” (Eisner, 1992, p. 11). Even though post-positivist researchers strive for standards of validity and reliability and the elimination of bias (Phillips & Burbules, 2000), they accept that personal values do affect the social context of the study and what the researcher chooses to notice, observe, and analyze (Creswell, 2013). Our personal lenses ensure the impossibility of value-free knowledge (Denzin, 2015). Evidence and knowledge gained through research will always be imperfect and fallible (Phillips & Burbules, 2000).

My study was designed, conducted, and analyzed within a post-positivist epistemological framework. Although numerical data in the quantitative phase may be interpreted by a traditional positivistic researcher as objective and value-free without need for negotiation or debate (Johnson & Onweugbuzie, 2004), my post-positivistic position rejects this claim. Historically, quantitative methodology aligned with a positivistic epistemology represented a researcher perspective in which nature and the phenomena of nature (human interactions, behaviors, attitudes, etc.) could be systematically observed, measured, statistically analyzed, and reported as a knowledge claim that could be generalized (Guba & Lincoln, 2005; Johnson 2004). As a result of modern research approaches, I believe it is not accurate to label quantitative researchers or
their methodologies as positivistic. Traditional positivism has been replaced by newer research epistemologies such as post-positivism (Yu, 2003). My choice to reject a positivistic claim of producing numerical generalizable knowledge is thoroughly supported by modern researchers (Guba & Lincoln, 2005; Mertens, Bledsoe, Sullivan, Wilson, 2010; Tashakkori & Teddlie, 2010). Indeed, post-positivism is the term that represents most current quantitative researchers (Phillips & Burbules, 2000).

Pragmatism. To attempt to understand the potential influence of self-efficacy and academic preparation in a mixed methods study, I adopted a post-positivist pragmatic position (Cherryholmes, 1992; Creswell, Plano Clark, Gutmann, & Hanson, 2003; Murphy & Rorty, 1990). Pragmatism has been called the “philosophical partner for mixed methods research” (Johnson & Onwuegbuzie, 2004, p. 16). A pragmatic and balanced approach helps to ease the metaphysical, epistemological, and methodological differences between the positivistic and qualitative perspectives (Johnson & Onwuegbuzie, 2004). Pragmatism balances the two different perspectives by focusing on the research problem, what people can do with the knowledge produced, and framing for the mixing of methods to maximize the benefit of the research (Hoshmand, 2003).

With a pragmatic viewpoint Creswell, Plano Clark, Gutmann, and Hanson, (2003) state, “Instead of methods being important, the problem is more important” (p. 209). When methodology is consistent with the researcher’s epistemology, theoretical framework, and the purpose for the study, any consistent methodological choice has value and merit (Johnson & Onwuegbuzie, 2004). Palmer and Marra (2008) note, “The researcher’s fidelity to principles of inquiry is more important than allegiance to procedural mechanics. Research should be judged
by the quality and soundness of its conception, implementation, and description, not by the genre within which it is conducted” (p. 327).

Additionally, a pragmatic position emphasizes, “what people can do with the knowledge they produce and not on abstract arguments about the possibility or impossibility of generalizability” (Morgan, 2007, p. 53). While the practicality and usefulness of my study outcomes are a high priority, it is understood that data, analysis, outcomes, and conclusions may be interpreted through myriad perspectives based on subjective lived experiences of the researcher and reader. My study acknowledges a single real world and that all individuals have their own unique interpretations of that world (Morse, 1991; Morgan, 2007). Any application or generalizations of the study findings are dependent upon the subjective lived experiences of the reader.

Theoretical Framework

Grounded in pragmatic post-positivism, this theoretical framework section addresses assumptions about knowledge claims through social cognitive theory (Bandura, 1986). Social cognitive theory includes social-cognitive career theory (SCCT) (Lent & Brown, 1996). SCCT is the theoretical perspective of my study.

Social cognitive theory. Bandura’s (1986) Social Cognitive Theory provides foundational constructs for human behavior. This theory is foundational in understanding how self-efficacy and academic preparation may influence students’ choice of and persistence in a college degree in a STEM discipline. The two factors are grounded in the actions of human behavior. The theory suggests that human functioning involves the processes of cognitive, self-regulatory, vicarious, and self-reflective operations (Bandura, 1986; Pajares, 2002). Bandura’s (1986) Social Cognitive Theory marked a shift from behaviorist philosophies of action caused by
external stimuli and towards the view that people’s actions and thoughts are a product of a complex relationship between environmental factors, personal (biological, affective, cognitive) factors, and behavior (Pajares, 2002).

At its core, Social Cognitive Theory embraces the value of human agency. This view holds that people proactively decide on actions that determine their own personal development. The personal beliefs people hold about themselves enable them to exert control over their thoughts and actions (Pajares, 2002). “What people think, believe, and feel affects how they behave” (Bandura, 1986, p. 25).

Human agency, central to Social Cognitive Theory, includes personal self-efficacy beliefs. Bandura (1986) defines self-efficacy as “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (p. 391). For example, if a person believes that he/she can behave in a manner that produces the outcomes he/she desires he/she may have incentive to act and persist towards the outcome even as obstacles arise.

Social Cognitive Theory is relevant to the two constructs of self-efficacy and academic preparation investigated in this study. Studies of the impact of self-efficacy are typically grounded in Bandura’s Social Cognitive Theory (Aschbacher, Li, & Roth, 2010; Brown, Lent, & Larkin, 1989; Bryan, Glynn, & Kittleson, 2011; Else-Quest, Mineo, & Higgins, 2013; Glynn, Taasoobshirazi, & Brickman, 2009; Maltese & Tai, 2011; Watt, Shapka, Morris, Durik, Keating, & Eccles, 2012). For example, Aschbacher, Li and Roth (2010), suggested that students’ self-efficacy shaped their consequent science, engineering or medicine career trajectories. In Else-Quest, Mineo and Higgins (2013), the research team found that students’ views of their personal self-efficacy were a strong predictor of STEM achievement. Studies related to individual
academic preparation are also grounded in Social Cognitive Theory (Crosnoe, Riegle-Crumb, & Muller, 2007; Muller, Riegle-Crumb, Schiller, Wilkinson, & Frank, 2010; Schneider, Swanson, & Riegle-Crumb, 1997). For example, Crosnoe, Riegle-Crumb and Muller (2007) suggest that students’ negative self-efficacy beliefs adversely affected their academic preparation and truncated their educational trajectories.

**Social cognitive career theory.** Specifically, my study was grounded in Social Cognitive Career Theory, a facet of Social Cognitive Theory that focuses on career interests. Social Cognitive Career Theory (SCCT) is the specific theoretical framework that guided my exploration of the influence of self-efficacy and academic preparation with regard to persistence in STEM degree pathways. SCCT suggests that student career interests, ambitions, and choices are selected to a significant degree by students’ self-efficacy beliefs (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Lent, Sheu, Gloster, & Wilkins, 2010; Wang, 2013). Students are more likely to pursue and persist in a career degree pathway they view themselves as proficient in, and less likely to be attracted to degree pathways for careers in which they doubt their capabilities (Lent, Brown, & Hackett, 2000). In an example using the SCCT framework, a high school student may earn a high score in a coding challenge that encourages her to continue her efforts towards her desire of obtaining a degree in computer science. She believes that she can act in a manner that produces her desired outcome. Her positive self-efficacy beliefs may instill confidence in her to select computer science as a post-high school endeavor, and give her encouragement, motivation and persistence towards her career goal even as obstacles arise.

SCCT was utilized in a number of studies related to persistence towards STEM-related degree pathways (Betz & Hackett, 1983; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010;

Additionally, SCCT provides a framework for choices in career ambitions. SCCT acknowledges that self-efficacy is an influential factor of personal career choices (Carpi, Ronan, Falconer, & Lents, 2016). Self-efficacy motivates behaviors including those that lead to the choice of and persistence toward attainment of a college degree in a STEM discipline. Within SCCT, an individual’s self-efficacy beliefs about whether they can successfully execute desired behaviors are powerful predictors of career choice and attainment. For example, if a high school STEM program graduate believes she is successful in performing STEM task-related behaviors, this sense of high self-efficacy will impact the development of her career interests and goals (Carpi et al., 2016).

SCCT supports each of the two study constructs of self-efficacy and academic preparation as separate malleable factors and as a combination interacting with each other. With regard to self-efficacy, SCCT posits that the acquisition of mastery skills has the strongest influence on self-efficacy beliefs (Lent & Brown, 2006). Additionally, Britner and Pajares (2006) suggest that only mastery experiences significantly predicted science self-efficacy. Mastery experiences can take many overlapping forms combining the constructs of self-efficacy and academic preparation. For example, a student may master a particular academic concept using acquired skill in the laboratory conducting experiments as a professional scientist would. This mastery experience may reinforce self-efficacy beliefs of academic and personal competency.

In applying SCCT to my study, it is important to note that research utilizing SCCT uses both the terms of self-concept and self-efficacy. Self-concept is closely related to self-efficacy
and can be considered jointly within SCCT (Lent et al. 2002). Both constructs relate to self-perceptions, although self-concept is a broader notion of the skills and abilities an individual possesses overall contrasted with self-efficacy that focuses on an individual’s belief regarding their competency in a given task or domain (Bandura 1997; Bong & Skaalvik 2003). Both self-concept and self-efficacy are empirically correlated (Bong & Clark 1999; Lent et al. 1997, 2002; Pajares & Miller 1994) and aim to explain career selections and accomplishments (Lent et al. 1994). Further, research suggests that the two conceptions might be more similar in practice than their theories imply (Pajares & Miller 1994; Bong & Clark 1999; Sax, Kanny, Riggers-Piehl, Whang, & Paulson, 2015). As a result, it is appropriate and advantageous to consider studies that relate to both self-concept and self-efficacy jointly under the umbrella of SCCT. In my study, I will use the term self-efficacy for clarity and for consistency with Social Cognitive Theory, which is the foundation for SCCT.

In summary, Social Cognitive Career Theory offers an appropriate theoretical lens to study the issue of choice of and persistence toward attainment of a college degree in a STEM discipline through the constructs of self-efficacy and academic preparation (Hernandez, et al., 2012; Lent, Brown, & Hackett, 1994, 2000; Maltese & Tai, 2011).
CHAPTER TWO: LITERATURE REVIEW

STEM Education in the 21st Century

It is imperative that I define STEM education in order to aim to increase our collective understanding of how self-efficacy and academic preparation emphasized in an inclusive STEM program influenced graduate’s choice of and persistence toward a college degree in a STEM discipline.

Definition of STEM

While the meaning of STEM education evolves, common themes and definitions emerge. Even though there are members of the education community who refer to STEM education as “business as usual” by merely continuing the near ubiquitous practice of disconnected science, mathematics, and technology education (Sanders, 2012), increasingly more educators have adopted an integrated definition of STEM education. The integrative form of instruction combines scientific study, technology, engineering design and mathematical analysis (President’s Council of Advisors on Science and Technology, 2010). “We must first recognize STEM as a unitary idea, not simply a grouping of the four disciplines in a convenient, pronounceable acronym” (Morrison & Bartlett 2009, p. 29).

To promote clarity on the unification of STEM disciplines, a University of Maryland engineering professor (Abts, 2008) used the term “metadiscipline,” meaning the realm of knowledge that speaks to the application of technical disciplines as they exist in the natural world, interconnected with one another. This approach breaks down the boundaries of disciplines devised by and for academia by Charles W. Eliot and the National Educational Association’s Committee of Ten in the late 1800’s (Morrison & Bartlett, 2009). The separation of disciplines into discrete categories and chunks of time during the learner’s day mirrors an outdated model
that does not reflect our global economy, interconnected disciplines, and careers formed at the intersections of subjects such as Bioengineering or Social Computing.

The implementation of integrative STEM education approaches is an extension of the past two decades of STEM education reform efforts. The Science for All Americans report (AAAS, 1989) and the Benchmarks for Science Literacy (AAAS, 1993) clearly stated the fundamental rationale for integrative STEM education: “The basic point is that the ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others” (Sanders, 2012; Bybee, 2010).

**STEM education in high school.** The degree to which high schools integrate STEM disciplines varies widely. Schools integrate any combination of science, engineering, technology, and mathematics content areas (Lynch, Spillane, House, Peters-Burton, Behrend, Ross, & Han, 2017; Means, Wang, Young, Peters, & Lynch, 2016; Peters-Burton, Lynch, House, & Han, 2015). For example, some schools integrate science with technology and engineering while others may integrate engineering with technology and math. Other schools integrate STEM disciplines with each other and with English language arts and social studies as well. Tsupros, Kohler, and Hallinen’s (2009) definition of STEM education is operationalized in my study:

> ...an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (p. 4).
In my study, I framed STEM education in high school with an integrated lens while understanding that many STEM subjects in high school remain distinct. The high school STEM program in my study focused on bioscience and genetics classes and integrated English language arts with engineering, math and computer science into the science learning. A full description of the school context follows in Chapter 3.

**University STEM education.** While the high school STEM context in my study is focused on bioscience with other subjects integrated in a real-world manner, the university STEM context is much different. It is relevant to understand the university context since the graduates in my study experienced learning in this environment after high school. Similar to many standard high schools, many university STEM subjects remain discrete from each other without integration (National Research Council, 2012).

In aiming to understand if the study constructs influence graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline, I define STEM disciplines in accordance with the National Science Foundation (NSF). For example the NSF defines STEM degree areas as including “biological and agricultural sciences, physical sciences, computer sciences, mathematics/statistics, engineering, psychology, chemistry, physics, astronomy, and earth/ocean/atmospheric sciences” (NSF, 2016).

**Inclusive STEM Schools and Programs**

**STEM schools.** Since my study investigated how the constructs of self-efficacy and academic preparation developed in an inclusive high school STEM program influenced graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline, it is important to understand the differences and similarities in the terms *STEM program* and *STEM school.* Inclusive STEM programs, as well as inclusive STEM schools, are an increasingly
prominent research focus as a potential means for increasing the numbers of STEM professionals (Eisenhart, Weis, Allen, Cipollone, Stich, & Dominguez, 2015; Means, Confrey, House, Bhanot, 2008). A STEM school is defined as one that focuses to some degree on science, technology, engineering and math (Eisenhart et al., 2015). Inclusive STEM High Schools are commonly referred to as ISHSs.

Inclusive STEM programs or ISHSs are different than historical STEM schools. STEM schools in the United States founded before 1999 were typically highly selective schools, only admitting 10% of applicants who possessed the highest achievement scores (Eisenhart, 2015; Means et al., 2008; National Research Council, 2014; Subotnik, Rayhack, & Edmiston, 2006). The more recent inclusive STEM schools have no admission requirements beyond local residency (Eisenhart et al., 2015; LaForce, Noble, King, Century, Blackwell, Holt, Ibrahim, Loo, 2016; Lynch, Behrend, Peters-Burton, Means, 2011; Means et al, 2008). This represents a shift from thinking that success in STEM relies on innate talent that must be identified to a current notion that success in STEM is inspired, fostered, and developed (Means, Confrey, House, & Bhanot, 2008). ISHSs tend towards beliefs that student interest combined with high quality teaching and learning experiences can prepare diverse students for STEM degree pathways and careers (LaForce et al., 2016; Means et al., 2008).

**STEM programs.** While ISHSs represent whole schools centered on STEM education, there are also STEM programs situated inside standard comprehensive high schools. Even though the limited research base regarding STEM schools is growing (Eisenhart et al., 2015; LaForce et al., 2016), research on inclusive STEM programs within comprehensive schools remains severely limited. According to Means, Confrey, House, and Bhanot (2008), 63% of STEM schools were either charter or public stand-alone schools and 38% were
A difference between STEM schools and STEM programs within a comprehensive school is where and when the STEM learning takes place. In a STEM school, the school and its classes have a STEM focus (Wiswall, Stiefel, Schwartz, & Boccardo, 2014). In a STEM program, only classes within the program provide a STEM focus while the remainder of the comprehensive school provides standard classes such as math, English, history, science, music and art.

The program-within-a-school model allows STEM program students to participate in non-STEM program classes with their schoolmates and for some non-STEM program students in the school to take advanced courses designed for the STEM program cohorts (Subotnik, Tai, Almarode & Crowe, 2011). For example, a student with six classes per day may take two STEM classes within the program and four classes from within the comprehensive high school outside of the STEM program.

In my study context, any student within the comprehensive school may choose to enroll in the inclusive STEM program without any admission requirements. Students from regional schools may choose to transfer to the comprehensive school in order to participate in the inclusive STEM program.

**Literature Review of Self-Efficacy and Academic Preparation**

In this section, the study constructs of self-efficacy and academic preparation are defined within the context of relevant research literature and expanded upon in relation to my theoretical framework of Social Cognitive Career Theory (SCCT). The two constructs are first discussed separately followed by how they connect to each other and to student persistence in STEM discipline degree programs and finally how self-efficacy and academic preparation relate with
SCCT.

The current research literature consists of a variety of complementary definitions of the constructs of self-efficacy and academic preparation in STEM that are anchored in foundational studies. In a general sense, self-efficacy is an individual’s belief about his/her ability to behave in certain ways to achieve a desired performance or goal (Bandura, 1986). Academic preparation is commonly defined as students having access to rigorous high school STEM courses and experiencing academic success in these courses (Eisenhart et al, 2015; Tyson, Lee, Borman, & Hanson, 2007).

**Self-Efficacy**

Self-efficacy is rooted in Bandura’s (1986) Social Cognitive Theory. Social Cognitive Theory provides foundational constructs for human behavior. The theory suggests that human functioning involves the processes of cognitive, self-regulatory, vicarious, and self-reflective operations (Bandura, 1986; Pajares, 2002). Humans are considered as “self-organizing, proactive, self-reflecting and self-regulating, rather than as reactive organisms shaped and shepherded by environmental factors or driven by concealed inner impulses” (Pajares, 2002, p. 1). Bandura’s (1986) Social Cognitive Theory marked a shift from behaviorist philosophies of action caused by external stimuli towards the view that people’s actions and thoughts are a result of complex relationships between environmental factors, and personal (biological, affective, cognitive) factors (Pajares, 2002).

Central to Social Cognitive Theory are elements of human agency including personal self-efficacy beliefs. Bandura (1986) defines self-efficacy as “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (p. 391). In other words, self-efficacy is a personal assessment about one’s ability
to perform actions to accomplish a desired goal (Bandura, 1997; Pajares, 2005; Rittmayer & Beier, 2008; Zimmerman, 2000). Self-efficacy influences the amount of effort an individual commits to a task, how long that effort would be sustained especially as challenges and obstacles arise, and how resilient they will be facing future barriers or failures (Bandura, 1982; Bandura, 1997; Hazari, Sonnert, Sadler, & Shanahan, 2010; Pajares, 2005; Sawtelle, Brewe, & Kramer, 2012). If a person believes that they can behave in a manner that produces the outcomes she desires she may have incentive to act and persist towards the outcome even as obstacles arise. Self-efficacy is assessed through respondents rating their level of confidence for achieving a particular goal. For example, science self-efficacy would be gauged by the following questions, “How confident are you that you can accurately analyze your laboratory results?” and “How confident are you that you can earn a B or better in physics?” (Bong & Skaalvik, 2003; Rittmayer & Beier, 2008).

Bandura’s construct of self-efficacy provides four elements for investigation: personal mastery experiences, vicarious learning experiences, social persuasion experiences, and physiological state.

**Mastery experiences.** Bandura (1997) suggested that people form their self-efficacy beliefs from personal mastery experiences. An individual’s confidence in his/her ability increases when a task is completed successfully. The converse is also noted. A person’s confidence in her/his ability to complete a task is negatively influenced by repeated failures attempting that task (Bandura, 1997). For example, if a student earned a high grade on his science test, he is likely to feel confident in his ability to earn another high grade on a future science test. However, if he earns a low grade, he is likely to doubt his ability to earn a high grade on a future science test. Lent and Brown (2006) suggest that achieving mastery in concepts or skills likely has the
greatest influence on a student’s self-efficacy beliefs. If a student feels successful at certain laboratory research skills, the student is more likely to view himself/herself as having a high degree of self-efficacy related to science research (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013).

**Vicarious learning experiences.** Bandura’s second element, vicarious learning experiences, is observed when an individual watches others conducting a task similar to the task he/she are evaluating their own performance on. A person’s belief regarding her/his abilities can be influenced by observing someone else’s failures or successes (Bandura, 1997). For example, a novice student may observe a more advanced student and think, “If she can use that technical piece of equipment, so can I.”

**Social persuasion experiences.** Everyday messages students receive, such as verbal suggestions, words of encouragement or discouragement or other social communications, can influence an individual’s self-efficacy. If a student receives positive social messages, he/she is motivated to maintain or increase interest and effort and will persist in their task. According to Carlone and Johnson (2007), if students are recognized by meaningful others (e.g. faculty role models) as ‘science people’ students’ self-efficacy increases as they internalize confidence in their own academic abilities. Conversely, social persuasion messages may discourage a person’s belief about his/her ability to succeed. For example, if minorities and women are routinely provided messages about stereotypical roles in society, they may become discouraged in their ability to succeed in non-stereotypical interests (Bandura, 1997; Hackett & Betz, 1981).

**Physiological state.** The fourth of Bandura’s elements of self-efficacy is the influence of a person’s physiological state. High levels of stress and/or anxiety often undermine a person’s confidence in his/her ability to perform or sustain a task. Zeldin and Pajares (2000) found that
stress and depression negatively influenced students’ self-efficacy beliefs. Conversely, students’ positive moods and attitudes fueled by enjoyment and relaxation will have a positive effect on their self-efficacy beliefs. For example, if a student is nervous or fears failure related to a task, her increased anxiety and doubts about her ability to succeed may be harmful to her level of performance. A lower than desired performance would likely have a negative effect on her self-efficacy beliefs.

**Self-efficacy and related terms.** Even though this study will examine self-efficacy, it is beneficial to increase the clarity of its definition through a comparison with the related terms of self-concept and self-esteem. These similar terms differ in important ways (Bong & Skaalvik, 2003; Gist & Mitchell, 1992; Pajares, 2005; Rittmayer & Beier, 2008; Zimmerman, 2000). Primarily, self-efficacy is a competence belief (Fortus, 2014) where a person has expectations regarding one’s capacity to learn or complete a certain task (Schunk & Zimmerman, 2006). Self-efficacy assessments consider task-specific expectations of behavior and performance; for example, “I am confident that I will get accurate results in my next experiment.”

Alternatively, in 1974 Coopersmith and Feldman defined self-concept as the “beliefs, hypotheses, and assumptions that the individual has about himself. It is the person’s view of himself as conceived and organized from his inner vantage [and] includes the person’s ideas of the kind of person he is, the characteristics that he possesses, and his most important and striking traits” (p. 199). Self-concept is known as a general affective perception people hold about themselves. Self-concept judgments reflect general self-perceptions that can include evaluative or affective components; for example, “I am good at science” or “I enjoy working with my lab partners” (Bong & Skaalvik, 2003; Rittmayer & Beier, 2008). In contrast, self-efficacy is belief in one’s capacity to complete a specific task. For example, a person could have a high self-
concept related to science but have low self-efficacy for succeeding in a laboratory setting (may know facts but not how to use or apply them). Additionally, if self-efficacy is consistently low in a particular domain (like science), self-concept in that domain will also be negatively affected (Rittmayer & Beier, 2008).

As in the previous example, the two terms of self-efficacy and self-concept often relate to each other. They may develop in similar ways through self-assessments gained from achievement (Rittmayer & Beier, 2008). In a study of women in STEM degree programs, Stout, Dasgupta, Hunsinger, and McManus (2011) found that an enhanced self-concept increased self-efficacy. Further, research suggests that the two conceptions might be more similar in practice than their theories imply (Pajares & Miller 1994; Bong & Clark 1999; Sax, Kanny, Riggers-Piehl, Whang, & Paulson, 2015).

Self-efficacy and self-concept are also related and sometimes confused with self-esteem. Self-esteem is defined as self-perceived affective judgments about the self that include feelings of self-worth and self-like (Gist & Mitchell, 1992; Rittmayer & Beier, 2008). Self-esteem is more of a global generalization of self-evaluative feelings, self-concept is a self-judgment related to a specific domain, and self-efficacy refers to a specific task or goal (Gist & Mitchell, 1992; Rittmayer & Beier, 2008).

Since my study investigated constructs that may contribute to high school students’ choice of and persistence toward attainment of a college degree in a STEM discipline, the specific task nature of self-efficacy is a more relevant term as opposed to the general nature of self-concept (Bong & Skaalvik, 2003; Britner & Pajares, 2006; Zimmerman, 2000). College students in a STEM degree pathway have, as indicated by their decision to enroll in the program, a specific task to complete: their STEM degree. Although self-efficacy influences the multitude
of smaller proximal tasks that lead up to acquiring the desired goal of a STEM degree, self-efficacy also relates to greater commitment to a goal through the achievement of smaller tasks. Self-efficacy is also believed to increase cognitive engagement, self-regulation, self-monitoring, and self-assessing of one’s performance of tasks toward a particular long-term goal (Bandura, 1998; Pintrich, 2003; Zimmerman, 2000). A person’s self-efficacy influences whether task performances towards a long-term goal are motivating or discouraging (Rittmayer & Beier, 2008). For example, a student’s expectation for a laboratory experiment result is 90% accuracy and she actually observes 40% accuracy. If she has high self-efficacy she will attribute her disappointing result to insufficient effort, “If I had checked the volumes of reagents more carefully, I would have had more accuracy. Next time I’ll be more careful.” Conversely, if she has low self-efficacy, she will attribute her result to a lack of ability, “I’m just not good with labs. I am not able to do them correctly” (Zimmerman, 2000). Smaller tasks or proximal goals, which contribute to an end goal, provide opportunities for task mastery experiences that strengthen self-efficacy (Rittmayer & Beier, 2008).

**Self-efficacy and persistence.** The research is clear regarding the connection between self-efficacy and students’ choice of and persistence toward attainment of a college degree in a STEM discipline. Self-efficacy influences students’ choice of STEM careers and persistence in STEM majors (Aschbacher, Li, & Roth, 2010; Brown, Lent, & Larkin, 1989; Bryan, Glynn, & Kittleson, 2011; Dalgety & Coll, 2006; Else-Quest, Mineo, & Higgins, 2013; Glynn, Taasoobshirazi, & Brickman, 2009; Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999; Maltese & Tai, 2011; Watt, Shapka, Morris, Durik, Keating, & Eccles, 2012).

In Simpkins, Price, & Garcia’s (2015) study, they suggested that self-efficacy is a stronger predictor of students’ degree choices even after controlling for individuals’ actual ability
and past achievement. Similarly, according to Ceci, Williams, and Barnett’s (2009) longitudinal study, college students’ personal self-efficacy beliefs were found to be the primary influential factor of persistence towards STEM degree attainment. “Self-efficacy has consistently been shown to be one of the strongest predictors of motivation and performance” (Fortus, 2014 p. 822; Schunk, Meece, & Pintrich, 2012). Additionally, “there is a general consensus among researchers that measures of science self-efficacy are useful in investigating college students’ choices of science-related activities, the effort and tenacity they put into the completion of these activities, and the extent to which they are successful” (Jack, Lin & Yore, 2014 p. 5; Usher & Pajares, 2008).

**Academic Preparation**

Academic preparation in STEM is defined in the research literature most commonly as students having access to rigorous high school STEM courses and experiencing academic success in these courses (Eisenhart et al, 2015; Tyson, Lee, Borman, & Hanson, 2007). Success in rigorous high school STEM courses is often measured by students’ grade point average (GPA), mathematics courses they have taken, and SAT (formerly called the Scholastic Aptitude Test) scores. Adelman (1998, 1999, 2006) and Anderson and Kim (2006) suggest that early exposure to math and science as well as proficiency in advanced math and science courses are influential in preparing students for STEM degree majors (Ellington, 2006; Wang, 2015).

Specifically, Wang (2015) suggests that a student’s desire to choose a STEM degree pathway is directly influenced by 12th-grade math achievement. For example, the National Center for Education Statistics (2015) compared the academic preparation of students who took algebra II/trigonometry in high school with students who took calculus and pre-calculus. Students who took calculus or pre-calculus and obtained a GPA of 3.5 or higher were more likely to persist in a
college STEM degree program (National Center for Education Statistics, 2015).

Access to rigorous high school STEM courses is a primary component of students’ abilities to persist in college STEM programs (Eisenhart et al., 2015). Students who have access to rigorous STEM courses and gain strategies to persist and succeed are more likely to be academically prepared for college STEM coursework. Tyson, Lee, Borman, and Hanson (2007) found that high school course-taking is a better predictor of STEM college degree attainment than background factors such as race, parental education, or income (Eisenhart et al., 2015). These findings illustrate the importance of students having access to rigorous academic coursework as well as encouraging students to pursue opportunities for postsecondary STEM options (Eisenhart et al., 2015). Additionally, participation in rigorous high school STEM courses influences students’ STEM career aspirations (Burkam, Lee, & Smerdon, 2003; Muller, Riegle-Crumb, Schiller, Wilkinson, & Frank, 2010), persistence in college (Horn & Kojaku, 2001), and college degree attainment (Schneider, Swanson, & Riegle-Crumb, 1997).

As the studies above relate, students’ high school academic preparation has a direct impact on their selection of STEM degree pathways and college persistence rates toward STEM discipline degrees. Additionally, students’ high school grade point average (GPA) and their highest level of high school math course taken are also viewed as indicators of success in college STEM degree achievement. According to the Center for Education Statistics (2013) with the following numerical findings, claim that potentially causal relationships may exist between high school GPA and highest level of math taken. For example, 46 percent of college students in STEM degree programs with a high school GPA of less than 2.5 did not persist to complete their degree. This is contrasted with 14 percent of college STEM majors with a high school GPA of 3.5 or higher switching to no-STEM majors or dis-enrolling from college. Also, 41 percent of
college students in STEM degree programs who did not take algebra II/trigonometry or higher math courses in high school dis-enrolled from their college before earning their STEM degree. Additionally, 12 percent of college STEM majors who took calculus in high school dis-enrolled from college.

In terms of switching majors out of STEM fields, 33 percent of college students choosing STEM programs with a high school GPA between 3.00 and 3.49 switched to a non-STEM major. This is compared with 26 percent of college STEM majors who earned a GPA of 3.5 or higher. About 32–33 percent of college students in STEM programs who took algebra II/trigonometry or pre-calculus in high school switched to non-STEM majors, while 24 percent of those who took calculus switched to non-STEM majors (National Center for Education Statistics, 2015). While the Center for Education Statistics data in the previous two paragraphs may represent causal relationships, I am not assuming causal relationships. Each data point for each individual student contains multiple other personal, social, and financial factors influencing it that may contribute to shaping data above.

A quantitative study by Chen and Weko (2009) employed longitudinal data sets from the Institute of Education Sciences (IES) found that students who entered and persisted in STEM degree programs had stronger academic preparation than their counterparts. Similarly, Crisp, Nora, and Taggart (2009) found that students’ decisions to pursue a STEM degree pathway and earn a STEM degree were influenced by their SAT math score and high school class rank percentile.

Other quantitative researchers (Adelman, 2006; Horn & Kojaku, 2001; Trusty, 2002, Tyson, Lee, Borman, & Hanson, 2007) examined the effects of “rigorous” high school coursework on student persistence in college STEM degree programs. The authors of these
studies defined rigorous courses as those that are more demanding such as Advanced Placement, Honors or specialized courses when compared with basic classes that satisfy a minimum requirement for graduation. For example, instead of Business Math consisting of balancing a checkbook and calculating interest payments, a student could choose to enroll in Statistics or Advanced Placement Calculus. Adelman (2006), Horn & Kojaku (2001), and Trusty et al. (2002) suggested that a more rigorous high school program was positively correlated with students’ completion of college STEM degrees.

Academic preparation in high school appears to be influential in students’ choosing to pursue STEM degrees and their persistence towards attainment. Specifically, achievement in math, participation in other rigorous high school courses, and a high grade point average are considered predictors of high school students’ choice of and persistence toward attainment of a college degree in a STEM discipline.

**STEM Persistence with Self-Efficacy and Academic Preparation**

While current research suggests that the constructs of self-efficacy and academic preparation are influential for students’ persistence in STEM degree programs, it is important to understand their impact in an interactive and holistic sense. Since each student is unique and is impacted differently by an infinite number of varying experiences, it is nearly impossible to attribute any outcome to any particular single construct or factor. By analyzing the two constructs of self-efficacy and academic preparation, as they exist in interacting relationships with each other in a mixed methods approach, my study provides increased richness and depth compared to a study analyzing these constructs separately within a single methodology.

Historically, research in education has suggested a causal relationship between high school academic success and post-high school academic success (Dewey, 1904; Harris, 1940,
Weitz, Clarke, & Jones, 1955; Spady, 1970; Peng & Fetters, 1978). A pivotal quantitative study by Ware and Lee (1988) found that high school grade point average (GPA) coupled with high educational aspirations were significantly associated with students declaring STEM majors. This study prompted other researchers to consider affective factors (such as self-efficacy) in conjunction with academic measures. Additionally, Ware and Lee (1988) showed the positive association between a positive attitude toward mathematics and the number of mathematics courses completed with the likelihood a student will declare a STEM major. Similarly, Tinto (1993) posits that the rigor of high school academic preparation together with a high degree of student self-efficacy is influential for student completion of a STEM degree program. Some studies, such as Bonous-Harmmarth’s (2000), indicate that students’ commitment to pursue a STEM degree (measured in freshman year) was more positively associated with self-efficacy than academic achievement shown on students’ high school GPA or SAT scores.

Results from Britner (2008) and Lau and Roeser (2002) conclude that self-efficacy significantly impacts high school students’ science and math achievement. Other quantitative studies show that self-efficacy influences students’ achievement in college STEM courses (Andrew, 1998; Lent, Brown, & Larkin, 1984; Multon, Brown, & Lent, 1991; Pietsch, Walker, & Chapman, 2003). Studies suggest that students’ intent to pursue a STEM degree reflects a combination of their 12th-grade math proficiency, participation in math and science courses throughout their years in school, and students’ self-efficacy beliefs (Sax et al., 2015; Wang, 2015). An individual’s judgment of their academic capabilities is “a pivotal factor in career choice and development” resulting from the notion that “unless people believe they can produce desired outcomes by their actions, they have little incentive to act or to persevere in the face of difficulties” (Capara, Fida, Vecchione, Bove, Vecchio, Barbaranelli, & Bandura, 2008, p. 187).
Personal beliefs about self-efficacy, academic performance, and persistence in a particular domain exist in mutual relationship, reinforcing each other over time (Nauta, Epperson, & Kahn, 1998; Nauta, Kahn, Angell, & Cantarelli, 2002; Zeldin, Britner, & Pajares, 2008; MacPhee, Farro, & Canetto, 2013).

Research suggests that personal beliefs including self-efficacy combine with academic preparation to increase the likelihood of a student persisting in a STEM degree program. In a quantitative study Sullins, Hernandez, and Fuller (1995) examined student persistence in college biology degree pathways and suggested that student self-efficacy and interest were significant predictors of a student’s completion of a degree in biology. The influence of students’ self-efficacy as a STEM professional seems to focus students on both developing academic proficiency and competing against or demonstrating proficiency in comparison with peers (Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013). Jack, Lin, and Yore (2014) suggest positive synergistic effects of affective factors such as self-efficacy on student academic performance.

Additionally, research suggests that foundationally, a stronger STEM self-efficacy is related to an increased likelihood of persisting in the academics of a STEM degree program. Hernandez et al. (2013) concluded that students who experienced positive growth in their self-efficacy showed positive growth towards their academic goals. Students with positive math self-efficacy exhibited higher than average academic achievement even while controlling for prior achievement (Hernandez et al., 2013). Correll, (2001) Tai, Liu, Maltese, and Fan, (2006), and Sax, et al. (2015) showed that two significant predictors of STEM degree completion are positive student self-efficacy and math and science achievement. Students with positive self-efficacies and attitudes towards STEM combined with math and science achievement in high school
experience were more likely to persist in college and graduate with STEM degrees.

Calabrese Barton, Kang, Tan, O’Neill, Bautista-Guerra, and Brecklin (2012) suggested that self-efficacy is a dominant framework for investigating student learning because it is formed in social environments through practice. One facet of self-efficacy is social persuasion (Bandura, 1986). The practice that forms STEM self-efficacy requires knowledge, skills, and ways of thinking specific to STEM (Calabrese Barton et al., 2012). Students develop STEM self-efficacy concurrently and in relationship with developing academic practices, skills and knowledge. Academic preparation and self-efficacy may mutually cultivate one another.

Additionally, research experiences that mirror the work of STEM professionals posits students for increased motivation, increased self-efficacy, higher academic performance and increased persistence toward STEM degree completion (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Chang, Sharkness, Hurtado, & Newman, 2014; Hernandez et al., 2013; Robnett, Chemers, & Zurbriggen, 2015). Studies by Laursen, Hunter, Seymour, Thiry, and Melton (2010), Harsh, Maltese, and Tai (2011) and Lopatto (2007) found that students and university mentors “identified learning to cope with failure and frustration as important predictors of persistence in science” (Hernandez, 2013, p.92). While working in the social environment of a laboratory, college students learned to view failed experiments not as a negative reflection of themselves but as an expected part of doing science. The students’ self-efficacy increased as they successfully learned to work through failure and frustration of specific tasks in the academic practices of science.

The relationship between self-efficacy and academic preparation is foundationally reciprocal and ongoing. As a student successfully completes an academic task he/she is likely to feel confident not only about achieving another similar task but also in taking on a more difficult
task or adopting a more challenging goal. Continued successful behaviors and performances on increasingly difficult or challenging tasks lead to greater academic achievement. This leads to even greater self-efficacy and the cycle continues (Bandura, 1997).

**Theoretical Framework with Self-Efficacy and Academic Preparation**

The theoretical framework of my study, social cognitive career theory (SCCT), was an appropriate lens to understand self-efficacy and academic preparation. SCCT suggests that student career interests, ambitions and choices are selected to a significant degree by students’ self-efficacy beliefs (Lent, Sheu, Gloster, & Wilkins, 2010; Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Wang, 2013). Although Bandura (1977, 1986) developed social cognitive theory, it was Hackett and Betz’s (1981) study that tied self-efficacy and career development together. Hackett and Betz highlighted ways in which a person’s career related behaviors can be limited or fostered through educational, familial, and social influences that become internalized as self-efficacy beliefs (Lent & Brown, 2016).

Students are more likely to pursue and persist in a degree pathway for a career they view themselves as proficient in, and less likely to be attracted to degree pathways for careers in which they doubt their capabilities (Lent, Brown, & Hackett, 2000). In an example using the SCCT framework, a university student may earn a high score in a coding challenge that encourages her to continue her efforts towards her desire of obtaining a degree in computer science. She believed she could act in a manner that produces her desired outcome. Her positive self-efficacy beliefs gave her academic success and may give her encouragement, incentive and persistence towards her career goals even as obstacles arise.

SCCT supports self-efficacy and academic preparation as separate malleable factors interacting with each other. With regard to self-efficacy, SCCT posits that the acquisition of
mastery skills has probably the strongest influence on self-efficacy beliefs (Lent & Brown, 2006). Additionally, Britner and Pajares (2006) suggest that only mastery experiences significantly predicted science self-efficacy. Mastery experiences can take many overlapping forms combining the constructs of self-efficacy and academic preparation. For example, a student may master a particular academic concept using acquired skill in the laboratory, conducting experiments as a professional scientist would.

Mastery experiences, such as in the previous example, may reinforce self-efficacy beliefs of personal academic competency. Students’ participation in rigorous STEM courses influences their STEM career aspirations (Burkam, Lee, & Smerdon, 2003; Muller, Riegle-Crumb, Schiller, Wilkinson, & Frank, 2010), persistence in college (Horn & Kojaku, 2001), and college degree attainment (Schneider, Swanson, & Riegle-Crumb, 1997).

Social cognitive career theory with persistence in STEM. Many studies utilized SCCT as a theoretical framework regarding persistence in STEM. SCCT has been applied to study the continuation of college students’ interest in STEM careers (Carpi, Ronan, Falconer, Lents, 2016; Chakraverty & Tai, 2003; Lent, Miller, & Smith, 2013; Soldner, Rowan-Kenyon & Inkelas, 2012), persistence in STEM degree programs (Deemer, Thoman, & Chase, 2014; Garriott, Flores, & Martens, 2013), and persistence in introductory engineering courses (Lent, 2005).

Additionally, the SCCT framework was utilized to understand high school students’ STEM career interest and motivation (Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; Dika, Alvarez, Santos, & Suárez, 2016; Falco, 2016; Garriott, Hultgren, & Frazier, 2016; Garriott, Raque-Bogdan, Zoma, Mackie-Hernandez, & Lavin, 2017; Shin, Ha, & Lee, 2016). Of these SCCT framed studies, a few investigated students’ self-efficacy beliefs (Garriott et al., 2016; Garriott et al., 2017; Shin et al., 2016).
The studies above were conducted in the contexts of traditional comprehensive high schools or in school-based clubs or other informal science programs. I did not locate any studies using a SCCT framework in the context of a STEM program situated within a comprehensive high school. I aim for my study to advance the field by applying SCCT in a high school STEM program context.
CHAPTER THREE: METHODOLOGY

Introduction

My study promoted understanding of how graduates’ self-efficacy and academic preparation, in an inclusive high school STEM program, influenced their choice of STEM degree pathways and their capacity to continue STEM focused learning in college. With an increase in STEM focused programs and stand-alone STEM schools in the United States, it is important to understand constructs that may contribute towards the success of their graduates. I collected and analyzed qualitative and quantitative data to identify whether the high school program’s emphasis on self-efficacy and academic preparation may influence students’ choice of and persistence toward college degrees in STEM disciplines. While academic preparation and self-efficacy are two separate constructs (independent variables), the concepts of graduates’ choice of a STEM major and the continuation of their STEM learning in college were one construct (dependent variable).

The assumptions underlying my study are grounded in the theoretical and empirical work discussed in Chapter 2. The participants were the graduates from the inclusive high school STEM program between the years of 2010 and 2016.

Research Question

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

Study Design: Epistemology and Theoretical Framework

Epistemology
A mixed methods approach for the proposed study was suitable because it is epistemologically appropriate to use mixed methods. Post-positivist quantitative researchers and qualitative researchers agree on many epistemological points that permit the synthesis of methods in a mixed methods research design. One point of agreement was regarding how our background of knowledge and experiences affect what we notice and how we observe. Observations are not unbiased representations of reality (Creswell, 2013; Johnson & Onwuegbuzie, 2004, p.4; Phillips & Burbules, 2000). Another point was agreement around induction. Researchers realize that we only obtain probabilistic evidence, not final proof of reality. Other points of agreement centered on the social nature of education research. It is accepted that since researchers are often embedded in the social communities they are studying, their attitudes, beliefs and values affect the people participating in the study (Creswell, 2013; Ivankova & Stick, 2007; Johnson & Onwuegbuzie, 2004). Additionally, researchers agree that inquiry is value-laden not value-free. The values of the researcher affects what we choose to notice and observe and how we interpret and analyze what we see (Creswell, 2013; Johnson & Onwuegbuzie, 2004).

My mixed methods study, grounded in post-positivist pragmatism, provided equal emphasis on both deductive quantitative approaches and the inductive logic of qualitative methodology. Although post-positivist and pragmatic, my study was designed to extend even weight to both quantitative and qualitative methods. It is important to note that my post-positivist pragmatic perspective may encompass a wide array of methods and does not assume that a full understanding can be reached based on deductive experimentation or on inductive investigations alone. Instead of adhering to a dichotomous viewpoint, inductive and deductive logic are mutually supportive in my mixed methods study.
My study was positioned in a mixed methods perspective acknowledging that the combination of quantitative and qualitative methods will increase the understanding of complex realities of situated human experiences. Conceptually, mixed methodologies mutually support quantitative and qualitative methods through the melding of narratives with numeracy (Morgan, 2007). The pairing of narrative-based qualitative methods with numerical-based quantitative methods initially seems inconsistent. To ameliorate this tension, Morgan (2007) advocates for a perspective that includes a single real world and that all individuals participate in and yet have their own unique interpretations of that world. While each person may interpret a study differently, they may have related or similar experiences in our shared world.

Additionally, Morgan (2007) suggests “this moves beyond technical questions about mixing or combining methods and puts us in a position to argue for a properly integrated methodology” (p.56). It is not the mixing of two distinct theoretical frameworks with subsequent methodologies that remain separate, similar to oil and water. A mixed methods study may have distinct quantitative and qualitative sections that culminate into a fully integrated analysis and conclusion (Tashakkori & Teddlie, 2010). The integration of distinct phases of a mixed method design may be an entirely new solution where the two methodologies dissolve into one another leaving their former properties behind. My study followed the logic of distinct quantitative and qualitative phases integrating into a more comprehensive and cumulative understanding.

To answer my research questions, it was imperative that qualitative and quantitative methodologies receive equal merit and application. Richness was created when the deductive logic of quantitative methods partnered and balanced with the indicative logic of qualitative methods (Glaser & Strauss, 1967; Charmaz, 2006).

Theoretical Framework
The theoretical perspective of my study supported mixed methods just as my epistemological position does. I believed it was important for researchers to understand the limitations of their theoretical framework and resulting methodology. No epistemology, theoretical framework, or methodology in social science will provide a holistic and true understanding of any phenomenon. An issue, phenomena or experience could be more fully understood through various research studies employing diverse epistemologies, theoretical frameworks and methodologies. Considering a topic or occurrence through a variety of diverse lenses may contribute toward a fuller more comprehensive understanding.

The lenses that define and create the perspective of my study are pragmatic post-positivism epistemology with Social Cognitive Career Theory (SCCT) as the theoretical framework. SCCT is an outgrowth of Social Cognitive Theory (Bandura, 1977) with a foundational position in self-efficacy as an influential component of personal career choices. Self-efficacy is defined as “the conviction that one can successfully execute the behavior required to produce the outcomes” (p. 193). In this study, behaviors include those that produce the outcome of persistence towards STEM degree completion. In SCCT, people’s beliefs about whether they can successfully execute particular behaviors are a powerful predictor of career choice and attainment. For example, if a high school STEM program graduate does not believe she can be successful in executing STEM related behaviors, this sense of low self-efficacy will drive the development of her career interests, goals, and actions (Carpi, 2016). SCCT was utilized in a number of studies related to persistence in STEM-related degree pathways (Betz & Hackett, 1983; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; Hackett, Betz, Casas, & Rocha-Singh, 1992; Lent, Lopez, & Bieschke, 1993; Lent, Lopez, Lopez, & Sheu, 2008; Wang, 2013).
The research literature includes studies considering Social Cognitive Career Theory (SCCT), through many diverse perspectives and methodologies. As a result of the variety of approaches utilizing SCCT, my theoretical framework does not limit the selection of my methods. Quantitative studies are framed with SCCT (Atadero, Rambo-Hernandez, & Balgopal, 2015; Lee, Flores, Navarro, & Kanagui-Muñoz, 2015; Lent, Miller, Smith, Watford, Hui, & Lim, 2015). Qualitative studies employing SCCT are also present in the research literature (Carpi, Ronan, Falconer, & Lents, 2016; Shoffner, Newsome, Minton, & Morris, 2015; Williams, Thakore, & McGee, 2016). Mixed methodology studies are also utilized within a SCCT framework (DuBow & James-Hawkins, 2016; Mueller, Flickinger, & Dorner, 2015; Quimby, Wolfson, Seyala, 2007). Although SCCT is utilized in quantitative, qualitative and mixed methods approaches, most studies are quantitative with cross-sectional designs (Lent et al., 2010).

Because SCCT is a multi-faceted framework that includes co-acting factors of self-efficacy, outcome expectations, contextual background considerations, academic achievement, and learning motivation (Carpi et al., 2016; Mueller, Flickinger, & Dorner, 2015;) it supports complexity and interactivity (Quimby, Wolfson, Seyala, 2007). With a capacity for complexity, SCCT clearly supports the two constructs of self-efficacy and academic preparation in my study.

Although my study only has two constructs, each construct is complex. A primary reason to select mixed methods approaches is to more fully understand the complexity of how self-efficacy and academic preparation, as individual constructs and as co-acting constructs, influence STEM program graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline. It is important to combine both numerical data and statistics with the
descriptive language of personal narratives to create a complex nuanced understanding. SCCT is a framework that is inclusive of diverse approaches and complexity in study designs.

In the following two sections, titled quantitative and qualitative perspectives, I detailed why each method was valuable to my study and why neither was sufficient by itself.

**Quantitative perspective.** In my study, quantitative methods were essential to understanding the influence of self-efficacy and academic preparation in a numerical and statistical context. Through statistical analysis of survey data from high school graduates, potential correlations and relationships may be identified between the constructs. A Likert scale survey was the basis of the quantitative approach in my study. The survey could show statistical correlations with graduates’ persistence in STEM degree pathways and either self-efficacy or academic preparation or with both constructs or with neither construct. There may also be correlations between the constructs themselves. This numerical data may also allow for the development of quantitative predictions.

Quantitative methods are beneficial in providing precise, measurable, numerical data (Johnson & Onweugbuzie, 2004). An advantage of quantitative methods is the ability to relatively quickly uncover correlations and statistical relationships. Once the survey was sent to the STEM program graduates, I received data to analyze within a couple of weeks. With the assistance of statistical software such as SPSS, the quantitative data analysis was relatively quick. Additionally, the data collection and the results of the statistical analysis were relatively independent of my position as a researcher, reducing personal bias.

While quantitative methodologies afford many benefits, Dika and D’Amico (2015) acknowledge that numerical quantitative methodology misses critical narratives and lived experiences of participants. Survey methods and other quantitative methods may analyze the
occurrence of particular phenomena from large samples of participants, although the depth and
diversity of experiences may be limited. “As we analyze data in large mixed groups, we learn
about the majority but little about those on the margins” (Stage, 2007, p. 96). Often, the designs
of statistical analyses omit narratives, stories, and lived experiences of participants from
discussions, implications and conclusions (Denzin & Lincoln, 2011). Since expressive language
and stories are usually absent from the quantitative study design, subsequent methodology, and
data collection, there is no reason to expect narrative or descriptive outcomes. Additionally, I
accept that social science is unlike research in the natural or physical sciences. A science
researcher may control all variables whereas a social science researcher cannot. Unique humans
interacting in complex situated communities (Lave & Wenger, 1991) are continually interacting,
adapting, changing, and experiencing full, rich, multifaceted experiences every moment of every
day. Attempting to understand the influence of self-efficacy and academic preparation by means
of quantitative methodology exclusively would severely limit the effectiveness of the study.

Even though a positivistic researcher may ground a study in the sense that nature is the
final authority, my post-positivistic epistemology acknowledges that there is a component of
subjective human variability in any interpretation of data. The need for representation of the
complex individualistic human experience within a changing situated community necessitates the
inclusion of rich personal narratives, requiring the presence of qualitative methods.

**Qualitative perspective.** Consistent with my post-positivist perspective, my study
utilized qualitative methods that acknowledge the diverse personal interpretations of data. The
value-laden nature of qualitative research positioned my interaction with participants within a
social, physical and interacting context that accounts for biases, presuppositions, and judgments.
Qualitative methods afford agreements or disagreements with the values and biases of my study.
I acknowledge that subjectivity is an appropriate and necessary opportunity for the reader to negotiate and debate any knowledge claims. Fundamentally, qualitative inquiry emphasizes the qualities and meanings of phenomena, entities and processes (Denzin & Lincoln, 2011).

Qualitative investigation attempts to understand the meaning, social context, positionalities, and identities through narratives and detailed descriptions (Denzin & Lincoln, 2011). For example, in my study, I interviewed graduates from the inclusive STEM high school program to understand their complex personal, social and academic realities. These interviews gave me detailed personal descriptions and individual information about social contexts, that I used to inductively develop an initial hypothesis or explanation (Johnson & Onweugbuzie, 2004).

As opposed to quantitative approaches, qualitative methods tend not to look for correlations in relationships between factors or the measurement of phenomena in terms of amount, quantity, frequency or intensity (Denzin & Lincoln, 2000; Newman & Hitchcock, 2011). In my qualitative phase, the interview responses provided the foundation for patterns and trends that informed explanations and understandings. This is the reverse of the deductive quantitative approach.

“Qualitative research may be described, for example, as naturalistic, interpretive, or hermeneutic or classified as narrative, ethnographic, autoethnographic, oral history, ethnomethodology, symbolic interaction, phenomenology, critical theory, or cultural studies” (Paul & Marfo, 2001, p. 17). Within these methodologies, qualitative researchers underscore the socially constructed nature of human reality, the interactions between researcher and participants, and situational contexts (Denzin & Lincoln 2000). My semi-structured interviews with STEM program graduates sought to emphasize their personal narratives and lived experiences.
Additionally, the qualitative phase of my mixed methods study was conducted with a theoretical framework that does not seek objectivity or “any method or theory or universal and general claim to authoritative knowledge” (Richardson, 2000). My purpose with the qualitative interviews was to “understand the other" using a “detached attitude to make sense of why actors and processes are as they are” (Lincoln, 2010, p. 24). This was consistent with my post-positivist perspective, which supports the notion of "friendly suspicion that all truth claims are suspect and provisional, at best, and that there is no single method which is guaranteed to produce final truth" (Denzin & Lincoln, 2011, p. 11).

While qualitative methods are effective, they have weaknesses just as quantitative methods do. Knowledge produced with qualitative approaches may be unique and only relevant to relatively few people who fit a specific context (Creswell, 2013; Johnson & Onweugbuzie, 2004). Because the data is textual, it is difficult to make correlations and predictions or test hypotheses and theories (Johnson & Onweugbuzie, 2004). The narrative nature of qualitative research means the process of analysis and the results can be more easily influenced by the researcher’s biases and particular ways of thinking. Additionally, the analysis of data gathered qualitatively is often more time consuming than statistical quantitative analysis.

Since both qualitative and quantitative methods have strengths and weaknesses, and neither is adequate for my study alone, it is necessary to utilize a mixed methods design. The mixed methods approach allows the study to glean the benefits of each methodology and enables their weaknesses to counteract each other.

**Study Design: Mixed Methodology**

Since neither qualitative nor quantitative methods in isolation are sufficient for my study, I used a mixed methods approach (Tashakkori & Teddlie, 2003). A mixed methods approach is a
research process for gathering, analyzing, and integrating both quantitative and qualitative data in a single study (Creswell, 2005). To more thoroughly answer my research questions, I used a mixed methods design to provide a detailed understanding at the intersection of two methodological perspectives.

The purpose of this design is “to obtain different but complementary data on the same topic” (Morse, 1991, p. 122) to best answer the research questions. In agreement, Tashakkori and Teddlie (1998) and Patton (1990) communicate the importance of focusing on the problem and using multiple approaches to uncover knowledge (Creswell, 2003). The mixed methods format allows for data triangulation as a way to seek “convergence across qualitative and quantitative methods” (Creswell, 2003, p. 15). The intent in implementing this design was to converge the opposing strengths of quantitative methods (large sample size, trends, generalization) with those of qualitative methods (small N, details, in depth) (Patton, 1990).

Mixed methodology was appropriate to answer my research question regarding self-efficacy and academic preparation (Aschbacher, Li, & Roth, 2010; Bryan, Glynn, & Kittleson, 2011). One of the considerations in selecting mixed-methods for my study was to increase the collective knowledge of the field of affective factors such as self-efficacy in a mixed methods approach. Even though the importance of affective factors such as self-efficacy is becoming recognized, Vedder-Weiss and Fortus’ (2011) quantitative study suggests there is a lack of research on motivation and persistence in STEM. Additionally, Fortus’ (2014) editorial suggests not only is there a lack of research on affect (motivation, identity, interest, self-efficacy and attitudes), but also there is a severe shortage of qualitative and mixed methods research on affect. Our collective knowledge regarding the influence of affective factors will remain limited until more qualitative and mixed methods studies show results from those perspectives.
Similarly to research conducted to understand self-efficacy, most research regarding academic preparation is conducted through a quantitative lens (Adelman, 2006; Chen & Weko, 2009; Crisp, Nora, & Taggart, 2009; Horn & Kojaku, 2001; Schneider, Swanson, & Riegle-Crumb, 1997; Trusty, 2002; Tyson, Lee, Borman, & Hanson, 2007). It is important for researchers to investigate academic preparation as a contributing factor of students’ choice of and persistence toward attainment of a college degree in a STEM discipline through a qualitative and mixed methods lens to promote a more balanced perspective with numerical data and nuanced descriptive narratives.

**Sequential Explanatory Design**

To capitalize on the benefits of both qualitative and quantitative methodologies, my study had distinct phases that reflected each approach (Tashakkori & Teddlie, 2010). Overall, my study employed a two-phase sequential explanatory design (Creswell, Plano Clark, Guttman, & Hanson, 2003; Tashakkori & Teddlie, 2010). In this design, the quantitative numeric data were collected and analyzed first, which informed the qualitative textual data that were collected and analyzed second (see Figure 1a (Creswell et al., 2003; Ivankova & Stick, 2007; Tashakkori & Teddlie, 2010). The qualitative data assisted in explaining and interpreting the findings of initial statistical quantitative results (Creswell et al., 2003). In this sequence, the qualitative data interpreted and elaborated upon the quantitative results collected in the first phase.

The two phases were situated in a specific mixed methods structure termed sequential explanatory design (Creswell et al., 2003; Tashakkori & Teddlie, 2010). I employed sequential explanatory design for two reasons. Both reasons related to using quantitative survey results to inform participant selection for the exemplar qualitative phase. I used qualitative data to explore any significant, and non-significant, results (Morse, 1991) (see Figure 1b) and to intentionally
select and follow up with participants through a subsequent qualitative phase (Creswell, Plano Clark, et al., 2003; Morgan, 1998; Tashakkori & Teddlie, 1998) (see Figure 1c). For example, in my study, I anticipated the possibility that the quantitative data would show some graduates with high self-efficacy and high academic preparation entered STEM degree pathways and persisted towards STEM degrees while others made different academic and life choices. To more fully understand what may have influenced their decision, these graduates were invited to participate in qualitative semi-structured interviews structured with exemplar methodology.

In the first phase of the Explanatory Design, I collected quantitative numerical data via an alumni survey. In the second phase, I employed a qualitative exemplar study approach to elaborate and extend the results of the alumni survey. Figure 1a, 1b, and 1c show the sequential explanatory design progression.

(a) Explanatory Design

![Diagram of Explanatory Design]

(b) Explanatory Design: Follow-up Explanations Model

![Diagram of Explanatory Design Follow-up Explanations Model]

(c) Explanatory Design: Participant Selection Model

![Diagram of Explanatory Design Participant Selection Model]

Figure 1. Explanatory design model modified from Creswell (2006)

Sample selection. Since the quantitative data informed the qualitative sample selection in sequential explanatory design, there was an initial lack of certainty regarding the qualitative
participant selection criteria. Despite exact certainty, I made a few predictions and framed my qualitative participant selection based on my research question. In my investigation to understand how graduates chose STEM degree pathways and were persisting toward STEM degrees in college by considering their individual perceptions of their self-efficacy and academic preparation, I anticipated the possibility that there would be some students who report high levels of both constructs. Since research confirms the influence of both constructs on student success in persisting towards STEM degree attainment, I selected a qualitative participant pool from the graduates who respond with high self-efficacy and high academic preparation. According to the research base, these students should have the best high school foundation and should be most likely to persist towards STEM degree completion. These students were considered as exemplars. As exemplars they exemplify the constructs of self-efficacy and academic preparation in a “particularly intense or highly developed manner” (Bronk, King, & Matsuba, 2013, p.1). The graduates selected as exemplars composed the study sample in the qualitative phase.

**School Context**

**Academic Preparation**

The study focused on graduates from an inclusive STEM program, the Center for Science and Technology (CST), situated within Lake Hills High School (LHHS), an urban comprehensive high school. LHHS serves approximately 1,500 students with equal gender ratios, 35% of students are non-white and 53% of students come from families living below the poverty line including 25% from extreme poverty situations with the school-wide four-year graduation rate 91.5% (State Office of the Superintendent of Public Instruction, 2018). The inclusive, equity-driven mission of the CST program states that it strives to provide an environment that includes the cultural, educational, and physical aspects that support great science, great learning,
and highly innovative and effective teaching. The CST program, originating in 2008, was designed to provide opportunities for any student to pursue research in molecular biology, bioinformatics, and biochemistry while completing a full college preparatory course sequence that includes mathematics, arts, social studies, English language arts, and technology courses. The program includes a sequence of three courses that are paired with standard science courses. Students double-up in science by taking a standard science class outside the CST program within the comprehensive high school such as biology or chemistry, with a CST course such as biotechnology, bio-solutions, or genomics. For example, the first-year course in the STEM sequence, biotechnology, is paired with chemistry or biology. The second-year course in the CST sequence, bio-solutions, is paired with Advanced Placement (AP) biology and/or anatomy and physiology. The third and fourth-year STEM course, genomic research, is paired with AP chemistry and physics/AP physics. The third and fourth year course, Genomic Research, provides CST program students the opportunity to conduct student-driven science-based, applied research related to their individual interest(s) within a community of peers, instructors and local scientists.

In the first-year CST course, Biotechnology, students become familiar with equipment and practices used in research and medical laboratories. For example, students use an ultraviolet visual spectrometer for molecular quantification. For DNA and RNA quantification and quality, students use a Nanodrop, while a qPCR is used to amplify DNA and RNA. Students also access the DNA sequencer to sequence DNA.

In the second-year CST course, bio-solutions, students become proficient in laboratory technology, computational biology, and database technology. They develop skills including pipetting, preparing gel electrophoresis, collecting field specimens, using thermocyclers to
prepare DNA, and sequence their DNA samples. Other technology integrated into the bio-
solutions course are the SDS PAGE for protein analysis, Agarose gel electrophoresis for DNA
analysis, electroporation for transformation and cloning genes, as well as micro-pipetting for
micro-volume liquid transfer. Students gained the conceptual understanding of how and why the
equipment is used, how the tests are run, along with the precise skills needed to operate the
sensitive equipment.

In the third and fourth year CST courses, genomic research, students use their cumulative
knowledge and skills from the previous two courses to create their own research agenda and
conduct laboratory experiments to further the knowledge of scientific field. Typically students
use the DNA Sequencer for sequence alignment and identification, DNA Subway for sequence
analysis, and Primer Quest for design of loci specific primers. Many students contribute their
unique research discoveries to the online National Center for Biotechnology Information (NCBI)
worldwide database that contains the entire collection of DNA sequences ever collected and
analyzed. When professional researchers discover a novel DNA sequence, they input the
information into the NCBI database. Many CST program students’ research is of such high
quality, and replicable, that they are granted access to input their sequences into the NCBI
database. Through the CST program, students contribute to scientific discoveries right along-side
professional researchers. The inclusive CST courses give students opportunities to experience the
interconnected nature of biology, computer science, equipment, engineering, and mathematical
analysis. This interconnected nature of the STEM disciplines in CST classes is consistent with
professional workplaces. The CST program serves approximately 130 students each year in
grades 9-12.

The students in the CST program, situated inside LHHS, have access to six classes per
day. Students in the CST program typically take one CST class each year of high school. Juniors and Seniors enrolled in genomic research may elect to take a second genomic research credit and are granted laboratory access before and after school for continuation of research projects. In addition to a CST class, students take math, science, English, history/social studies, art, physical education, and music with other students at LHHS. Students enrolled in the CST program typically receive personalized advising from their CST program teacher and school counselor to create a multi-year class schedule with rigorous courses. Rigorous courses are defined as those that are more demanding such as Advanced Placement (AP), Honors or specialized courses when compared with basic classes that satisfy a minimum requirement for high school graduation (Adelman, 2006; Horn & Kojaku, 2001; Trusty, 2002, Tyson, Lee, Borman, & Hanson, 2007). For example, CST program students are advised to take AP biology, AP physics, or AP chemistry instead of standard biology, physics, or chemistry courses. Freshman and sophomore students are encouraged to accelerate their progression in math if needed by taking online courses so they are prepared to take calculus by their senior year. If a student is already on an accelerated math trajectory, he/she will take calculus B/C and AP statistics before graduating. The emphasis on rigor for CST program students also applies to English, history, and electives. CST students are advised to enroll in as many AP English, history and elective courses as possible. For example, a CST program student is encouraged to maximize her/his participation in the high school options of AP United States history, AP comparative government, AP world history, AP human geography, AP American literature, AP language and composition, honors English, advanced orchestra, advanced choir, advanced band, AP photography, and AP studio art. Additionally, CST program students are advised to enroll in the available Career and Technical Education (CTE) classes of principles of engineering, engineering design and
computer science offered at the high school. According to the founder and lead teacher, Mr. Martin, the STEM program is:

Not a canned ‘open up a textbook’ program. We’ve developed it almost daily for years now. There are parts that are predictable and consistent but we pride ourselves in doing labs and activities and research that we don’t have answers to. For example, we are doing a freshman project on the genetic diversity of Puget Sound sharks. Not much is known about these sharks. Our sophomores are studying local deer populations, gut microbes in honeybees, and an extinct buffalo species from Montana. Juniors and seniors are working on projects such as genetic diversity in endangered species and in invasive plants, and exploring the mysteries in celiac disease that we don’t know the answers to. It’s exciting because we don’t know the answers. We are devising techniques and protocols that allow us to create the answers.

The high school principal, Mr. Berg, and Mr. Martin captured the reflections of graduates who came back to visit the school while in their first year of college before this study began. Their reflections extend the founding teacher’s description of the STEM program in relation to the graduates’ college experience so far.

Example 1

It was conducted differently. We were not just sitting around being told what to do. We had to do our own planning, budget our time, how to look for useful articles, and learn how to collaborate with others. We learned that the reward for the hard work is the success of having done it. It has helped me a lot in college.

Example 2
It was a lot more like college than regular high school classes. We had to be independent. Teachers did not just provide the knowledge. We had to go through things and learn on our own, which is very helpful with college classes.

The process of conducting a research project was long and intense for the CST program students. To begin, the students formed groups around a problem they were interested in. For example, a few students were concerned about loss of genetic diversity in local species. The students then defined their problem relating to particular species of crayfish, located in a local watershed. Then the research team investigated the research literature online relating to that particular species of crayfish. Their next step was to contact and interview experts in that field to more fully understand the problem. The students then determined what information they need to reach their answer. In this case, the team needed to sequence a particular section of the crayfish’s DNA. The team investigated online to determine which laboratory protocols they might use for researching a particular segment of the DNA. They talked with their teacher about the protocol and the reagents, solutions, materials, and equipment needed to conduct the experiment. After they located their required components, the team wrote up a research proposal and submitted it to their teacher before beginning their work. Once the proposal was approved the team could begin the chemistry of determining how to formulate their solutions. When they were done planning and completely ready to begin their research, the team went to sample the crayfish from various locations in the watershed to obtain DNA from various populations. They began their study to understand genetic diversity among local crayfish populations. The foundational research process in this example was relatively consistent for most of student-driven research in the CST program. Even though the problem and focus of the research changes, the general research methodology changes slightly. This process of adapting procedures and lab protocols to
specific problems mirrors the work of professional researchers. Although the general research process is relatively consistent, students were guiding their own projects by making decisions, adjusting to new information, collaborating, overcoming setbacks, and modifying equipment for specific research needs. The projects were centered on student-driven problem solving. Appendix A contains three scientific posters showing the culmination of research projects conducted by students in the STEM program. The posters show how the CST students applied deep academic knowledge and advanced laboratory protocols to solve real-world problems.

**Project-Based Learning**

Through understanding the school’s and CST STEM program’s academic context, I found that not only were the instructional strategies employed in the CST program synonymous with project-based learning, but that project-based learning connected both study constructs of academic preparation and self-efficacy.

Project-based learning is a term used for “a set of instructional strategies that empower learners to conduct research, integrate theory and practice and apply knowledge” (LaForce, Noble, Blackwell, 2017, pg. 4). Although there is not one definition of project-based learning, the literature commonly recognizes project-based learning as problem-solving projects where students gain learning in the service of solving a real-world problem while collaborating, overcoming challenges, manage timelines, and typically producing a product (Buck Institute for Education, 2016; LaForce, Noble, Blackwell, 2017; Savery, 2006). The academic learning in the CST classes, as described in the section above, seemed consistent with this definition. A feature of a STEM program’s context within the comprehensive high school is not only academic learning in CST classes but also in non-CST Advanced Placement classes. Figure 2 represents how academic preparation for students in the CST program is composed of both project-based
learning experiences and Advanced Placement classes.

Figure 2. Academic preparation is composed of project-based learning and Advanced Placement

In addition to academic achievement, research suggests that students who experience project-based learning have increased self-efficacy regarding STEM and increased interest in pursuing STEM learning in college (Baran, Maskan, 2010; Berk, Muret-Wagstaff, Goyal, Joyal, Gordon, Faux, Oriol, 2014; LaForce, Noble, Blackwell, 2017; Mergendoller, Maxwell, Bellisimo, 2006). Studies suggest that students who participate in project-based experiences have an improved attitude toward learning the academic concepts, a better understanding of what it means to be a scientist or engineer, and an increased desire to pursue university STEM education after high school (Caccavo, 2009; Verma, Dickerson, & McKinney, 2011; Brownell, Kloser, Fukami, & Shavelson, 2012; Moore, 2009). Figure 3 shows how project-based learning seems to connect both academic preparation and self-efficacy.
Figure 3. Project-based learning connects both academic preparation and self-efficacy

Self-Efficacy

The relationship between academic preparation and self-efficacy is foundationally reciprocal and ongoing. For example, students in the STEM program who successfully complete an academic task are likely to feel confident not only about achieving another similar task but also in taking on a more difficult task or adopting a more challenging goal. This leads to even greater self-efficacy and the cycle continues (Bandura, 1997).

In following reflections from different CST graduates in their first-year of college there was a sense that their academic preparation mutually developed their self-efficacy. Even though these students were not part of my study, their responses contribute to overall understanding of the relationships between constructs in Figures 2 and 3.

Example 3

I did a lot of hard math. Sometimes I was kind of frustrated, but I knew I could push on.

Example 4

I have not yet been able to take science classes that will go to my major, but I can walk into any science class and know that I can do it.

Studies have suggested that when students have high beliefs about their abilities in STEM and are motivated by that confidence, students increase their academic achievement, increase
STEM course-taking, increase their likelihood of pursuing a STEM major, completing a STEM degree, and pursing a STEM career (Degenhart, Wingenbach, Dooley, & Lindner, 2007; Lent, Lopez, & Bieschke, 1993; Simpkins, Davis-Kean, & Eccles, 2006; Stevens, Olivarez, Lan, & Tallent-Runnels, 2004; Tai, Liu, Maltese, & Fan, 2006; Wang, 2013). The teachers in the CST program guided student-driven projects so that students were faced with academic and problem solving challenges to overcome leading to persistence and increased self-efficacy. There were four parts of the CST program context that, through project-based learning pedagogy, seemed to cultivate increased self-efficacy; successful failures, teacher influence, and symbolism.

**Successful failures.** The teachers in the CST program used the term ‘successful failure’ to encourage the students to persist even with obstacles and adversity. The founding teacher, Mr. Martin, regularly encouraged students who might have scored low on a test, or spent days incorrectly preparing for an experiment, or obtained erroneous data and results. Since Bandura (1997) suggested that a person’s confidence in his/her ability to complete a task is negatively influenced by repeated failures attempting that task, Mr. Martin’s efforts were aimed at countering a decrease in self-efficacy. He explained that there was powerful and important learning in every case of perceived failure. Mr. Martin’s social encouragement to continually strive for improvement bolsters the students’ confidence. Even if a student received disappointing score or result, she/he knew that there was powerful learning in the experience so it is no longer a failure that could negatively affect his/her self-efficacy. As a result of this social persuasion, the students’ belief in their ability to master content or lab skills is promoted and their sense of self-efficacy can be maintained. As students learn to not accept anything as a failure but as a powerful learning opportunity, they gain a sense of mastery over their task that positively influences their self-efficacy beliefs (Bandura, 1997). Whether a student experiences
success or a successful failure, individual confidence in his/her ability to succeed increases.

Additionally, researchers identified that learning to cope with failure and frustration is an important predictor of persistence in science (Harsh, Maltese, and Tai, 2011; Hernandez et al., 2013; Laursen et al., 2010; and Lopatto, 2007). It is possible that over four years of successes and successful failures in the CST program, students gained mastery experiences with academic concepts and laboratory skills that may have had a substantial positive influence on their self-efficacy beliefs (Lent & Brown, 2006).

The following quotes were from first year college students who visited the CST program. These graduates were not part of my study. They reflected on mastery they experienced in CST classes through successes and successful failures.

Example 5
It definitely helped me with persistence. We had a lot of problems with various parts of our research and I learned to work through it.

Example 6
In our first project this year, we kept getting false results, but we learned to work through it. It carries over to college. Work hard.

Example 7
It’s really good to know that even if things don’t work well, I need to keep trying and it will eventually work, even if not as expected.

Teacher influence. Mr. Martin, the founder and lead teacher of the CST program, and two other CST teachers, intentionally promoted self-efficacy in the context of rigorous academic preparation. Mr. Marin reflected on his role in developing students’ self-efficacy:

There are no limits here because the students are so capable. As soon as you threw lab
coats on them they became scientists – they act like scientists and believe they are scientists. The best part of the program is embracing successful failure because labs don’t always work - persistence, grit, attacking really challenging topics, teamwork, independence, how to collaborate on difficult topics, how to access difficult information. Not only creating STEM students for STEM jobs – our nation needs independent thinkers, kids who can start independently, work hard towards their goal, have failures, persist right through those failures and keep on trucking. We are producing a generation of students who are capable of persisting even under really adverse conditions. We give them a chance to show persistence, be independent and problem-solve. They are knowledge creators not knowledge receptors. We don’t open up their head and pour knowledge in; they are actually generating and making their own knowledge.

Symbolism. The STEM program emphasized self-efficacy in a variety of ways. One method was through a symbol called YATO. Near the main door to the CST laboratory there is a picture of Albert Einstein with the letters YATO vertically displayed to the side of Einstein’s face. The letters of YATO represent You Are The Ones. The CST teachers regularly emphasized to the students that they are the ones that who will graduate from high school and go on to do amazing things and change the world. According to Carlone and Johnson (2007), if students are recognized by meaningful others (such as their teachers) as ‘science people’ students’ self-efficacy increases as they internalize confidence in their own academic abilities.
Quantitative Phase

In the first phase of the Explanatory Design mixed methods approach, numerical data was collected through an alumni survey of graduates from the inclusive high school STEM program. Quantitative survey approaches are frequently used for self-efficacy (Herdandez, Schultz, Estrada, Woodcock, & Chance, 2012; Jack, Lin, & Yore, 2014; MacPhee, Farro, Canetto, 2013; Robnett, Chemers, & Zurbrigggen, 2015; Ruby, 2006; Sawtelle, Brewe, & Kramer, 2012; Wang, 2013) and academic preparation in STEM (Gnagey, Wattis, & Lavertu, 2015; Long, Conger, & Iatarola, 2012; Maltese & Tai, 2010; Simpkins, Price, C., & Garcia, 2015; Slovacek, Whittinghill, Flenoury, & Wiseman, 2012; Tai. Sadler, & Loehr, 2005).

Survey Development

To develop the survey, I met with Mr. Martin. Together, we identified factors related to the constructs self-efficacy and academic preparation that we sought to operationalize. The factors that surfaced for academic preparation included CST classes, Advanced Placement classes, computer science, and mathematics. The team felt we should align with Bandura’s (1997) research and utilize his four components of self-efficacy as factors. We reached a general understanding of each factor and consensus on which factors we would utilize for both constructs of academic preparation and self-efficacy. Our next step was to determine components under each factor. For example, in attempting to understand the role of laboratory experiences in the development of self-efficacy, we listed primary components of laboratory experiences the graduates participated in as students. We then organized each component under one of Bandura’s four self-efficacy factors. A component of laboratory experiences were students’ perceptions regarding their ability to correctly select or develop and follow a laboratory protocol. This component was categorized under the factor mastery (Bandura, 1997). Together with Mr. Martin,
I developed a matrix of the two constructs (self-efficacy and academic preparation) with corresponding factors and components within each factor. For the two constructs, there were 4 factors identified for each construct with 6-8 total factors, 12-16 components and 50 survey items. We intentionally developed more items than we would use. It was important to the team to inclusively expand our thinking before combining and/or eliminating items. The items were written in statement format for a standard Likert-type scale. Figure 4a and Figure 4b reflects the format of our process.

*Figure 4a. Survey item development: academic preparation*
In meeting again with Mr. Martin, we re-evaluated our items with emphasis placed on capturing the essence of each construct, factor and component. We found the information regarding academic preparation we sought would be optimally gained through open-ended, non-Likert scale questions such as “what math classes did you take in high school?” We modified the academic preparation items into four open-ended questions. Only the self-efficacy items remained in statement form with the Likert-scale. A spreadsheet with the survey items related to Bandura’s (1997) self-efficacy constructs could be found in Appendix B.

Additionally, along with self-efficacy items in Likert style statements and open-ended academic preparation questions, we developed six open-ended questions to collect the experiences of individual graduates. These items included what year they graduated, if they went on to college, if they pursued a STEM discipline degree, and if they attained a college degree in a STEM discipline. These items allowed for understanding the rates at which graduates chose various post-high school paths. This information was essential in determining which graduates entered and persisted with STEM degree programs. Additionally, the post-high school pathway
data were analyzed with the constructs to uncover potential patterns between levels of self-efficacy and academic preparation and potential persistence in graduates’ post-high school choices.

Each piece of open-ended, non-Likert scale, data regarding academic preparation in high school and post-high school choices corresponded to discrete arbitrary numerical values. For example, if a graduate reported to have graduated from the inclusive CST program in 2012 he/she was assigned a number 4, representing the number of years since graduation (with 2016 as the current year). Variables were positioned into categories and assigned arbitrary values (Nardi, 2015). For example, for the 4-year university category, a value of 1 would be assigned for enrolling in a 4-year university, a value of 2 for majoring in a STEM degree pathway, 3 for earning a STEM degree. Assigning variables a numeric value enabled effective statistical comparisons across and between variables (Nardi, 2015). Another type of discrete and arbitrary variables were high school and university grade point averages (GPAs). The numerical variables were represented on an Excel spreadsheet corresponding to their category and value-code.

To finalize self-efficacy items, the school team and I combined items, and eliminated items that were repetitive or unnecessary. The final Likert-scale survey contained 20 items each regarding self-efficacy. Of the 20 items: 10 related to mastery, 5 to social persuasion, 3 to psychological factors, and 2 to vicarious learning experiences. Each final survey item related to self-efficacy was written using a standard Likert-type scale ranging from “Never” (score 0/10 0) to “Always” (score 10/10 10). The scale was from zero to ten, based on the work of Pajares, Hartley, and Valiante (2001) who suggested that efficacy scales with 10-intervals were stronger predictors of performance than ones with a 5-interval scale.

My next step was to improve the clarity of how each self-efficacy item was worded. The
wording of each item was intentional in content as well as in format. According to Bandura (2006), intentional word selection is necessary since the items soliciting a self-efficacy assessment are concerned with perceived capability. In order to relate to capability, the items were phrased in terms of could rather than would. ‘Could’ is a judgment of capability whereas ‘would’ is a statement of intention (Bandura, 2006). The intentional use of the past tense was due to the retrospective nature of the high school STEM program graduates’ responses. The graduates reflected back in time between 1 and 8 years post-graduation. There are many examples of studies of retrospective alumni research throughout the literature (Carpi et al., 2016; Cobb, Brown, Hammond, & Mossop, 2015; Faupel-Badger, Raue, Nelson, & Tsakraklides, 2015; Kenny, Catraio, Bempechat, Minor, Olle, Blustein, & Seltzer, 2016; Kingsnorth, King, McPherson, & Jones-Galley, 2015; Plint, Ball, Hughes, & Desbrow, 2015).

To ensure the survey was acceptable, I had a member of my committee review the survey to check for errors such as confusing, leading or double-barreled questions (Collingridge, 2016). Once the survey was approved, I secured IRB exemption before piloting it with seniors in the inclusive CST program. The survey was formatted into an online form using the Qualtrics platform. Please see Appendix C for the survey. The seniors piloted the survey in May of 2017 before graduating in June. I chose to pilot with seniors in the STEM program because they understand the context the items are written from and they are relatively close in age to the recent graduates. There were approximately 25 seniors in the CST program in May of 2017. The pilot group of 25 seniors represented approximately 17% of the graduate population if there are about 25 graduates for each year for 6 years, for approximately 150 total graduates. At my request, the CST teachers provided access to the online survey for students using school computers. The teachers asked the students to locate and share with them about any places of
confusion as they took the survey. In addition, I asked the CST teachers to write down how long the survey took to complete and the students’ thoughts about the items once the survey was completed. Please see Appendix D for the instructions the CST teachers verbally read to the students prior to piloting the survey.

After the survey instrument was piloted, I imported the data into SPSS and checked the data to ensure the accuracy of the import. I then analyzed the internal consistency of each self-efficacy Likert-scale item with Cronbach’s alpha (Crocker & Algina, 1986; Gliem & Gliem, 2003). This alpha coefficient communicated how well the items measured the construct of self-efficacy. Cronbach’s alpha coefficient measured reliability and checked whether the responses were consistent across items (Collingridge, 2016). The Cronbach’s alpha test for validity and reliability of the twenty self-efficacy items exceeded the minimum acceptable of (a = 0.70) with a score of (a = 0.93).

I anticipated the possibility of observing a high level of relatedness between the items since they were developed from the same construct of self-efficacy and of potentially removing certain items if they were problematic. Factor Analysis was considered to understand patterns of relationships within items and simplify the relationships between the items (Beavers, Lounsbury, Richards, Huck, Skolits, & Esquivel, 2013). Specifically, Exploratory Factor Analysis (EFA) through a series of analytical steps might be used to determine the number of common items that may influence the survey and the strength and relationship between each common item (DeCoster, 1998). EFA is commonly used to evaluate the validity of a measurement scale, examine the relationship between items, and reduce the number of items while maintaining variance (Williams, 2010). Before I began EFA, I set up a correlation matrix in SPSS to investigate the appropriateness of EFA. The correlation matrix showed that the items were
discrete and were similar without overlapping, so EFA was not necessary.

Once the survey was analyzed and appropriate edits were made, I sent the survey, test data, and results to my committee member with quantitative expertise for feedback. After I made changes based on faculty feedback, the survey was ready for participants.

**Participants**

After I analyzed the pilot survey data, and made recommended changes, my next step was to get the online alumni survey link to the graduates. As a partner with the school, I requested contact information for the graduates from the Lake Hills High School. The principal, Mr. Berg, acknowledged that the school does not have contact information for the CST program graduates, only the phone numbers of their parents/guardians. I requested the names of former students who participated in the STEM program for all four years of high school who had graduated in years 2010 through 2016 and the phone numbers for their parents/guardians. I called each family on the list, introduced myself, my purpose, and inquired as to the best way to reach their son or daughter. If I was given a graduate’s phone number by their parent/guardian, I called her/him and verbally shared the link to the alumni survey. If I was given an email address, I emailed the link to the graduate. Some graduates were not able to participate because his/her parent phone number was no longer in service, their voicemail box was full or not set up yet, or they did not return my call. Some graduates chose not to participate by not responding to my calls or emails. There were approximately 18-28 program graduates each year for six years. With an average of 23 graduates a year for a total of about 138 graduates, a response rate of 50-60% or 69-82 graduates was anticipated.

To attempt to mitigate the loss of participation due to incorrect parent/guardian phone numbers, I contacted the organizer of the CST alumni Facebook page. She posted my
introductory information and the link to the alumni survey. It was unclear how each survey respondent accessed the survey, whether through direct communication with me, through the forwarding of my email to a former classmate, calling a former classmate to verbally share the survey link, or through Facebook.

After each graduate completed the survey, I assigned her/him a numerical code and a pseudonym to maintain anonymity. These identifiers are referred to in my study. Additionally, the code sheet and graduate identity were kept in separate locations. As a result of the relatively small numbers of study participants, great care was taken to avoid revealing any information that may have unintentionally revealed a graduates’ identity.

**Quantitative Analysis**

After four months of having the survey open, May 20th-August 25th 2017, and hundreds of phone calls and emails connecting with families of graduates and graduates, I decided to close the survey and analyze the data. The survey data from Qualtrics was imported into SPSS. As with the pilot survey, I checked the data to ensure the accuracy of the import and explored the internal consistency of each item with Cronbach’s alpha. I expected Cronbach’s alpha scores to remain consistent with the pilot survey results. The Cronbach’s alpha test for validity and reliability remained consistent, exceeding the minimum acceptable of (a = 0.70) with a score of (a = 0.93).

The items were analyzed using multiple regression through ANOVA to determine any relationships between choices related to STEM degree persistence and academic preparation. Multiple regression was a suitable analysis to identify the strength of effect the items may have on each other. The focus of the multiple regression analysis was to understand the relationship between self-efficacy, academic preparation, and students’ choice of and persistence toward a
college degree in a STEM discipline. For example, I checked to see if higher perceptions of self-efficacy predicted graduates entering STEM discipline degree programs. The focus of the ANOVA analysis was to understand whether there were any significant differences between the means of the academic preparation or self-efficacy variables.

In addition to attempting to understand the relationships between the 20 self-efficacy items as a whole with students choosing STEM majors, persistence in those majors, and academic preparation, I also analyzed the individual subsets of self-efficacy. I conducted multiple regressions with the subsets of social persuasion, mastery experiences, vicarious experiences, and psychological factors, as potential predictive factors of graduates choice of a STEM major and type of college.

**Demographics of the quantitative analysis sample.** In total, 58 graduates participated in the survey. Of those 58 graduates, 6 graduated from the CST program earlier than 2010 and were excluded from any analysis due to potential inaccurate reflections over a longer period of time. As a result, 52 graduates were included in the quantitative analysis. This represented a 38% response rate. Table 1 shows the high school graduation year of graduates who were included in the analysis.

<table>
<thead>
<tr>
<th>Graduates by Year</th>
<th>Number of Graduates</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Graduation Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>16</td>
<td>30.70%</td>
</tr>
<tr>
<td>2015</td>
<td>9</td>
<td>17.30%</td>
</tr>
<tr>
<td>2014</td>
<td>6</td>
<td>11.50%</td>
</tr>
<tr>
<td>2013</td>
<td>7</td>
<td>13.50%</td>
</tr>
<tr>
<td>2012</td>
<td>4</td>
<td>7.70%</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>9.65%</td>
</tr>
<tr>
<td>2010</td>
<td>5</td>
<td>9.65%</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>100%</td>
</tr>
</tbody>
</table>
Table 2 shows the type of college the CST program graduates attended. 100% of the 52 survey participants attended post-secondary institutions.

<table>
<thead>
<tr>
<th>Type of College</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Year College</td>
<td>17.3%</td>
</tr>
<tr>
<td>9 Graduates</td>
<td></td>
</tr>
<tr>
<td>Four Year College</td>
<td>82.7%</td>
</tr>
<tr>
<td>43 Graduates</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows that the majority of the CST graduates chose STEM majors and a minority pursued non-STEM majors. Each of the 52 graduates who participated in the survey had pursued post-secondary education. Additionally, a majority of STEM majors were bio-science related fields.

<table>
<thead>
<tr>
<th>Graduates’ Majors</th>
<th>Number of Graduates</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM</td>
<td>38</td>
<td>73%</td>
</tr>
<tr>
<td>- Bioscience</td>
<td>27</td>
<td>71%</td>
</tr>
<tr>
<td>- Non-Bioscience</td>
<td>11</td>
<td>29%</td>
</tr>
<tr>
<td>Non-STEM</td>
<td>14</td>
<td>27%</td>
</tr>
<tr>
<td>Total (STEM + Non-STEM)</td>
<td>52</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Threats to validity.** My study utilized procedures to ensure the validity of the data, results and interpretation (Creswell & Plano Clark, 2007). However well planned my study was, there are inherent places of weakness and threats to validity. One area of weakness was a comparatively small number of survey respondents. The power of the statistical tests increases with the number of factors being analyzed.

Even though Cronbach’s alpha test for validity and reliability of the twenty self-efficacy items exceeded the minimum acceptable of (a = 0.70) with a score of (a = 0.93), there are likely
to be latent threats to construct validity and criterion-related validity since it was a new tool I designed specifically for this study. Instruments are typically refined over time to ensure they measure what they intend to measure. Initially I sought an instrument that was previously validated and showed reliability. I did not find an instrument in the research literature that was compatible with my research questions and school context. Since there were no fitting instruments to compare item scores with, there are likely threats to criterion-related validity (Creswell & Plano Clark, 2007). Even though these threats existed, I planned to check the internal validity by determining if it was sufficient to draw valid conclusions from. If there were correlating relationships, I could protect the internal validity of the survey (Creswell & Plano Clark, 2007). Additionally, there are epistemological threats to the concept of external validity. My study is founded on the post-positivistic perspective that it is not necessary for research results to apply to a larger population or be generalizable. Since each individual has their own unique interpretations of a single ‘real world’ (Morse, 1991; Morgan, 2007), the impact of my study resides in whether the reader determined my findings are informative to their particular context or initiative.

**Qualitative Phase**

**Quantitative to Qualitative**

In the two-phase sequential explanatory design mixed methodology, the qualitative phase followed and was informed by the initial quantitative phase. In the study, equal priority was given to both phases and approaches (Creswell, Plano Clark, Guttman, & Hanson, 2003) because each yields distinctive and valuable insights towards understanding the research questions. In the results chapter, the findings from both approaches are communicated as well as a section connecting (Hanson, Creswell, Plano Clark, Petska, & Creswell, 2005) analyses from both
datasets into a mixed, full, rich and nuanced understanding of each research question. The flow of the Explanatory Design from quantitative to qualitative to an interpretation of both approaches is shown in Figure 5.

Figure 5. Explanatory design flow chart modified from Ivankova & Stick (2007)

**Qualitative Design**

The qualitative phase consisted of developing semi-structured interview questions based
on analysis of the CST program graduates’ survey responses, selecting certain graduates for interviews, conducting the interviews, and analyzing the verbal qualitative data to uncover any patterns or themes. The purpose of the qualitative interviews was to gain understanding of the STEM program graduates’ life experience with academic preparation, self-efficacy, and their post-high school academic choices.

**Interview protocol development.** The substance of the interview protocol was grounded in the quantitative results of the alumni survey from the first phase of the study. This was consistent with the Sequential Explanatory Design methodology where the aim of the qualitative phase is to extend, augment, elaborate, and deepen the results of the quantitative statistical tests (Creswell et al., 2003).

The school team, Mr. Berg, Mr. Martin, Mr. Shaw, and I met in June 2017 after 25 graduates had participated in the survey. With an initial understanding of the knowledge we would glean from the survey, we were able to design interview questions that would prompt fuller, richer insight from their numerical responses. Our initial brainstorm produced 16 questions that were focused on post-high school academic choices, academic preparation, and the same self-efficacy components as the survey; mastery experiences, social experiences, vicarious experiences, and psychological state. We recognized that to maximize participation the interview needed to be conducted in 30 minutes or less. In order to fit into that time frame, the school team and I condensed similar or repetitive questions into a final list of 7 primary interview questions. These 7 questions consisted of:

- A general opening question that focused on post-high school choices and academic preparation,
- A question focused on self-efficacy through mastery,
• A question focused on self-efficacy through social persuasion,
• A question focused on self-efficacy through psychological state,
• A question focused on both academic preparation and self-efficacy through mastery,
• A question focused on self-efficacy through mastery, vicarious experiences, and social persuasion, and
• A general closing question with prompting for self-efficacy, academic preparation, and post-high school experiences.

Each primary question had probing questions to prompt an extension of participants’ responses if necessary. See Appendix F for the interview questions.

Before conducting interviews, I applied for and received an addendum to my previous IRB exemption regarding the alumni survey. It was necessary to pursue IRB exemption in two stages since the interview questions were developed from the alumni survey responses. With Sequential Explanatory Design methodology, where the quantitative data informs the qualitative phase, it was not appropriate to concurrently submit the alumni survey and the interview questions.

Participants

To identify participants for the qualitative interviews, I used the STEM program graduates’ responses to the alumni survey regarding self-efficacy, academic preparation, and post-high school academic choices. In my investigation to understand how self-efficacy and academic preparation influence graduates’ choice of and persistence toward a college degree in a STEM discipline, I selected graduates who reported high levels of both constructs. Since research confirms the influence of both constructs on graduates’ choice of and persistence toward a STEM degree, I selected a qualitative participant pool from the graduates who had
responded with high self-efficacy and high academic preparation. According to the research base, these students should have an optimal high school foundation, related to the two constructs, and should be most likely of the STEM program graduates to choose STEM degree pathways and persist towards STEM degree completion.

I anticipated the possibility that some of the graduates with high perceptions of self-efficacy and high academic preparation would have chosen to enter post-secondary STEM degree pathways while others may have made different career or life choices. Regardless of post-high school choices, if a graduate met the selection criteria she/he was included in the qualitative sample and invited to participate in semi-structured interviews. Of the sample population, each graduate chose a post-high school academic pathway, a majority chose to pursue a college degree in a STEM discipline, and a minority chose to pursue a college degree in a non-STEM discipline. The selection criterion for these graduates was guided through an exemplar approach.

**Exemplar approach.** The graduates who reported high self-efficacy and high academic preparation were considered exemplars regardless of their college discipline choice. As exemplars they represented the constructs of self-efficacy and academic preparation in a “particularly intense or highly developed manner” (Bronk, King, & Matsuba, 2013, p.1). Exemplar approaches were used to analyze the qualitative interview data. A benefit of exemplar methodology was its usefulness in revealing the leading edge of a construct of interest (Damon & Colby, 2013). In utilizing exemplar methods, I decided to focus on graduates that exhibited high scores for self-efficacy and academic preparation instead of graduates with average or typical scores (Matsuba, King & Bronk, 2013). The exemplar approach emphasized personal strengths instead of weaknesses. This methodology evolved with the advancement of the positive psychology effort (Benson & Scales, 2009; Damon 2004; Seligman & Csikszentmihalyi, 2000;
Exemplar methods helped shift research away from focusing on personal deficiencies and vulnerabilities to highlighting wellness and flourishing (Bundick, Yeager, King, & Damon, 2010; Seligman, 2011; Wissing, 2000). In chapter five, the exemplars are illustrated through in-depth explanations of the data collected from the quantitative survey and with qualitative data from semi-structured interviews (Bronk, King, & Matsuba, 2013).

Since it was not feasible or necessary to interview each graduate, my committee deemed a sample of approximately 15% the survey population as sufficient. About 15% of 50 participants were 8 graduates. In total, 58 graduates participated in the survey. Of those 58 graduates, 6 graduated from the CST STEM program earlier than 2010 and were excluded from any analysis due to CST program changes that took place in 2010. To identify the 8 STEM program graduates out of 52 who exemplified self-efficacy and academic preparation, I set criteria based on their survey responses. For the 20 self-efficacy items with the 0-10 Likert scale, I observed that there were 15 graduates with average self-efficacy scores of 9.40 or higher. With academic preparation, it is important to note that all graduates in the study were initially selected for the alumni survey because they participated in 4 years of the STEM program. Each graduate had those courses in common. To identify exemplars with optimal academic preparation, I observed how many non-STEM program Advanced Placement (AP) science and math courses the graduates had chosen to take. The AP science classes were commonly AP Biology, AP Chemistry, and AP Physics. The AP math classes were commonly AP Calculus AB, AP Calculus BC, and AP Statistics.

Table 4 shows how many graduates took challenging science and math courses. Out of 52 survey participants, 41 took at least 2 AP science and/or 2 AP math classes.
Table 4

<table>
<thead>
<tr>
<th>Advanced Placement Courses Taken</th>
<th>Graduates</th>
<th>Courses taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
<td>2 or more AP science classes</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>2 or more AP math classes</td>
</tr>
</tbody>
</table>

The majority of graduates scored high in one of three areas: self-efficacy, math, and science while a minority scored high in two out of those three areas. For inclusion as exemplars into the qualitative participant pool, graduates needed to meet the criteria in two out of the three areas. 17 students met this criterion. These 17 students all had high science, high math, and high self-efficacy, or they were high in either science or math and self-efficacy, or high in science and math without high self-efficacy.

There was only one graduate who responded to the alumni survey and reported high self-efficacy with low math and low science preparation. I included this intriguing outlier because this graduate was attending a 4-year, private, small, liberal arts university and is working towards a Health Sciences/Pre-Medicine degree. There were two other outliers whom I also included. One graduate, Zoe, reported low math and low science preparation as well as low self-efficacy scores, even though Zoe studied at a 4-year, public, more selective, university with the highest level of research activity (R1 university) towards a degree in Genetic Counseling (Carnegie Classification of Institutions of Higher Education, 2018). The other outlier for inclusion reported high academic preparation in math, low in science, and low self-efficacy scores. This graduate, Alexa, studied at a 4-year, private, most selective, R1 university and attained a Molecular and Cellular Biology degree, and was pursuing Osteopathic Medicine. These three outliers chose STEM degree pathways and persisted towards STEM discipline degrees in a way that differs from the other 17 participants. Their stories were intriguing to me. In total, 20 graduate
exemplars were selected for participation in the qualitative interviews.

When the graduates completed the alumni survey, they entered their email address and phone numbers. I emailed each of the 20 exemplars inviting them to participate in one 30-minute interview. Realizing that there would be exemplars that do not respond to my emails or phone calls, a pool of 20 allowed up to 12 non-participants and the ability to still meet my minimum of 8 interviews. I was able to contact two of the three outliers, Zoe and Alexa, and six graduates from the group of 20 for interviews.

Table 5 is a snapshot of each of the 8 graduates’ self-efficacy score, academic preparation, the university the graduate attends, and the major and minor(s) the graduate is pursuing. The table is organized in terms of self-efficacy from highest to lowest scores based on the ten-point twenty-item Likert scale survey. A score of 10 indicated highest self-efficacy and a score of 0 indicated lowest self-efficacy. The graduates’ universities were assigned classification categories according to the Carnegie Classification of Institutions of Higher Education (2018).

Table 5

<table>
<thead>
<tr>
<th>Graduate</th>
<th>Self-Efficacy Score</th>
<th>Academic Prep</th>
<th>University</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audrey</td>
<td>9.95</td>
<td>Chemistry, AP Chemistry, AP Physics, AP Biology, Algebra II, Pre-Calculus, AP Calculus BC</td>
<td>4 year, public, selective, R1</td>
<td>Animal Sciences/Veterinary Medicine</td>
</tr>
<tr>
<td>Emily</td>
<td>9.95</td>
<td>Chemistry, AP Chemistry, AP Physics, Algebra II, AP Calculus, AP Statistics</td>
<td>4 year, public, R1</td>
<td>Chemical Engineering</td>
</tr>
<tr>
<td>Name</td>
<td>GPA</td>
<td>AP Courses</td>
<td>Type</td>
<td>Major</td>
</tr>
<tr>
<td>--------</td>
<td>-----</td>
<td>------------------------------------------------</td>
<td>-----------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Ryan</td>
<td>9.6</td>
<td>AP Chemistry, AP Physics C, Algebra II, Pre-Calculus, AP Calculus, AP Calculus BC</td>
<td>4 year, public, R1</td>
<td>Chemical Engineering</td>
</tr>
<tr>
<td>Leah</td>
<td>9.5</td>
<td>AP Chemistry, AP Bio, AP Physics, Algebra II, Algebra II Honors, Pre Calculus, AP Calculus</td>
<td>4 year, private, small, liberal arts</td>
<td>Biology and Health Sciences</td>
</tr>
<tr>
<td>Lily</td>
<td>9.5</td>
<td>AP Chemistry, AP Biology, AP Physics, Algebra II, Pre-Calculus, AP Calculus, AP Calculus BC</td>
<td>4 year, public, R1</td>
<td>Applied Mathematics</td>
</tr>
<tr>
<td>Aiden</td>
<td>9.45</td>
<td>Chemistry, AP Biology, AP Chemistry, and AP Physics I, Algebra II, Pre-Calculus, AP Calculus AB, AP Stats</td>
<td>4 year, public, more selective, R1</td>
<td>Chemical Engineering</td>
</tr>
<tr>
<td>*Alexa</td>
<td>9.05</td>
<td>Chemistry, Physics, Algebra II, AP Calculus</td>
<td>4 year, private, most selective, R1</td>
<td>Molecular &amp; Cellular Biology, enrolled in Medical school</td>
</tr>
<tr>
<td>*Zoe</td>
<td>7.7</td>
<td>Chemistry, AP Bio, Algebra, Geometry, Algebra II, AP Stats</td>
<td>4 year, public, more selective, R1</td>
<td>Psychology &amp; Genetic Counseling</td>
</tr>
</tbody>
</table>

* = outlier

**Exemplar methodology.** The exemplar approach to the qualitative phase of my study was both similar to and deviated from other studies employing exemplar methods. My approach partially agrees with some exemplar studies utilized in case studies by examining interviews through coding and theme/pattern finding, and analyzing within and across exemplars. My approach differs from some exemplar studies in that the researchers tend to have matched comparison groups and translate codes into numerical values to analyze with statistical tests for quantitative results (Dunlop, Walker, & Matsuba, 2013; Frimer, Walker, Dunlop, Lee & Riches,
2011; Frimer, Walker, Lee, Riches & Dunlop, 2012; Matsuba & Walker, 2004; Matsuba & Walker, 2005; Walker & Frimer, 2007; Walker, Frimer, & Dunlop, 2010). My study partially utilized the exemplar methods by conducting interviews, coding, pattern/theme finding, analyzing within and across exemplars, while not forming matched comparison groups or translating codes into numerical values for statistical tests and results. It would be difficult to find graduates of similar STEM program within a similar context in relation to self-efficacy and academic preparation in a different location to recruit as a matched comparison group. Additionally, my research questions and purpose of my study is focused on this specific population of graduates, not on comparisons between them and graduates of other programs.

Exemplar research is used consistently in mixed methods research (Bronk, King, Matsuba, 2013) although it often progresses in the opposite direction as sequential explanatory design. Exemplar research often starts with qualitative interviews and translates narrative data into numerical data for statistical analysis and results. Sequential explanatory design methodology initiates the study with quantitative methods followed by expansion and elaboration with qualitative methods. Exemplar research is an appropriate frame for analyzing graduate exemplars that exemplify the constructs of self-efficacy and academic preparation in a “particularly intense or highly developed manner” (Bronk, King, & Matsuba, 2013, p.1). The exemplar research methodology progressed through interviews, coding, pattern/theme finding within exemplars and across exemplars, and did not continue into translating qualitative data into quantitative.

Included in the two-level exemplar analysis was a full descriptive narrative for each of the ten individual exemplars and a summary of cross-exemplars. Once the ten individual exemplar narratives were complete, I sent them to the graduates I interviewed for member
checking. I asked the participants to evaluate whether the findings are accurate reproductions of their experiences. This is a frequently used approach to protect validity in qualitative research (Creswell & Plano Clark, 2007).

**Qualitative Analysis**

The following sections contain a two-level exemplar study analysis of the qualitative data including the comparison of the interview data within each exemplar and across the exemplars (Matsuba, King & Bronk, 2013). Each graduate in the sample group who met the criteria for inclusion, or was an intriguing outlier, was considered an exemplar. The analysis began with the exemplar interviews. Each interview was audio recorded (Creswell, 2005) using the microphone on my computer and with the microphone on my phone. I utilized two recording devices to provide increased assurance of a successful recording.

The interview analysis was performed at two levels: within each exemplar and across the exemplars (Walker & Frimer, 2007). I used ALTAS.ti qualitative software for data organization, coding, and theme development. To begin, I conducted an initial exploration of the data by reading through the interview transcripts and writing analytic memos and notes (Saldana, 2015). Reading through the interview responses resulted in tentative ideas about patterns, trends and potential categories (Walker & Frimer, 2007). I identified three main options for analyzing qualitative data: memos, categorizing strategies, and connecting strategies (Maxwell (2005).

In analysis of the first level, a categorizing strategy was used within an individual exemplar context (Patton, 1990). In this approach, the context of each exemplar was retained, and the data were interpreted within that context, to provide an account of a particular instance, setting, person, or event (Hesse-Biber & Leavy, 2010). This strategy sought to avoid a phenomenon where the researcher obscures the context by splitting textual data into analytic
codes and categories across interviews. The neglect of context is viewed as a major defect of coding and other categorizing strategies (Hesse-Biber & Leavy, 2010). I used coding (Saldana, 2015) as a categorizing strategy within each graduate exemplar. I coded and categorized each graduate’s responses to interview questions by labeling and grouping the text (Saldana, 2009). After I retained the context of each exemplar by categorizing within the exemplar, I categorized (coded) across the exemplars (Walker & Frimer, 2007; Yin, 2003). This synthesis technique allowed patterns and themes to emerge contextually from within each exemplar before being categorized and aggregated across participants to connect overall patterns and relate themes (Creswell, 2003; Yin, 2003).

**Codes.** As I examined the first interview, I noticed themes and patterns in the CST graduates’ responses. These themes were related to the survey items as well as underlying components. I translated these themes into 18 codes. Table 6 shows seven codes related to interview items:

<table>
<thead>
<tr>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP &amp; CST: Advanced Placement and the CST (STEM program)</td>
</tr>
<tr>
<td>CST Academic Prep: Academic Preparation from CST classes</td>
</tr>
<tr>
<td>CST Collaboration: Collaboration skills in CST classes</td>
</tr>
<tr>
<td>CST Field to Podium: The research process in CST classes</td>
</tr>
<tr>
<td>CST Successful Failures: Self-efficacy, persistence in CST classes</td>
</tr>
<tr>
<td>Major: What university major the graduate selected</td>
</tr>
<tr>
<td>University: What university the graduate attends</td>
</tr>
</tbody>
</table>

There were some codes that developed from within the participants’ responses to the
interview questions. These underlying latent themes were not represented in the survey items or interview questions; they arose through responses to other interview questions or tangents the graduates’ explored as they replied to an interview question. These 11 latent themes were noticed in the interviews and adopted as codes.

Table 7

<table>
<thead>
<tr>
<th>Latent Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codes</td>
</tr>
<tr>
<td>CST Confidence Belief in Self: A personal confidence as a result of CST classes</td>
</tr>
<tr>
<td>CST Pride In Work: A sense of pride in the work done in the CST classes</td>
</tr>
<tr>
<td>Student Directed: The impact of student-directed pedagogy in the CST classes</td>
</tr>
<tr>
<td>LHHS Academic Prep: The impact of classes in the comprehensive high school, separate from CST classes</td>
</tr>
<tr>
<td>Collaboration with Researchers: The impact of students in CST classes working with professional researchers</td>
</tr>
<tr>
<td>CST Teacher Influence: The influence of teachers in CST classes, separate from the teachers in the comprehensive high school</td>
</tr>
<tr>
<td>LHHS Teacher Influence: The influence of teachers in the comprehensive high school, separate from CST teachers</td>
</tr>
<tr>
<td>STEM Interest: The impact CST classes had on fostering an interest in STEM</td>
</tr>
<tr>
<td>Support People: People in the graduate’s life who encouraged them to pursue STEM</td>
</tr>
<tr>
<td>University Academics: Relating to university academics</td>
</tr>
<tr>
<td>Working in the Field: Relating to graduates working in the field aligned with their major</td>
</tr>
</tbody>
</table>

As the qualitative analysis progressed with multiple cycles of coding, I noticed that some codes were not used frequently as compared with the majority of codes. After examining the context further, I found the quotations with these codes were more accurately represented by other codes. The codes ‘collaboration with researchers’, ‘university academics’, ‘working in the field’, and ‘pride in work’, had quotations coded to them, 2, 7, 8, and 14 respectively. Each one
was double coded with another code that more accurately recognized the speaker’s context.

These quotations were double coded with other codes and will be reported as part of those other codes. I kept the less frequent codes in Atlas.ti to acknowledge my initial analysis. Additionally, the code ‘student directed’ was too limiting for the learning experiences the alumni described. That code was re-named to Project-Based learning pedagogy.

After multiple cycles of coding and revisions to the codes, the condensed code chart, Table 8, contains a total of 15 codes; seven codes from interviews and eight latent codes.

Table 8

Condensed Code Table

<table>
<thead>
<tr>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP &amp; CST: Advanced Placement and the CST (STEM program)</td>
</tr>
<tr>
<td>CST Academic Prep: Academic Preparation from CST classes</td>
</tr>
<tr>
<td>CST Collaboration: How collaboration skills in CST classes</td>
</tr>
<tr>
<td>CST Field to Podium: The research process in CST classes</td>
</tr>
<tr>
<td>CST Successful Failures: Self-efficacy, persistence in CST classes</td>
</tr>
<tr>
<td>Major: What university major the graduate selected</td>
</tr>
<tr>
<td>University: What university the graduate attends</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Latent Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST Confidence Belief in Self: A personal confidence as a result of CST classes</td>
</tr>
<tr>
<td>Project-Based Learning Pedagogy: The impact of Project-Based Learning pedagogy in the CST classes</td>
</tr>
<tr>
<td>LHHS Academic Prep: The impact of classes in the comprehensive high school, separate from CST classes</td>
</tr>
<tr>
<td>CST Teacher Influence: The influence of teachers in CST classes, separate from the teachers in the comprehensive high school</td>
</tr>
<tr>
<td>LHHS Teacher Influence: The influence of teachers in the comprehensive high school, separate from CST teachers</td>
</tr>
<tr>
<td>STEM Interest: The impact CST classes had on fostering an interest in STEM</td>
</tr>
</tbody>
</table>
Limitations

Methodological

The limitations of my mixed methods approach include trade-offs regarding the depth of outcomes in either traditional qualitative or quantitative perspectives. My study does not have a large participant group with multiple levels of detailed statistical analyses. Conversely, the study will not be based entirely on full detailed narratives. Aspects of both methods will be present although not to the depth as a traditional one-methodology study.

Participants

There were inherent limitations resulting from the sample population in both the quantitative survey and the qualitative interviews, beyond their choice to participate or not. To encourage graduates’ participation in the survey, it was titled Alumni Questionnaire for maximum inclusivity. Additionally, the opening paragraph stated the intent of the survey and a personal motivation for participating. The intent was to connect with graduates about life after high school, gain reflections from their experience in the STEM program, and to honor the legacy of Mr. Martin before his retirement.

Missed communication opportunities kept many potential graduates from participating in both the survey and the interviews. In initially recruiting survey participants, I was challenged with not having access to graduates’ contact information. Mr. Berg provided me with school records to connect with families to gain the graduate’s phone number or email address. Many graduates were not able to participate in the survey as a result of their family members changing phone numbers, not returning my calls, or having voicemail boxes that were full or not set-up yet. Additionally, many graduates did not have an opportunity to participate in the survey or
interviews because they did not respond to my phone and/or email invitations. The participant pools were biased towards graduates whose family members returned my calls and/or emails.

Additionally, the exemplar method of participant selection in my study had limits and constraints resulting from not translating the qualitative data into quantitative data and by not including a matched comparison group. Additionally, the interviewees were selected as exemplars based on their survey responses, and may not be representative of other graduates. Even though they were selected based upon their self-perceptions of their academic preparation and self-efficacy, their situation and experiences may be completely individualized and unlike any other graduates.

A further participant limitation resulted from my study design. Since initial participants were selected for the survey based on graduating from the STEM program, there was not an emphasis on the opportunity structures of participants. My study did not use a social justice lens to address gender, majority minority students, low-income or historically disenfranchised groups.

**Generalizability**

The findings of my study were limited in generalizability resulting from the specific STEM program context and the epistemological approach of my study. Even though there are other STEM programs within comprehensive schools, each has its own unique context. My study context may be similar to other STEM programs in some ways, but each will differ from another in other ways. The findings of my study may be relevant depending upon the context and life experiences of the reader.

As discussed in Chapter 1, my epistemological choice to reject a positivistic claim of producing generalizable knowledge is supported by a multitude of researchers (Guba & Lincoln, 2005; Mertens, Bledsoe, Sullivan, Wilson, 2010; Tashakkori & Teddlie, 2010). I acknowledge
that “objective reality can never be captured” (Lincoln, Lynham, & Guba, 2011, p.99) and that research is “not ever truly objective” (Hughes, King, Rodden & Andersen, 1994). Since research is never truly objective, findings are not generalizable to diverse contexts. It is my intention to understand my research question within the specific STEM program context, not to produce generalizable findings.

**Threats to Validity**

In the qualitative phase, validity is determined by whether the narrative provided by the researcher and participants can be trusted, is credible, and is accurate (Lincoln & Guba, 1985). Validity was checked using member checking (Creswell & Plano Clark, 2007), with the graduates evaluating whether the narratives from their interviews matched their reflections of their experiences. Even though member checking helped protect validity, there remained threats to reliability. Since my study was designed and conducted by me, there are no intercoder agreements or interrelater reliability methods. If I had worked with a team of researchers, we would have established methods for multiple individuals to code a transcript and compare their coding decisions to determine whether they arrived at the same or different codes and/or themes (Miles & Huberman, 1994). Ultimately, even with protections to ensure validity and reliability, evidence and knowledge gained through research will always be imperfect and fallible (Phillips & Burbules, 2000).
CHAPTER FOUR: RESULTS

This chapter discusses the results of the quantitative and qualitative analyses to understand the impact of self-efficacy and academic preparation developed in an inclusive STEM high school program on graduates’ choice of and persistence toward a college degree in a STEM discipline.

The study and following analyses were grounded in the research question:

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

While academic preparation and self-efficacy are two separate constructs (independent variables), the concepts of graduates’ choice of a STEM major and the continuation of their STEM learning in college were one construct (dependent variable).

This chapter begins with a presentation of the statistical results, followed by a discussion of these in relation to the research question and theoretical framing. Next, the qualitative results are presented through a discussion of each graduate followed by an analysis across the eight participants.

Quantitative Analysis

The quantitative analysis was conducted with 52 graduates of the CST STEM program. Of these 52 graduates, 100% participated in post high school education with 83% attending a four-year college (see Table 2). A majority, 73% of graduates, pursued a STEM major in college (see Table 3).
In the quantitative analysis, the dependent variable was graduates’ choice of and persistence toward a college degree in a STEM discipline. The multiple independent variables are shown in Table 9.

Table 9

<table>
<thead>
<tr>
<th>Dependent</th>
<th>Independent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of STEM major and persistence toward college degree in STEM discipline</td>
<td>Self-efficacy</td>
</tr>
<tr>
<td></td>
<td>• High school career goal</td>
</tr>
<tr>
<td></td>
<td>• Self-efficacy scores</td>
</tr>
<tr>
<td></td>
<td>• Self-efficacy subsets:</td>
</tr>
<tr>
<td></td>
<td>o Social persuasion</td>
</tr>
<tr>
<td></td>
<td>o Mastery experiences</td>
</tr>
<tr>
<td></td>
<td>o Vicarious experiences</td>
</tr>
<tr>
<td></td>
<td>o Psychological factors</td>
</tr>
<tr>
<td>Academic Preparation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Grade point average</td>
</tr>
<tr>
<td></td>
<td>• Science</td>
</tr>
<tr>
<td></td>
<td>• Math</td>
</tr>
</tbody>
</table>

The quantitative results are presented as an analysis of independent variables, self-efficacy and academic preparation, in relationship with the dependent variable, choice of and persistence toward a college degree in a STEM discipline. First, the analysis of the self-efficacy variables is presented followed by the discussion of self-efficacy results. Second, the analysis of academic preparation variables are presented followed by the discussion of academic preparation results.

Self-Efficacy Analysis

High school career goal, choice of and persistence toward STEM degree. The simple linear regression analysis was conducted to predict graduates’ choosing and persisting toward a STEM degree based on graduates’ high school career goals. A significant regression equation was found (F(1, 50) = 7.00, p < .05), with an $R^2$ of .123. Participants’ scores predicted choice of
and persistence toward STEM degree is equal to \( .462 + .359 \) high school career goal when choice of and persistence toward STEM degree is measured by \( 0 = \text{non-STEM} \) and \( 1 = \text{STEM} \), and career goal is measured as a \( 0 = \text{non-STEM} \) or \( 1 = \text{STEM} \). Graduates’ choice of and persistence toward STEM degree increased \( .359 \) for each high school career goal as a \( 0 \) or \( 1 \).

Table 10

<table>
<thead>
<tr>
<th>High School Career Goal &amp; STEM Major</th>
<th>( \beta )</th>
<th>SE</th>
<th>B</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Career Goal &amp; STEM Major</td>
<td>.359</td>
<td>.136</td>
<td>.350</td>
<td>2.646</td>
<td>.011</td>
<td></td>
</tr>
</tbody>
</table>

The following self-efficacy survey results were derived from graduates’ responses to twenty-items, each on a ten-point Likert scale.

**Average self-efficacy scores, choice of and persistence toward STEM degree.** The graduates whose choice of and persistence toward STEM degree had higher average self-efficacy scores than the average self-efficacy scores of the 52 graduates. The graduates who chose non-STEM majors reported lower than the average self-efficacy scores of the 52 graduates.

Table 11

| Self-Efficacy Scores And Choice Of And Persistence Toward STEM Degree, \( n = 52 \) |
|---------------------------------|-----------------|----------------|
| Graduates’ self-efficacy scores | 8.48            | 100%           |
| STEM majors                     | 8.76            | 73%            |
| Non-STEM majors                 | 7.79            | 27%            |

As a result of the low level of variance in the self-efficacy scores, the multiple linear regression analysis conducted to predict graduates’ choice of and persistence toward STEM degree based on graduates’ self-efficacy scores resulted in a non-significant regression equation. The equation was \( (F(19, 30) = .861, p > .05) \), with an \( R^2 \) of \( .353 \). Participants’ scores predicted choice of and persistence toward STEM degree is equal to \( .214 + .023 \) self-efficacy when STEM
major is measured by $0 = \text{non-STEM}$ and $1 = \text{STEM}$, and self-efficacy is measured on a 0-10 scale.

Table 12

<table>
<thead>
<tr>
<th>Regression for Self-Efficacy Predictors of Choice Of And Persistence STEM Degree, $n = 52$</th>
<th>$\beta$</th>
<th>SE</th>
<th>B</th>
<th>Beta</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Efficacy &amp; STEM Major</td>
<td>.023</td>
<td>.950</td>
<td>.183</td>
<td>.063</td>
<td>.615</td>
<td></td>
</tr>
</tbody>
</table>

Self-efficacy subsets, choice of and persistence toward STEM degree. Additionally, as a result of low variance, regression analyses showed that self-efficacy sub-sets of social persuasion, mastery experiences, vicarious experiences, and psychological factors did not predict a graduate choosing of and persisting toward a STEM degree.

Social persuasion. The multiple linear regression analysis was conducted to predict graduates’ choice of and persistence toward STEM degree based on graduates’ social persuasion scores. A non-significant regression equation was found ($F(5, 45) = .581, p > .05$), with an $R^2$ of .061. Participants’ scores predicted choice of a STEM major is equal to $0.551 + 0.025$ social persuasion scores when choice of and persistence toward STEM degree is measured by $0 = \text{non-STEM}$ and $1 = \text{STEM}$, and self-efficacy is measured on a 0-10 scale.

Mastery experiences. The multiple linear regression analysis was conducted to predict graduates’ choice of and persistence toward STEM degree based on graduates’ mastery experience scores. A non-significant regression equation was found ($F(9, 41) = 1.565, p > .05$), with an $R^2$ of .256. Participants’ scores predicted choice of and persistence toward STEM degree is equal to $1.137 - 0.036$ mastery experience scores when choice of and persistence toward STEM degree is measured by $0 = \text{non-STEM}$ and $1 = \text{STEM}$, and self-efficacy is measured on a 0-10 scale.
Vicarious experiences. The multiple linear regression analysis was conducted to predict graduates’ choice of and persistence toward STEM degree based on graduates’ vicarious experience scores. A non-significant regression equation was found (F(2, 49) = 1.484, p > .05), with an R² of .057. Participants’ scores predicted choice of and persistence toward STEM degree is equal to 1.137 - .021 vicarious experiences scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and self-efficacy is measured on a 0-10 scale.

Psychological factors. The multiple linear regression analysis was conducted to predict graduates’ choice of and persistence toward STEM degree based on graduates’ psychological factor scores. A non-significant regression equation was found (F(3, 48) = .578, p > .05), with an R2 of .035. Participants’ scores predicted choice of and persistence toward STEM degree is equal 1.05 + .038 to psychological factors scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and self-efficacy is measured on a 0-10 scale.

Table 13

<table>
<thead>
<tr>
<th>Self-Efficacy Subset Predictors of Choice Of And Persistence Toward STEM Degree, n = 52</th>
<th>β</th>
<th>SE</th>
<th>B</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Persuasion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEM Major</td>
<td>.025</td>
<td>.062</td>
<td>.074</td>
<td>.407</td>
<td>.771</td>
</tr>
<tr>
<td>Mastery Experiences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEM Major</td>
<td>.036</td>
<td>.058</td>
<td>.147</td>
<td>.624</td>
<td>.158</td>
</tr>
<tr>
<td>Vicarious Experiences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEM Major</td>
<td>.021</td>
<td>.056</td>
<td>.067</td>
<td>.372</td>
<td>.237</td>
</tr>
<tr>
<td>Psychological Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STEM Major</td>
<td>.038</td>
<td>.049</td>
<td>-.148</td>
<td>-.942</td>
<td>.632</td>
</tr>
</tbody>
</table>
**Self-Efficacy Discussion**

The quantitative survey data regarding the potential influence of an emphasis on self-efficacy on graduates’ choice of and persistence toward a college degree in a STEM discipline yielded mixed results. Table 14 is a summary of these results.

Table 14

*Summary of Self-efficacy Analyses, Choice of and Persistence Toward STEM Degree, n = 52*

<table>
<thead>
<tr>
<th></th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Career Goal</td>
<td>.011</td>
</tr>
<tr>
<td>Self-Efficacy Scores: 20 Likert scale items</td>
<td>.615</td>
</tr>
<tr>
<td>Social Persuasion</td>
<td>.771</td>
</tr>
<tr>
<td>Mastery Experiences</td>
<td>.158</td>
</tr>
<tr>
<td>Vicarious Experiences</td>
<td>.237</td>
</tr>
<tr>
<td>Psychological Factors</td>
<td>.632</td>
</tr>
</tbody>
</table>

The survey participants, graduates of the CST STEM program, showed that their high school career goal predicted their choice of and persistence toward a college degree in a STEM discipline. The significant relationship suggests that persistence in STEM relies on a combination of student goals (the desire to obtain a STEM degree) and self-efficacy (the personal assessment of ability to behave/act in ways needed to succeed in a STEM major). The significant result of graduates’ high school career goal predicting their choice of and persistence toward STEM degree is meaningful since according to Lent, Brown, and Hackett (2000), persistence in STEM majors is a function of the interconnected nature of career goals and self-efficacy. It may be that the development of a STEM career goal requires self-efficacy even though my survey data did not show this. For example, in previous studies, high school students personally self-assessed themselves to form judgments about their ability to perform actions to accomplish a desired goal (Bandura, 1997; Pajares, 2005; Rittmayer & Beier, 2008; Zimmerman, 2000). It is unknown if the graduates in my study who chose a STEM career goal self-assessed
themselves as having the ability to perform actions to accomplish a desired goal of a STEM career.

Although graduates’ STEM career goals significantly related with their choice of and persistence toward STEM degree, self-efficacy in relation to graduates’ choice of and persistence toward STEM degree presented non-significant results. It is important to note that the self-efficacy results were derived from the ten-point twenty-item Likert scale portion of the survey and graduates’ college majors. The high school career goal was a singular item analyzed with graduates’ college majors. See Table 10 for details. As previously stated, the low variance in average self-efficacy scores resulted in non-significant correlations. If graduates’ had a wider range of average scores, the results would have reinforced the literature that self-efficacy is believed to increase cognitive engagement, self-regulation, self-monitoring, and self-assessing of one’s performance of tasks towards a particular long-term goal (Bandura, 1998; Pintrich, 2003; Zimmerman, 2000). Multiple studies suggest self-efficacy is a stronger predictor of students’ degree choice even after controlling for individuals’ actual ability and past achievement (Simpkins, Price & Garcia, 2015).

**Limitations.** The apparent mismatch between the quantitative self-efficacy results and existing literature was due to the low variance of average for the ten-point twenty-item Likert scale survey items. As shown on Table 11, the average self-efficacy score was 8.48, it was 8.76 for 73% of graduates who chose a STEM major, and 7.79 for 27% of graduates who did not choose a STEM major. The variance was less than one point from the lowest average to the highest. It is possible that this low variance impacted the non-significant result.

Even though Cronbach’s alpha test for validity and reliability of the twenty self-efficacy items exceeded the minimum acceptable of (a = 0.70) with a score of (a = 0.93), latent threats
may be present in the nascent survey since I designed it specifically for this study. Instruments are typically refined over time to ensure they measure what they intend to measure. Initially I sought an instrument that was previously validated and showed reliability. I did not find an instrument in the research literature that was compatible with my research question and school context. Since there were no fitting instruments to compare item scores with, there are may be threats to criterion-related validity (Creswell & Plano Clark, 2007).

Additionally it is possible that the twenty Likert scale survey items were methodologically insufficient to significantly capture the nuanced personal nature of self-efficacy that may have been developed in the STEM program. If the survey was methodologically limited in uncovering self-efficacy in the rich context of connected human reality, with interactions between students, teachers, families, and other influential people, the qualitative interviews may enrich our understanding. In addition, the interviews may bring self-efficacy to light within the mutually supportive relationship between academic preparation and self-efficacy.

**Academic Preparation Analysis**

This section is the second part of the quantitative analysis that examines the independent variables, self-efficacy and academic preparation, in relationship with the dependent variable, choice of and persistence toward a college degree in a STEM discipline. Previously, the analysis of the self-efficacy variables and discussion of the self-efficacy results were presented. This second section contains the analysis of academic preparation variables followed by the discussion of academic preparation results.

**Grade point average, choice of, and persistence toward STEM degree.** The simple linear regression analysis was conducted to predict a graduate’s choice of and persistence toward
a STEM degree based on high school Grade Point Average (GPA). A significant regression equation was found (F(1, 50) = 9.322, p < .005), with an $R^2$ of .157. Participants’ scores predicted choice of and persistence toward STEM degree is equal to -2.025 + .734 grade point average when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and GPA is measured on a 0-4 scale. Choice of and persistence toward STEM degree increased .734 for each grade point.

Table 15

| Regression for GPA Predictors of Choice Or And Persistence Toward STEM Degree, n = 52 |
|---------------------------------|----------------|----------------|----------------|----------------|
|                                  | β              | SE B           | Beta           | t              | p               |
| GPA & STEM Major                | .734           | .240           | .396           | 3.05           | .004            |

**Science.** The multiple linear regression analysis was conducted to predict graduates’ academic preparation in science on graduates’ choice of and persistence toward STEM degree. For three or more AP classes, a significant regression equation was found (F(1, 50) = 8.779, p < .05), with an $R^2$ of .149. Participants’ scores predicted choice of and persistence toward STEM degree is equal to .622 + .378 academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

For participants who took two AP classes, a significant regression equation was found (F(1, 49) = 10.951, p < .05), with an $R^2$ of .183. Participants’ predicted choice of and persistence toward STEM degree is equal to .538 + .382 academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses and 1 = taken the courses.

For participants who took one AP class, a non-significant regression equation was found (F(1, 50) = 1.057, p > .05), with an $R^2$ of .021. Participants’ scores predicted choice of and
persistence toward STEM degree is equal to \( 0.600 + 0.162 \) academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

Table 16

<table>
<thead>
<tr>
<th>Science as Predictor of Choice Of And Persistence Toward STEM Degree, ( n = 52 )</th>
<th>( \beta )</th>
<th>SE</th>
<th>B</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 or More AP Classes</td>
<td>.378</td>
<td>.128</td>
<td>.386</td>
<td>2.963</td>
<td>.005</td>
</tr>
<tr>
<td>2 AP Classes</td>
<td>.382</td>
<td>.115</td>
<td>.427</td>
<td>3.309</td>
<td>.002</td>
</tr>
<tr>
<td>1 AP Class</td>
<td>.111</td>
<td>.108</td>
<td>.145</td>
<td>1.028</td>
<td>.309</td>
</tr>
</tbody>
</table>

Regression analyses showed that science preparation predicted a graduate’s choice of and persistence toward STEM degree. This positively correlated and predictive relationship was shown for most levels of science preparation; graduates with three or more Advanced Placement (AP) science classes and graduates with two AP science classes. There was no predictive or significant relationship with graduates who took one AP science class.

**Math.** The multiple linear regression analysis was conducted to predict graduates’ academic preparation in math on graduates’ choice of and persistence toward STEM degree. For 2 or more AP classes plus AP calculus a significant regression equation was found \((F(1, 50) = 8.779, p < .05)\), with an \( R^2 \) of .149. Participants’ scores predicted choice of and persistence toward STEM degree is equal to \( 0.622 + 0.378 \) academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

For participants who took one AP class, plus AP calculus, a significant regression equation was found \((F(1, 50) = 2.524, p < .05)\), with an \( R^2 \) of .048. Participants’ scores predicted choice of and persistence toward STEM degree is equal to \( 0.696 + 0.304 \) academic preparation.
scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

For participants who took AP calculus, a significant regression equation was found (F(1, 50) = 6.723, p < .05), with an R² of .119. Participants’ scores predicted choice of and persistence toward STEM degree is equal to .600 + .309 academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

A non-significant regression equation was found for participants who did not take calculus (F(1, 50) = 10.134, p < .05), with an R² of .169. Participants’ scores did not predict choice of and persistence toward STEM degree is equal to .556 + .364 academic preparation scores when choice of and persistence toward STEM degree is measured by 0 = non-STEM and 1 = STEM, and academic prep is measured as 0 = not taken the courses 1 = taken the courses.

Table 17

<table>
<thead>
<tr>
<th>Math as Predictor Of Choice And Persistence Toward STEM Degree, n = 52</th>
<th>β</th>
<th>SE</th>
<th>B</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 or More AP Classes + AP Calculus</td>
<td>.304</td>
<td>.192</td>
<td>.219</td>
<td>.219</td>
<td>2.089</td>
<td>.043</td>
</tr>
<tr>
<td>1 AP Class + AP Calculus</td>
<td>.309</td>
<td>.119</td>
<td>.344</td>
<td>.344</td>
<td>2.593</td>
<td>.012</td>
</tr>
<tr>
<td>AP Calculus</td>
<td>.364</td>
<td>.114</td>
<td>.411</td>
<td>.411</td>
<td>3.183</td>
<td>.003</td>
</tr>
<tr>
<td>Did Not Take Calculus</td>
<td>.466</td>
<td>.139</td>
<td>.429</td>
<td>.429</td>
<td>3.356</td>
<td>.102</td>
</tr>
</tbody>
</table>

Regression analysis showed that math preparation predicted a choice of and persistence toward a STEM degree for most levels of math. Significant results were observed with two AP classes plus AP calculus, graduates with one AP class plus AP calculus, and for graduates with AP calculus. There was a non-significant relationship for graduates who did not take calculus.
Academic Preparation Discussion

The results relating to the potential influence of academic preparation on graduates’ choice of and persistence toward a college degree in a STEM discipline in an inclusive high school STEM program were mostly significant. Table 18 is a summary of these results.

Table 18

<table>
<thead>
<tr>
<th>Summary of Academic Preparation Analyses, Choice of and Persistence STEM Degree, n = 52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
</tr>
<tr>
<td>3 or More AP Classes</td>
</tr>
<tr>
<td>2 AP Classes</td>
</tr>
<tr>
<td>1 AP Class</td>
</tr>
<tr>
<td>Math</td>
</tr>
<tr>
<td>2 or More AP Classes + AP Calculus</td>
</tr>
<tr>
<td>1 AP Class + AP Calculus</td>
</tr>
<tr>
<td>AP Calculus</td>
</tr>
<tr>
<td>Did Not Take Calculus</td>
</tr>
</tbody>
</table>

Grade point average, choice of and persistence toward a STEM degree. The results of overall academic preparation, as measured by a graduate’s grade point average (GPA), showed a significant predictive relationship with graduates’ choice of and persistence toward a STEM degree. This finding is aligned with a substantial body of existing research that suggested the predictive influence of a graduates’ GPA on college choice, major, and college completion (Burkam, Lee, & Smerdon, 2003; Center for Education Statistics, 2013; Muller, Riegle-Crumb, Schiller, Wilkinson, & Frank, 2010).

Course-taking. From the survey results, graduates of the STEM program indicated that academic preparation in science and math was predictive of their choice of and persistence toward a STEM degree. Almost every level of math and science course taking showed a predictive relationship to a graduate’s choice of a STEM major. See Table 18 for details.
**Science.** With regard to course taking in science, a significant predictive relationship was found between rigorous science course taking and a graduates’ choice of and persistence toward a STEM degree. This was found for graduates who took three or more Advanced Placement (AP) classes and at least two AP classes. The results of graduates who took one AP class or less, a less rigorous academic preparation experience, showed a non-significant relationship with the choice of and persistence toward a STEM degree.

**Math.** With regard to course taking in math, a significant relationship was found between math course taking and a graduates’ choice of and persistence toward a STEM degree. This was found for most levels of math course-taking; graduates who took two or more AP math classes plus AP calculus, and at least one AP math class plus AP calculus, at least AP calculus. There was not a predictive relationship between graduates who took non-Calculus math classes and choice of and persistence toward a STEM degree.

**Summary.** Academic preparation through rigorous course taking was shown to be predictive of graduates’ choice of and persistence toward a STEM degree. For example, the National Center for Education Statistics (2015) compared the academic preparation of students who took algebra II/trigonometry in high school with students who took calculus and pre-calculus. Students who took calculus or pre-calculus and obtained a GPA of 3.5 or higher were more likely to choose a college STEM degree program and persist in it. Studies suggest that students’ intent to pursue a STEM degree reflects a combination of their 12th-grade math proficiency, participation in math and science courses throughout their years in school, and students’ self-efficacy beliefs (Sax et al., 2015; Wang, 2015). There is substantial research on the interconnected relationship between self-efficacy and academic preparation. Students with positive math self-efficacy exhibited higher than average academic achievement even while
controlling for prior achievement (Hernandez et al., 2013). Correll, (2001) Tai, Liu, Maltese, and Fan, (2006), and Sax, et al. (2015) showed that significant predictors of students choosing a STEM degree and persisting to completion are positive student self-efficacy and math and science achievement. Some studies, such as Bonous-Harnmarth’s (2000), indicate that the commitment to pursue a STEM degree (measured in freshman year) was more positively associated with self-efficacy than academic achievement shown on students’ high school GPA or SAT scores.

Qualitative Analysis

The mixed methods approach to my study allowed for the following research question to be examined through two approaches. The quantitative analysis was reported first and is followed by the qualitative analysis in this section. The research question guiding this study:

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

The sequential explanatory design format guided the operationalizing of the mixed methods approach with the quantitative analysis informing the qualitative participant selection. From the 52 CST graduates who participated in the survey, eight were selected as exemplars for interviews based on their self-efficacy scores and academic preparation as described in chapter three. These CST graduate exemplars exhibited a “particularly intense or highly developed manner” of self-efficacy and academic preparation (Bronk, King, & Matsuba, 2013, p.1).

The following tables provide an overview to assist in understanding how each code was referenced by each graduate’s interview quotations (Table 19) and how many total quotations of each code were represented across the eight exemplars (Table 20). The initializations are as
follows:

CST: Center for Science & Technology, the inclusive STEM program within LHHS

LHHS: Lake Hills High School, the comprehensive high school

AP: Advance Placement courses

Table 19

Frequency of Codes per Exemplar, n = 8

<table>
<thead>
<tr>
<th>Code</th>
<th>Leah</th>
<th>Emily</th>
<th>Alexa</th>
<th>Aiden</th>
<th>Audrey</th>
<th>Zoe</th>
<th>Lily</th>
<th>Ryan</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST Self-Efficacy</td>
<td>7</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>7.0</td>
</tr>
<tr>
<td>CST Teacher Influence</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>CST Academic Prep</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>4.4</td>
</tr>
<tr>
<td>Project-Based Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedagogy</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>3.9</td>
</tr>
<tr>
<td>AP &amp; CST</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>STEM Interest</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>CST Successful Failures</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>CST Collaboration</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>CST Field to Podium</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.9</td>
</tr>
<tr>
<td>LHHS Academic Prep</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>Support People</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>1.8</td>
</tr>
<tr>
<td>LHHS Teacher Influence</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Table 20

Total quotations per code, n = 8

<table>
<thead>
<tr>
<th>Code</th>
<th>Number of quotations per code</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CST Self-Efficacy</td>
<td>56</td>
<td>18.7%</td>
</tr>
<tr>
<td>CST Teacher Influence</td>
<td>44</td>
<td>14.6%</td>
</tr>
<tr>
<td>CST Academic Prep</td>
<td>35</td>
<td>11.7%</td>
</tr>
<tr>
<td>Project-Based Learning</td>
<td>30</td>
<td>10%</td>
</tr>
<tr>
<td>AP &amp; CST</td>
<td>26</td>
<td>8.7%</td>
</tr>
<tr>
<td>STEM Interest</td>
<td>20</td>
<td>6.7%</td>
</tr>
<tr>
<td>CST Successful Failures</td>
<td>19</td>
<td>6.3%</td>
</tr>
<tr>
<td>CST Collaboration</td>
<td>18</td>
<td>6.0%</td>
</tr>
<tr>
<td>CST Field To Podium</td>
<td>15</td>
<td>5.0%</td>
</tr>
<tr>
<td>LHHS Academic Prep General</td>
<td>14</td>
<td>4.7%</td>
</tr>
<tr>
<td>Support People</td>
<td>14</td>
<td>4.7%</td>
</tr>
<tr>
<td>LHHS Teacher Influence</td>
<td>9</td>
<td>3.0%</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td>100%</td>
</tr>
</tbody>
</table>
For the analysis, I condensed similar codes into larger themes for increased efficiency in reporting and discussion. Table 21 shows the codes per theme.

Table 21

*Codes per theme, n = 8*

<table>
<thead>
<tr>
<th>Theme</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy</td>
<td>CST Self-Efficacy</td>
</tr>
<tr>
<td></td>
<td>CST Successful Failures</td>
</tr>
<tr>
<td></td>
<td>STEM Interest</td>
</tr>
<tr>
<td>Adult Influences</td>
<td>CST Teacher Influence</td>
</tr>
<tr>
<td></td>
<td>Support People</td>
</tr>
<tr>
<td></td>
<td>LHHS Teacher Influence</td>
</tr>
<tr>
<td>Project-Based Learning &amp; AP</td>
<td>CST Academic Prep</td>
</tr>
<tr>
<td></td>
<td>Project-Based Learning Pedagogy</td>
</tr>
<tr>
<td></td>
<td>AP &amp; CST</td>
</tr>
<tr>
<td></td>
<td>CST Collaboration</td>
</tr>
<tr>
<td></td>
<td>CST Field To Podium</td>
</tr>
<tr>
<td></td>
<td>LHHS Academic Prep General</td>
</tr>
</tbody>
</table>

The interview analysis was performed at two levels: for each graduate and across all responses (Walker & Frimer, 2007). The presentation of the results of the analysis begins with a presentation of the results from each graduate and concludes with a discussion of the patterns found across all [participants or graduates].

**Analysis of Individual Graduates**

In the following accounts of each graduate, the themes will be reported in this order:

- High school academic preparation
- University academics
- Adult influences
- Project-Based Learning and Advanced Placement
Leah

Leah graduated from high school in 2015. At the time of her interview, in December 2017, she was a junior at a four-year private, selective, R1 college studying Biology and Health Sciences with minors in Public Health and Gender Studies. She planned to attend medical school to become a physician. She was hopeful that her “gender science classes weave into that [medicine] really well so I can be more of a compassionate caregiver.”

Quantitative self-efficacy results. On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Leah scored an average of 9.5. Out of eight exemplars she tied for fourth highest in ranking of self-efficacy scores.

High school academic preparation. Leah chose to take rigorous courses including AP chemistry, AP biology, AP physics, algebra II honors, pre-calculus, and AP calculus. In the context of academic preparation in the CST STEM program, she spoke about learning to “understand a really complicated journal article, like a 30 pager in molecular biology, like I’ve done numerous times, it really made a huge difference in my ability to do hard things in college.” Leah said she took too many AP classes, ten in total, and was disappointed when her university did not grant her credit for them. The university she chose to attend discontinued their practice of accepting a score of three on AP tests. Universities have latitude to determine what level of scores they will accept. AP scores range from one to five with some universities accepting threes, others just fours and/or fives.

University academics. At her university, Leah had taken science and math classes including a full year of chemistry and a full year of biology, calculus, statistics, genetics,
molecular biology, biochemistry, a full year of organic chemistry, epidemiology, public health, and nutrition. Before graduating, she planned to take cell biology, ecology, and animal physiology and anatomy. In addition to science classes, she had taken courses in gender history, gender perspectives, gender medicine, and other ethics and liberal arts courses.

**Adult influences.** Leah was grateful for her experience in the CST program and for Mr. Martin, the lead CST teacher. She expressed that she “has a really strong foundation in how science works and how the knowledge seeking process in the sciences actually works. I wouldn’t have had that at all if it hadn’t been for Mr. Martin and the CST.”

Leah talked about how Mr. Martin cared about each student individually. She said “from the moment you walk in there you have a purpose and somebody there that cares about your potential and what you can do if you want to.” For Leah, “the whole philosophy behind the CST was like the largest impactful thing for me in all of high school.” She shared that she has “a 16 year old brother at LHHS right now and he’s not in the CST, and it breaks my heart.”

Leah seemed excited, confident, and passionate about her path to medical school. She attributed her passion to Mr. Martin. “That’s one thing about Mr. Martin that was so impactful, he was excited to learn everyday, that he was passionate everyday, so you could be passionate in your work too.” Mr. Martin would encourage his CST students to dream big by saying if the students want to they could be a doctor or cure cancer. He had an unwavering belief in the ability of his students to do great things. This belief in students was “the best gift you could ever give to a kid. I feel like at least for myself it fostered this lifetime learning thing.” Mr. Martin would say “you are loved, you can rise to whoever you want to be.” His confidence in Leah “was so important for being able to stay afloat in college and in my major.”

**Project-based learning and advanced placement.** As conveyed above, Leah took ten
AP classes in high school. She described AP classes as quite structured although she didn’t mind because she had classes like that in college, too. At her university, she became aware of many friends who came from rural communities who didn’t have access to AP classes. This realization made her grateful for LHHS and the rigorous learning she experiences she had. Overall “they were wonderful classes and I enjoyed taking them – it’s just a different way of learning.” She expressed her preference for the CST program. “There’s something really beautiful about getting to do authentic research, that really made a difference for me.” She enjoyed creating her own timelines and managing her own work. She contrasts this with “AP classes where it was more typical lecture based, these assignments, this project, not a ton of room to kind of create your own path so to speak.” Conversely, she described the CST courses as “fostering creativity, independent learning, and an acceptance that we don’t have all the answers - that we are working towards getting the answers.”

A component of the project-based learning at CST was collecting samples in the environment. A summer trip to Montana with peers and CST teachers was a highlight for Leah. They took fin clips at various locations to use for a fish bottleneck project to test genetic drift in a population. Collecting samples to test made her feel as if she “were a real-life scientist.” While in Montana the group toured Rocky Mountain Labs in Hamilton Montana. Leah said “it was really awesome because like they have an E. coli level 4 National Institutes of Health lab and a bunch of cool stuff.” She could “see this field as something that is realistic, and these people started in similar spots as us and were our age too.” The trip bonded the students and teachers together. It “really gave us a chance to get really close to Mr. Martin and Mr. Berg and Mr. Shaw.” For her the trip was “like one of the coolest things ever.”

Months later, when her samples were analyzed and conclusions were made she presented
her work at a local university and a region-wide research symposium. The experiences presenting “were huge, I don’t think a lot of my university classmates have ever done that.” In summary she expressed that “the CST was perfect, it fostered independence and allowed me to feel comfortable making my own path in the sciences.”

Collaboration. Leah enjoyed the collaboration in her CST classes. She admitted, “we goofed around sometimes, and we got so close. I was in a period with a really strong group of students, and it was awesome. We got to talk through our methods and got feedback and additional ideas.” She said, “we were never competing for who was going to get the best results.” Leah has noticed a similar culture of collaboration at her university. “I have friends who are in pre-med at other colleges and it’s so competitive at other schools. At my school it’s not, I love it because that’s what I’m used to.” Leah reflected “that’s the best for learning and growing – in an environment of ‘we’re all going to screw up together, support each other, and work together.”

Self-efficacy. Leah’s confidence grew through successful failures in the CST classes. She learned “that every single failure is teaching you something and what it means to be a scientist, which is to fail like a thousand billion times.” Even when she got a C on a test, or had errors in her lab experiments, Leah shared that “it’s like I know that much more for the next one. I know how to do things differently.” She said this resilience “was something that was fostered in the CST, and I think definitely I’m at a greater advantage being ok with failures, because I’ve dealt with it and it’s all contributing to something better.”

Emily

Emily graduated in 2016. At the time of her interview, in December 2017, she was a sophomore at a 4-year, public, R1 university majoring in chemical engineering and minoring in German and mathematics. She was in the honors college and played rugby on an intramural
team.

**Quantitative self-efficacy results.** On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Emily scored an average of 9.95. Out of eight exemplars she tied for the first highest in ranking of self-efficacy scores.

**High school academic preparation.** Emily chose to take rigorous courses including chemistry, AP chemistry, AP physics, algebra II, AP calculus, and AP statistics. As a result of having high scores on her AP tests, she had 30 transfer credits upon entering her university so although she was a sophomore she had junior standing. “I passed out of the introductory science classes but I decided to take them again as a refresher. I wish I hadn’t, it was like a semester long review.” Emily said her high school classes definitely prepared her in “knowing how to handle lots of course work, knowing how to process lots of mathematical and scientific things in your brain at once, and how to juggle 3 or 4 science or 3 or 4 math classes at once.” Emily credited her AP classes for her successful transition to college. She said her “AP classes taught me how to process more information than a regular high school class.” She thought of “AP classes as twice the information of a regular class, and a college class is twice the information of an AP class, so if you don’t take AP classes you’re trying to process four times the information at once.” This “adjustment to the rate of information helped a lot with how I did here, especially my freshman year and making that transition.”

**University academics.** So far in her university experience Emily had taken courses including a full year of chemistry, four German classes, physics, organic chemistry, and two 200 level chemical engineering classes.

**Adult influences.** Emily expressed a deep appreciation for Mr. Martin. “I think what Mr. Martin did, the way he ran the CST, and the way he connected with students, it changed my life.”
Mr. Martin “is somebody I look up to, he’s like a father to me, he’s just an amazing man, and he taught me a lot of science and he taught me how to expect more from myself and push myself.”

In addition to Mr. Martin, Emily credited Mrs. Katos, her AP chemistry teacher, for teaching her how to think. Emily said, “knowing how to think is really important in college and that’s not the focus of a lot of regular high school classes.”

Emily was thankful for her family as a source of support. “I think I’m really lucky, everybody in my family is very supportive of me, I’m lucky that way. Not everybody has a family that is supportive of them.” Emily said her “Grandpa is an engineer and he’s always told me that he thought I’d be a great engineer, and he is very supportive of me pursuing a scientific field.”

**Project-based learning and advanced placement.** Emily reflected on the differences between her AP classes and her CST classes. In remembering an AP teacher, Emily said, “she’s got this calendar printed out of everything you need to have done everyday and it’s totally structured.” In CST classes, “you are not just being handed answers to remember.” She said, “that’s completely different from the CST where you figure out your project on week one or the end of the year before, and we plan our own time out, and figure out how to solve our own problems.”

For Emily, “the CST did something else, it made me value hard work more and made me value my success more.” She said her AP classes were “great, hard and very good for preparing me but I think the CST gave me a values set that I didn’t have before.” She explained that “it’s the unstructured nature of it makes you either be dedicated to what you are doing and do it or not care.” She boiled it down to “having two choices; you can be dedicated to what you are doing and work for this goal and this product that you can be extremely proud of or not.” She chose the
path of hard work towards her goals. Emily said she was “extremely proud of my work in CST. I have this eight page paper and this poster to show for those two years of work, but it wasn’t for a grade.” She explained that her work was “for that physical thing that I could say ‘I did this’ and ‘I contributed to a scientific journal,’ ‘I contributed to a symposium,’ and ‘I contributed to the scientific community.’ For Emily “it’s about being proud of what you are doing, and I didn’t have that before I came into the CST.”

**Collaboration.** In the CST, “we learned how to work in independent study groups, research groups, and if you don’t have the same CST class with them then you meet whenever you can, and do your stuff. You are expected to do your stuff.” In their everyday work in CST classes, Emily and her lab partners would ask Mr. Martin questions although, “you are expected to figure out what to do and what your next steps are and where you need to go next once you’ve completed something.” They modified existing lab protocols to meet their needs, refined their processes, and came up with solutions and conclusions as a lab group.

**Self-efficacy.** To build self-efficacy, Mr. Martin had a poster in the lab that said ‘You Are The Ones (YATO)’ above Einstein’s picture that became an emblem of persistence. She remembered, “he explained the YATO picture on the first day of class freshman year and he’d always say it, you are the ones, but after that he’d say ‘remember you are a YATO’.” In thinking back, Emily recalled, “I didn’t pay attention to all the little things he said like ‘you are going to do great things’, ‘no matter what, hardships or roadblocks, you need to keep trying because you will be somebody who does something great’.” Emily reflected, “I did not realize that that had such a profound impact on my life and what I’m doing right now.”

Emily credited Mr. Martin for her knowledge of the nature of science and her understanding that she could not expect everything to work right. She reflected, “Mr. Martin
made sure we understood that we were going to fail and you were going to make mistakes.” She learned that, “sometimes the process doesn’t work because you made a mistake and sometimes just the process itself doesn’t work. You first have to figure out which is making it not work and then figure out how to solve it.” Emily concluded with, “this helped a lot with resilience. He taught us to not get dragged down by making mistakes.”

Alexa

Alexa, graduating from high school in 2011, was the oldest graduate when she was interviewed in December 2017. After graduating, she went to a four-year private, most selective, R1 university on the East Coast where she completed a four-year Bachelors of Science in Molecular and Cell Biology and a second degree in Decision Studies. Following university graduation, she worked in molecular and cellular translational cancer research for neuro-oncology. After two years of working in research, she entered medical school for Osteopathic Medicine, where she intended to complete her degree in a couple of years.

**Quantitative self-efficacy results.** On the ten-point twenty-item Likert scale survey regarding self-efficacy in the context of the CST STEM program, Alexa scored an average of 9.05. Out of eight exemplars she ranked seventh highest for self-efficacy scores.

**High school academic preparation.** Alexa took a few rigorous courses including chemistry, physics, algebra II, and AP calculus. As one of the two outliers, Alexa was not as strongly academically prepared as the other exemplars. Compared to all other exemplar graduates who had at least four AP science and/or math classes, Alexa only took one AP math class. In reflection, she shared that “I’m not that academically inclined, so it takes a lot for me to do well in book work.” She was able to excel after high school because “I had experience in high school where I could be hands-on with my work.”
University academics. Alexa didn’t provide exact course titles. Perhaps this was because she had already completed her degrees. While at her undergraduate university, she had many accomplishments, including one of her university’s research grants, an undergraduate research honorable mention award, a research grant through a different university, and multiple STEM-related publications in peer reviewed journals.

Adult influences. Alexa appreciated Mr. Martin’s teaching style. “He was able to tailor to each student. Some students, like myself, just needed to have my space.” She would seek his help when she needed it. She contrasted her needs to that of some peers, “other students needed constant appraisal and constant encouragement which he would give.” She appreciated that “he was so able to be in tune with what each student as an individual needed and wanted, that was one of his greatest strengths.” While Alexa thrived on independence, she noticed that “some people could be independent and for others Mr. Martin would hold their hand and that would be great, he would do whatever they needed.”

Alexa also credited her peers for her success in high school. She described her graduating class as a distinctive group of high achievers who had a lot of pride. Her “core group” came together as freshmen and stayed together all 4 years. They “did the same activities as far as student government, the same AP classes, and most of us did distance running.” She shared that “we were definitely very snooty, very over-confident in our skills that we did, and what we achieved, it wasn’t even about the skills in Mr. Martin’s classes—we excelled in all other things, not just science.” Alexa had a couple members of her core group go to east coast universities near hers. She struggled going to a prestigious university on the east coast, “because the thing about LHHS is that we were all big fish.” She said “honestly, the only reason I was able to last as long as I did was because I had classmates who went over there with me. I saw them every
couple weeks and they encouraged me to keep going.”

In a high school where 53% of students come from low socio-economic families, including 20% from extreme poverty situations, Alexa had an interesting perspective of her place in those demographics. She said, “I’m a very privileged child, I’m not LHHS’s typical student. My parents live in upper middle class, both have degrees, are both together, and neither of them has been in jail.” She believes that “it’s critical for children to and adults to acknowledge the positionality you come from and see the world through.”

**Project-based learning and advanced placement.** Alexa said her AP classes emphasized critical thinking and her “teachers did a really good job of trying to make us think beyond the text and find what we are supposed to pull out of it.” She felt in her senior year that her AP classes “focused more on getting kids into college versus just passing the AP tests.” That did not bother Alexa because she “was taking AP classes just to take them, the test scores didn’t matter to me, it was just good to be in AP at school.” It was very possible that Alexa’s “core group” of high achieving friends took many AP classes together. Since AP classes in high school typically have a different demographic than regular classes, with AP historically having more-advantaged students and students of high academic potential, many students take AP classes for the social value of being with other students like themselves. Since Alexa did not elaborate on her statement that “it was just good to be in AP at school” it is not clear whether she chose the AP classes for their academic or social value.

In reflecting on her CST classes, Alexa said she “liked that it was very hands-on, very independent-oriented study, and we had all the equipment to allow us to actually do the scientific research.” In conducting her research, Mr. Martin “would make us question our results, ask us why, and not just give us answers but make us think about why this didn’t work, and what can
we do better.” She “was inspired by hands-on experiments such as cell culture and PCR (polymerase chain reaction).” By learning in a hands-on problem-solving manner she was able to understand the science and have an interest in it after graduation. As a result of her CST experience, she chose her university because they emphasized cellular research.

A clear theme in Alexa’s CST learning experience was independence. She shared that she “was allowed to come in at 7:00 a.m. and do my own experiments and use the equipment and, for me, being able to be in charge of my own schedule was very important for me.” She “needed to be independent and that’s what helped me grow.”

**Collaboration.** Alexa did not talk about collaboration. Conversely, she talked several times about how she valued independence.

**Self-efficacy.** Alexa did not talk about her self-efficacy directly; instead she chose to generalize herself in with her core group of friends. With this group, with Alexa included, “excelled in other things besides just science. We experienced well-rounded success in all aspects.” Alexa allowed a window into her personal self-efficacy experience when she expressed her struggles going to a university on the east coast.

**Aiden**

Aiden graduated from high school in 2016. At the time of his interview, he was a sophomore at a four-year, public, more selective, R1 university majoring in Chemical Engineering.

**Quantitative self-efficacy results.** On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Aiden scored an average of 9.45. Out of eight exemplars, he ranked sixth highest for self-efficacy scores.

**High school academic preparation.** Aiden took rigorous courses including chemistry,
AP biology, AP chemistry, and AP physics, algebra II, pre-calculus, AP calculus AB, and AP statistics.

**University academics.** So far, halfway through his sophomore year, he had finished the calculus series (calculus 1, 2, and 3), a full year of chemistry, introductory programming for engineers, physics 122: electricity and magnetism, and differential equations. Aiden entered the university with 15 Advanced Placement (AP) credits. Even though he didn’t have to take the calculus series from the beginning or chemistry, he decided he would take those courses anyway. “From day one it was definitely, it was for sure just a shock, the homework was already at a level up and I really struggled for the first time. I really had to get help.” In high school he was “used to doing things independently and just getting things done on my own, for once it actually felt really difficult.” He learned that working with others was beneficial so he developed study groups for his classes. He sees himself as a “testament that hard work does pay off because I’ve done pretty well.”

His laboratory research experience in CST classes allowed him to earn a coveted research position at his more selective R1 university. He expressed that “the CST classes really motivated me to try to find some sort of research experience.” Last year, as a freshman, he “started looking for a potential lab to work in.” As a result of “the sheer amount of experience I had just from high school with the CST, the Principal Investigator who runs the lab said I was one of the top people they were considering to hire for the position.” In accepting the position, he was “very humbled for the experience I gained from LHHS.” He said “I don’t know if it hit me yet—it’s sort of surreal to think that I’m only 19 and doing research already. It’s crazy to think that but it feels great.”

**Adult influences.** Aiden reflected on how Mr. Martin taught him to be collaborative and
persistent. He gave an example from his junior year when “I just messed up an experiment, I pretty much failed and I was really nervous to talk to Mr. Martin. I was afraid he would point out how I had just wasted money on reagents doing this unsuccessful experiment.” He explained how Mr. Martin “was really kind about it and he talked about the countless times he had failed, how he had messed up much worse than I did. In that moment, he started showing me how to overcome the fear of failure.”

In addition to Mr. Martin in the CST classes, he attributed Mrs. Katos his AP chemistry teacher for his interest in chemical engineering. he expressed that “she really influenced me in the way that she was passionate about chemistry and that influenced my career path now.” His experience in her chemistry class “helped me tremendously because general chemistry here is known as a ‘weed out’ class and I really did well so I attribute a lot of that success to her for showing that passion for chemistry and teaching well.”

In addition to the influences of his teachers, Aiden expressed gratitude for the support of his family. Aiden was “grateful my mom in the first place, if it weren’t for my mom I wouldn’t have even had the CST experience. I’m thankful she transferred me from another nearby high school to LHHS.” Aiden reflected that “my family made a lot of sacrifices, and with me coming to college they are understanding that it is a lot harder here.” He said they “know I work hard, they appreciate that, and they support me so that means the world. I am grateful to have a lot of people support me, which keeps me going, even though it does get really hard.”

**Project-based learning and advanced placement.** With 15 AP credits, Aiden was very familiar with the contrast between AP classes and his CST classes. He said that AP classes were “definitely a lot more structured, more fast-paced than regular (non-CST) classes, and they were limited in that you did what you were directed to do, there was no choice or independence.”
Aiden elaborated on the independence in CST classes, “it’s completely dependent on the time you allocated to spend time on research or experiments.” He liked the format of CST classes better than AP classes, although he could see the benefits of both.

In his senior year, Aiden and his lab partners went to a regional STEM competition at a local university to present their research project in poster sessions. These experiences were a highlight for him. “It was really amazing to see what we had worked on up to that point and to finally see the final product and for people to be interested in our work. It was very rewarding.”

Collaboration. He credited the social nature of CST classes for teaching him collaboration skills. Collaboration was “not something I had ever been exposed to before my CST classes.” He was “thankful we were taught about collaboration in high school. Those skills are especially necessary when the dynamic in the group is not always smooth.” In his CST classes, Aiden and his lab partners “were able to communicate and work out what each of us should do in a given week and how we can get along better. That was a big help in being able to work together as a group.” These skills carried over to his university lab position. “Even now in the current lab I’m in we have lab meetings and being able to understand what everyone is doing and where I fit in is important. Collaboration in CST was definitely a valuable thing.”

Self-efficacy. Aiden credited the CST for his ability “to aspire to do things at a high level regardless of whether it’s in lab work or just in general life whatever comes my way.” His failures in CST classes fostered persistence. He said, ”when failures happen, now it’s become easier to shake off and just evaluate where I went wrong, so it’s great.” He said that resilient mentality had “transcended outside of the lab work into my course work where I just try to keep going, even if the going gets tough.”

When Aiden entered his more selective, R1 university, he “realized very quickly that the
average student is just like me, if not better.” He credits his success to hard work and the persistent mindset he gained in his CST classes. “I think just being able to work with people and being really resilient, I think are qualities that sort of keep me going and have probably prepared me the most for college.” In closing, Aiden summarized his CST experience. “The CST was really valuable. It’s been pivotal to my passion for science, aspiring to do and dream big, and do things at the highest level I can.”

Audrey

Audrey graduated from high school in 2016. At the time of her interview in December 2017, she was a junior at a four-year, public, selective, R1 university but only in her second year in college because her AP credits pushed her a year ahead. She was majoring in animal science with a pre-veterinary option and intended to attend veterinary school.

Quantitative self-efficacy results. On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Audrey scored an average of 9.95. Out of eight exemplars she ranked tied for highest for self-efficacy scores.

High school academic preparation. Audrey took rigorous courses including chemistry, AP chemistry, AP physics, AP biology, algebra II, pre-calculus, AP calculus AB (first year calculus), and AP calculus BC (second year calculus). Audrey was not nervous about university academics as a result of her rigorous academic preparation and how her CST classes had “prepared me for the presentations, communicating, and making friends.”

University academics. With her AP credits, Audrey is in her second year but had junior standing. She skipped much of her freshman year, only taking statistics for math, the organic chemistry series, and physics before diving into animal science classes. At the time of her interview, Audrey was part of a research lab where she worked on “hormones in feral stallions,
which is pretty cool, and I got an abstract published in the Journal of Theriogenology.” In addition, she was able to present her abstract “at a conference in Colorado last summer to about 50 veterinarians.”

**Adult influences.** A highlight of Audrey’s time at LHHS was when she and her lab partners were finally able to get a grant for their research. Before acceptance, they had gone through cycles of rejection, re-writing, and re-submitting. Her teachers “Mr. Martin and Mr. Smith and Mr. Shaw were all impressed with our project, that we were able to get the grant for our research, and being able to do groundbreaking stuff that nobody in the CST had done before.” This experience “definitely boosted my confidence.”

Audrey had more knowledge of the CST program than most students when she began. She remembers, “I knew how life changing Mr. Martin and the CST could be because my older brother went through and he wanted to do computer science and he’s now getting a Ph.D. in microbiology.” Audrey “knew the CST could change your outlook on science and I was really into science already and kept really looking forward to going into the CST when I went into high school.”

Her family was a strong support for Audrey. They would comment that she was doing “really cool stuff” that they wished they could have done at her age. Audrey “felt kind of praised because I has having this unique experience, I felt really privileged and that gave me confidence that I’ll have the skills to go into the world that other people don’t have.”

**Project-based learning and advanced placement.** Audrey enjoyed her CST classes more than her AP or regular classes: “The CST was always something I enjoyed a lot more than just reading an AP History textbook.” She feels that AP and CST classes both provided a strong academic background for college, although the CST classes offered more. “I feel that AP classes
give you credits to pass college classes, but the CST gives you skills that you don’t learn in other classes, like presentation and collaboration skills. AP classes were just cramming material for the test.”

Audrey remembered, “Pushing yourself and grit was really instilled in the CST, whereas in AP classes it was more ‘here’s your assignment, you have to get it done’.” The CST classes “didn’t really have deadlines unless you had an journal abstract or something you had to submit, but that was more on yourself.” Audrey said “you felt that it was definitely all on you to succeed or fail but whereas in AP classes it was on your abilities to complete the assignment.”

She felt like the independence in the CST classes allowed her to “push myself for as hard as I wanted to go and I feel like it was at least as hard if not harder than in my AP classes.”

Audrey reflected, “Being able to do things on your own in the lab and not have to continually ask questions or be given instruction was really one of my highlights.”

Audrey felt that her AP and CST classes were similar in the amount of reading she did. In AP classes, “we were doing a ton of reading all the time, and I also did a ton of reading in CST classes, trying to read as many research articles from journals as possible.” She enjoyed the research articles more than reading in her AP classes because she chose articles that applied to her research project. In her AP classes, the teacher selected reading assignments given in the curriculum regardless of student interest. Audrey credited Mr. Martin for “pushing us to read so many journal articles. That pushed me ahead of my current classmates who don’t really understand how to read journal articles decisively or how to summarize or how to understand all the complicated words.”

The projects Audrey worked on exposed her to new career paths. “I did two projects about sea mammals, so I learned that I really had an interest in that, so I changed my career path
to now I’m going to do veterinary medicine on marine mammals.” A highlight of her high school experience was “figuring out what I was interested in and being able to choose your project and see if that’s something you are really interested in or could be interested in later in your career or life.”

**Collaboration.** Audrey felt “that collaboration is a big thing in the CST. Collaborating with your group mates—we were like a family, we knew everyone.” She said the summer trips to collect samples for their projects “built bonding into us.” Her group mates were her two best friends. They helped each other, were able to communicate outside of the class, and succeed together. “Having them at my side, definitely gave me the skills to be confident.” They told Audrey what she needed to fix and she helped them, as well as leading in ‘we should do this then’ and charting the course for their research. Seeing the bigger picture of where they wanted their project to go and identifying the steps to get there “definitely gave me the confidence to manage a project on my own.”

**Self-efficacy.** A major factor in Audrey’s self-efficacy development was her experience procuring a grant to fund their research. “We kept applying to get a grant with a marine biologist with an Indian tribe to sample whale bones and we kept getting rejected, and that was really disappointing, but we kept making improvements and applying again.” They were approved for the grant just before Audrey graduated. Audrey and her lab partners passed on the project, and grant, to current students to complete. After graduation, they had visited the CST to mentor the current students a couple of times.

Audrey felt “that the independence you learn in the CST with being self-motivated and grit and of all of that really converted to my study skills, sitting down and actually doing my courses, really studying for them.” The inspiration of Mr. Martin “instilled in us for all four
years, gave me the mentality that no one can get in my way if I want to do something spectacular.” For Audrey, “having the inspiration that you could do something amazing boosted our goals as far as we could be the ones that make a major change.”

She carried the mentality that no one could get in her way to college. Audrey reflected that “when I kind of slacked in my studies and didn’t do well on a midterm or a quiz, that’s when I hear ‘successful failures’ in the background. I learned I had to keep going and not get hung up on it.” She had applied her confident mindset to other situations, not just her studies. Audrey explained that after extensive volunteering with animals, she wanted to get involved in a veterinary organization, and when they denied her application she “just brushed it off and thought ‘ok I’ll just go try somewhere else’.” Audrey also applied her self-efficacious mindset to her desire to complete a double major. After a denial from an advisor in her second major, she “was like ‘ok, I’m going to try to do it a different way’.” After she took classes out of that major that interested her, she met with the head advisor, who approved her double major. In reflection, Audrey said, “I’ve learned to just keep doing what I plan on doing even if I get ‘no’s’. I know if I keep on trying I’ll get to where I want to be.”

Zoe

Zoe graduated from LHHS in 2014. At the time of her interview in December 2017, she was a senior at a 4-year, public more selective, R1 university majoring in Psychology. She planned to graduate in the spring of 2018 with a Bachelors of Science in Psychology and with the Biochemistry and Genetics requirements met to apply to a Masters of Genetic Counseling program.

Quantitative self-efficacy results. On the ten-point, twenty-item Likert-scale scale survey regarding self-efficacy in the context of the CST STEM program, Zoe scored an average
of 7.7. Out of eight exemplars, she ranked lowest for self-efficacy scores. Zoe’s low self-efficacy score and lower academic preparation separated her from other exemplars. As an outlier, Zoe’s story was intriguing since she was persisting towards Genetic Counseling at her more selective R1 university.

**High school academic preparation.** Zoe took rigorous courses including chemistry, AP biology, algebra, geometry, algebra II, and AP statistics. She was the only exemplar who did not take calculus in high school. Zoe and Alexa, as outliers, were the only interview participants that took just one AP math class. Other exemplars took at least four AP science and/or math classes.

**University academics.** Instead of talking about the college courses she had taken, she talked about how she chose her academic path. Zoe knew she wanted to study psychology when she entered college. From her CST experience with Mr. Martin, “I knew I was interested in genetics, so as a way to combine those two interests of mine I got really interested in genetic counseling and that’s what I’m still pursuing now.”

Even though she was studying at a more selective R1 university, Zoe found herself ahead of her peers. In her first genetics class as a sophomore “our TA brought in a gel and said ‘ok who wants to load one well?’ to start polymerase chain reaction (PCR), and I’m like ‘we were running PCR in high school, didn’t other people do this in high school?’” Zoe said, “there were a lot of times where I was the only one who knew the various pieces of equipment and standard protocols.”

In spite of her academic preparedness, Zoe felt it was sometimes “hard to go from being a big fish in small pond at LHHS and now, in college, I’m a small fish in big pond.” She felt like she was “in a whole different realm, where all the students are high-level achievers.”

**Adult influences.** Zoe credits Mr. Martin for sparking her ambition. She reflected that “I
think I’ve always been ambitious to some extent but he really made us all believe that we could
do anything and that it’s all about hard work.” Mr. Martin’s passion was “a huge influence on a
lot of us—yeah, that’s where I found out that learning is cool and learning is fun.” She
internalized that passion for learning and carried it with her to college. “In college it’s a good
feeling to have, that desire to learn and a passion for something.” Mr. Martin “was so passionate
that it made me feel passionate about what I was doing and in the career I am pursuing.” She
explained that “passion makes a big difference; it’s a lot easier to pursue something and study
something when I’m excited about it and genuinely interested in it.” For her to see “Mr. Martin
who was so passionate about his teaching, it showed me what it should be like when you are
doing something that you love, so not only am I pursuing a career but I’m pursuing that passion.”

In addition to Mr. Martin, Zoe expressed that “honestly, my success has a lot to do with
my support system, because it’s easy to get down on myself, but there’s a lot of people in my life
who refuse to believe that I can’t do it.” It was not clear what specific people comprised her
support system, although she mentioned her sorority sisters as a source of support. The
encouragement she has received has helped when “the voices in my head are getting me down on
myself, I have learned to pick myself back up.”

**Project-based learning and advanced placement.** Zoe reflected on her experiences
with AP classes compared with her CST classes. She explained that her AP classes “were very
much by the book, just very organized material coming at you.” Her CST classes “were a lot
more hands-on, practical learning. We were never reading out of a textbook, we were seeing
things happen, we did a lot of trial and error, it was just really cool and unique.” Outside of her
CST classes, Zoe saw “high school as jumping through hoops with adults telling you what to
do.” In her CST classes, Zoe appreciated the freedom to decide what to study and research. Since
she chose a project she was interested in she expressed that “learning became something that is so exciting, we were doing advanced things, and for me it was exciting and really cool.” Zoe relayed a great appreciation for her CST classes. “It’s hard to know for sure just how much they impacted me because I don’t know where I’d be without it.” She concludes by stating that her CST experience was “the best way to prepare for what you might experience in college, even if you don’t pursue science, it’s deep thinking, it’s team work, it’s challenging, exciting, and it’s really an awesome opportunity we have at LHHS.”

**Collaboration.** Zoe expressed that “the classroom environment in the CST was very much a teamwork environment. We were all experiencing the same things, and we had camaraderie.” As opposed to other classes, “in the CST classes you didn’t have the option to sit back and do nothing. It was very collaborative and very interactive, and you really had to get involved.” Zoe found that at first it was “intimidating to collaborate or speak up to people about your opinions but I learned how to communicate effectively and work together.” Her CST classes were “the only time in high school that I had experiences like that and those skills have benefited me in college.”

**Self-efficacy.** In the midst of adjusting to the increasing work load in college, Zoe found confidence in her science classes in having “that familiarity of ‘yeah I’ve done this before’.” She discussed her struggles with comparing herself to other students at her university. “When you are surrounded by so many amazing people doing amazing things it’s easy to be discouraged especially when you might be experiencing failure.” Zoe said her CST classes “made me less willing to give up on what I’m doing, like when I hit roadblocks or like when I was taking those challenging classes.” Her self-efficacy allowed her to persist in her STEM degree ambitions. “I didn’t start looking at other majors because I knew what I wanted to do, I knew I could do it, I
kept my sights on my goals, and I’m still going towards my goals.”

Lily

Lily graduated from LHHS in 2014. At the time of her interview she was a senior at a four-year, public, R1 university in the honors college majoring in applied mathematics with an emphasis in modeling and a minor in chemistry. She planned to attend the university’s School of Pharmacy in the fall of 2018.

**Quantitative self-efficacy results.** On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Lily scored an average of 9.50. Out of eight exemplars, she tied for fourth highest for self-efficacy scores.

**High school academic preparation.** Lily took rigorous courses including AP chemistry, AP biology, AP physics, algebra II, pre-Calculus, AP calculus AB (first year calculus), and AP calculus BC (second year calculus).

**University academics.** Instead of talking about the college courses she had taken, she chose to talk about her academic path from high school to grad school. Mr. Martin encouraged Lily to apply to a specific university and pursue that university’s early acceptance program into its pharmacy school. His support lead to her applying and being accepted to the university and its pharmacy school, which she will attend after completing her degree in Applied Mathematics.

**Adult influences.** Lily’s “step-dad and Mr. Martin taught me is that there is no such thing as a failure. If you learn from your experience, and don’t make that mistake again, then it’s a learning experience.” She learned that first-hand in the CST. “If your experiment went wrong or your primers didn’t work, you didn’t fail, you just need to change a few things and try again. I learned a lot from that.” Her mantra was “if you succeed at everything you’d never learn.”

**Project-based learning and advanced placement.** Lily reflected on her academic
preparation by comparing AP classes and CST classes. “With taking CST, you don’t learn so much book knowledge as you do skills and a thinking method, and so I think there is a lot more to learn from CST than AP credits.” She expressed that they both have practical applications in college: “With CST, you have a better way of thinking in your classes, experiments, synthesizing things that other peers aren’t able to, but the AP credits allow you to skip entry level classes and go straight into what you need.”

Lily’s experience in CST classes changed her post-high school plans. Instead of thinking “here’s what I need to do—get out of high school and get a job—it was like, here’s what I can apply my brain to.” She said her “interest in science just exploded. I was interested in science but once I got to LHHS and the CST, it was ‘nope that’s it’, that sealed the deal. I definitely made up my mind to go into science.”

**Collaboration.** Lily shared insights regarding the CST’s collaborative methods and how that benefited her. She “learned to understand how other people think.” The CST classes “definitely made me appreciate seeing where others were coming from instead of just wanting to do it my way.” She “learned to listen to other opinions and combine all of them so we can work together and have the best outcome and see everyone’s thought processes.” Lily applied these collaboration skills to a university lab setting where she worked with her mentor. She had to “work with my mentor and think together about how we are going to proceed.” In conclusion, Lily said “the CST group work defiantly enhanced my listening ability and reduced my hardheadedness and my wanting to do it my way.”

**Self-efficacy.** Lily expressed that “here at college my confidence is high because I know once I set my mind to something I can do anything.” She gained this self-efficacy from designing and conducting her own experiments in her CST classes. Whether the experiment worked or not,
she saw it all as a learning opportunity. Her self-efficacy extended beyond science, as well. “Even if you aren’t applying it to science, it’s a big confidence booster to know you can do anything if you want to and work hard at it.”

**Ryan**

Ryan graduated from LHHS in 2015. At the time of his interview, he was a junior at a four-year, public, selective, R1 university, a member of the honors college, and was majoring in chemical engineering.

**Quantitative self-efficacy results.** On the ten-point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, Ryan scored an average of 9.60. Out of eight exemplars he ranked third highest for self-efficacy scores.

**High school academic preparation.** Ryan took rigorous courses including AP chemistry, AP physics C (second year physics), algebra II, pre-calculus, AP calculus AB (first year calculus), and AP calculus BC (second year calculus).

**University academics.** As a junior, Ryan had already taken many rigorous classes. He has completed classes including biology, genetics, physics, chemistry, a programming course called process optimization, physical chemistry, the calculus series, differential equations, linear algebra, the organic chemistry series and a transport processes class.

Ryan was disappointed in his first semester at the university because he came in with “a bunch of AP credits but, when it came to course selections, I was more passive and took advice from university staff to not get in deep water early on.” For example, “they made the first math course something that it was not. I already had credit for it but I took it anyway. They said it would ramp up but it didn’t.” He realized that “LHHS did a really good job of preparing me.” He expressed that his “first semester was a disaster, I think a heavy course load with tougher courses
is better than a light course load.”

At his university, Ryan “joined a club of students for sustainable energy where we work with hydrogen in a cryogenic lab to find ways we can liquefy it on a smaller scale to use it for things like refueling operations and energy storage.” He hoped this work would help him with a career in the sustainable energy industry.

Adult influences. Mr. Martin was a positive influence in Ryan’s life. Ryan recalls that Mr. Martin “always believed in his students.” On the first day of a CST class, Mr. Martin explains that “we have the potential for you to do the most important things ever; I believe one of you will be a part in curing cancer, and I believe we have the future Nobel prize winner in here.” He encouraged Ryan and his CST classmates saying, “you are the ones who will go forward, you are the ones who will make changes in this world, you can and you will.” Mr. Martin “really truly and genuinely believed in everyone and he made you believe it. It never came across as fake or insincere.” Ryan’s confidence grew as Mr. Martin “guided and mentored him and gave me the ability to believe in myself and do these things that turned out to be bigger than us.” Additionally, Mr. Martin “had respect for the intellect of his students and for me that was really important for my success to have someone who believed in me when sometimes I did not.”

Ryan felt that he had “won a lottery” with his teachers. In reflecting back to his freshman year of high school, Ryan said, “I didn’t believe in myself, I wasn’t going into STEM or anything like that.” He was “thrown into” an AP biology course because he had high middle school math scores. Ryan “wouldn’t have taken that first AP course if my teachers hadn’t forced me into it – and I’m grateful that they did.”

Another influential teacher was Mrs. Katos. She was Ryan’s AP chemistry teacher at LHHS. He remembered her saying “you have this amazing curiosity for things.” Ryan was
thankful for “great teachers who recognize things about their students that they don’t always see in themselves and for me that was the biggest character building moment of my life.” Mrs. Katos’ AP chemistry class “set me in the direction I’m going, was her believing in me and telling me and showing me I can do these things, and even though I didn’t believe in myself.” He said “I can’t hit home enough how profound the impact that good teachers have had on me, inspiring me to go on—how they believe in students is huge.” Additionally, Ryan expressed that “when a teacher believes in a student and shows them that they can do it and really cares, students get inspired and that’s when they go on to do great things.” “It all starts with good teachers, if I didn’t have the teachers I did I wouldn’t be where I am now.”

Although Ryan did not mention his family, he did say he transferred from a nearby high school to LHHS specifically for the CST program. The transfer process involves families, since students cannot transfer themselves without parent(s) or guardian(s) permission. At some point Ryan’s parent(s) or guardian(s) either advocated for him to go to LHHS, or passively signed the paperwork as Ryan advocated for himself. It is unclear from the interview which scenario took place.

**Project-based learning and advanced placement.** Ryan saw his AP classes as being a linear progression from A to B. The information, A, is delivered to the students to prepare for the AP test, B. He said his AP classes allowed him to “learn good information along the way, you know what you need to do, and you know how to get there.” In CST, “you have no idea what’s going on, no idea what you are putting into it or what’s going to come out of it.” Ryan said that in the CST “everyone can learn and be successful because Mr. Martin fosters a culture where people take their skills, creativity, work ethic to get where they need to be, there’s not a point A to point B.”
Ryan found inspiration in problem solving when his lab group did not have access to the expensive equipment that was necessary for their protocol. His lab group adapted the existing equipment to make it work. Ryan said “that’s a huge part of engineering: being able to use what’s at your disposal to solve a problem. When you understand the fundamental processes, you can see where other things can do that and accomplish that.” Ryan credited Mr. Martin for helping him and other students learn how to solve problems creatively. He said “you had to find a very real world unique problem, where you didn’t know the solution, and Mr. Martin didn’t know the solution.” Ryan reflected, “Sometimes there is a problem where nobody has done anything like that before and you have to find the best way to solve it. The way he taught creative problem solving and critical thinking overlaps a lot with chemical engineering.”

Ryan’s experience “solving extremely complex real-world problems pretty much blew my mind as a senior in high school, I didn’t think this was something that high school students could do and that was really profound in me.” His CST classes changed what he believed he was capable of and “gave me confidence to go into a hard field like chemical engineering that has some of the most rigorous courses.”

**Collaboration.** Ryan’s research partner was someone who had been his long-time best friend. He described the pros and cons of partnering with his best friend. He said it “is great in a lot of ways, communication is easy, but it also means you two are a lot more confident with butting heads and in disagreements.” Ryan reflected, “It was a big lesson in conflict resolution and finding middle ground.” When deciding what to do going forward with their research, Ryan said, “it is more than just thinking you are right, it is about understanding where others are coming from and seeing where they might be right.” He said, “Sometimes that means you learn how to really fight for what you believe in when you have a point and not just saying ‘oh, you
have this idea and mine probably isn’t good enough.” Ultimately, he reflected, “it is about believing in yourself, having respect for the knowledge of others, seeing where they are coming from, seeing the bigger picture of their idea, and how they might be right just in a different way than you.”

**Self-efficacy.** Ryan’s work in his CST classes fostered self-efficacy and resiliency. In his research, Ryan learned that “sometimes things are easy and sometimes they are not and you fail a lot.” Because “we were doing something that’s unique and novel there were a bunch of things that would work or would not work, what’s important is learning from what didn’t work or what did work and why that happened.” He gave an example of a project where he and his lab partner did not have industry standard plates with tiny wells for bacterial growth. Since those plates were too expensive, they used the CST’s larger welled plates and “ran some calculations to say ‘this is the concentration we would need in the little tiny wells with point x and when we scaled it up to our size.’” When they “accounted for all the variables, like concentrations and temperature, we ran the tests and found that everything we were doing was way too low, and then way too high.” Eventually, “we learned that we can do this, the concept works at a larger scale. We don’t have to follow exactly what the researchers in the journal article did, but we do have to change things.”

Ryan was thankful he gained an innovative and persistent mindset in his CST classes. “There are so many opportunities with not having the right equipment and having to change things, and say ‘hey this might work’, throw it out there and do it. That’s something I had never gotten to do before.” “That was my mindset and my favorite part of the class.” Ryan summarized with “when your brain comes up with an idea and you see that it worked, almost worked, or even if it failed, you figure out why it failed. I feel this is the best way a student could possibly learn.”
Analysis Across Graduates

To understand how the themes played out across interview participants, a comparative analysis was conducted. The experiences of the eight exemplars was compared to the research question:

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

In this analysis, I will present the results regarding self-efficacy and academic preparation in relation to graduates’ choices of and persistence toward a college degree in a STEM discipline. The analysis will be presented with self-efficacy first, followed by academic preparation, and concluding with the relationship between self-efficacy and academic preparation.

Specifically, the current section on self-efficacy contains framing with the quantitative self-efficacy results, characteristics of teachers in the CST program, and role of project-based learning. The following section regarding academic preparation contains discussion of academic preparation in high school with Advanced Placement (AP) classes and project-based CST classes. The concluding section examining the relationship between self-efficacy and academic preparation will contain discussion on how both factors, in the project-based context of the CST program, influenced graduates’ choice of and persistence toward a college degree in a STEM discipline.

Self-efficacy Analysis

**Quantitative framing.** To provide a backdrop for the following qualitative analysis regarding self-efficacy, a short description of the quantitative results is included. On the ten-
point, twenty-item Likert-scale survey regarding self-efficacy in the context of the CST STEM program, the eight CST graduate exemplars had an average self-efficacy score of 9.34. The average score for the 52 survey participants was 8.48. Six out of the eight graduate exemplars scored between 9.45 and 9.95. The outliers, Alexa and Zoe, had scores of 9.05 and 7.7 respectively. As discussed in Chapter 3, Alexa and Zoe were considered outliers because they had lower science and math academic preparation and lower self-efficacy scores than the other exemplars, yet they persisted towards STEM degrees at most selective (Alexa) and more selective (Zoe) universities.

**Teachers.** My results suggest that the teachers in the study context shared a distinctive set of characteristics that, according to graduates’ interviews, promoted the development of self-efficacy in the CST classes. It is important to note that although this study was not focused on the teachers or their characteristics, the graduates frequently discussed their influence as contributing to the CST program. These attributes included promoting successful failures, having an unwavering belief in students’ abilities, and communicating personal care for each student.

**Supporting successful failures.** Successful failures was a notion that as the CST graduates learned to accept failure as a meaningful learning opportunity, they developed a sense of mastery over their task that positively influences their self-efficacy beliefs (Bandura, 1997). In the CST classes it did not matter if the student experienced success or a successful failure, individual confidence in his/her ability to succeed increased. Additionally, researchers identified that learning to cope with failure and frustration is an important predictor of persistence in science (Harsh, Maltese, and Tai, 2011; Hernandez et al., 2013; Laursen et al., 2010; and Lopatto, 2007).

In project-based context of CST classes, Mr. Martin intentionally taught the concept of
successful failures. These were real-time, in the moment lessons as opposed to lecture or book based. Since students were learning through research projects, failure was viewed as an inevitable catalyst for problem solving, learning, improving, and growing. For example, even when she earned a C on a test, or had errors in her lab experiments, Leah shared that “it’s like I know that much more for the next one. I know how to do things differently.” Emily concluded with “this helped a lot with resilience. He [Mr. Martin] taught us to not get dragged down by making mistakes.”

The CST graduates carried their increased self-efficacy through successful failures to their universities. The reflections of the CST graduates align with self-efficacy research. Self-efficacy influences the amount of effort an individual commits to a task, how long that effort would be sustained especially as challenges and obstacles arise, and how resilient they will be facing future barriers or failures (Bandura, 1982; Bandura, 1997; Hazari, Sonnert, Sadler, & Shanahan, 2010; Pajares, 2005; Sawtelle, Brewe, & Kramer, 2012). These exemplar graduates did commit to tasks, sustained effort even as challenges and obstacles arose, and they developed resiliency for future barriers or failures.

Beyond academics, the graduates’ reflections on their personal self-efficacy seemed to imply a level of permanency and future application. Aiden credited the CST for his ability “to aspire to do things at a high level regardless of whether it’s in lab work or just in general life whatever comes my way.” Audrey expressed, “I’ve learned to just keep doing what I plan on doing even if I get ‘no’s’. I know if I keep on trying I’ll get to where I want to be.” Leah remembers how Mr. Martin “had an unwavering belief in the ability of his students to do great things.” This belief in students was “the best gift you could ever give to a kid. I feel like at least for myself it fostered this lifetime learning thing.” Lily’s self-efficacy extends beyond science as
well. “Even if you aren’t applying it to science, it’s a big confidence booster to know you can do anything if you want to and work hard at it” (Lily). For Aiden, “the CST was really valuable. It’s been pivotal to my passion for science, aspiring to do and dream big, and do things at the highest level I can.” Audrey said the inspiration that Mr. Martin “instilled in us for all four years gave me the mentality that no one can get in my way if I want to do something spectacular.”

Unwavering belief in students’ abilities. Every graduate, except Alexa, discussed the impact of YATO and other verbal encouragements in the CST classes. Emily described how Mr. Martin had a poster in the CST lab that said You Are The Ones (YATO) above Einstein’s picture that became an touchstone for Mr. Martin’s resolute belief in the potential of his students. She remembered that, “he explained the YATO picture on the first day of class freshman year and he’d say ‘you are the ones who will do amazing things’, but after that he’d say ‘remember you are a YATO’.” Emily reflected, “I didn’t pay attention to all the little things he said like ‘you are going to do great things’, [or] ‘no matter what, hardships or roadblocks, you need to keep trying because you will be somebody who does something great’. Mr. Martin expressed the concept of YATO and other encouragements of his enduring belief in students so often that this became a ubiquitous part of the CST culture. Students understood that even challenges and setbacks would not reduce Mr. Martin’s steady belief in their potential and this encouraged them to believe in themselves. Ryan reflected that, Mr. Martin “really truly and genuinely believed in everyone and he made you believe it.”

Personal care for each student. Every graduate talked about how Mr. Martin valued students and cared for her or him personally. Leah said “from the moment you walk in there [CST class] you have a purpose and somebody there that cares about your potential and what you can do if you want to.” In addition to Mr. Martin, Ryan, Aiden, and Emily spoke of Mrs. Katos, a
LHHS AP Chemistry teacher. She had a significant impact on their self-efficacy and career choices. Mrs. Katos “set me in the direction I’m going, was her believing in me and telling me and showing me I can do these things, and even though I didn’t believe in myself” (Ryan). It was interesting to note Ryan, Aiden, and Emily are each successfully pursuing chemical engineering majors at their universities. Ryan summarized, “when a teacher believes in a student and shows them that they can do it and really cares, students get inspired and that’s when they go on to do great things.”

A theme that became apparent through my analysis was that each student felt personally known by Mr. Martin and Mrs. Katos. These teachers knew each student’s individual interests, had a resolute belief in their potential, and encouraged their success towards their personal goals.

While these teachers certainly made positive contributions to CST graduates’ self-efficacy, and graduates felt they had “won a lottery with teachers” (Ryan), it is important to reflect on the characteristics they demonstrated since individual teachers cannot be replicated. A significant finding from the data shows the impact on student self-efficacy when teachers exhibit the attributes of successful failures, unwavering belief in students’ abilities, and personal care for each student. Any teacher in any context might choose to internalize these acquired characteristics to promote the development of student self-efficacy.

**Project-based learning.** In addition to the characteristics of the CST teachers, the pedagogical context of project-based learning also significantly contributed to the development of students’ self-efficacy. The project-based nature of teaching and learning in the CST classes promoted increased self-efficacy by allowing for successful failures, student pride/ownership in their work, self-efficacy through problem solving, and self-efficacy through collaboration skills.

In the interviews, the CST graduates did not talk about self-efficacy in the context of
Advanced Placement classes or standard classes within LHHS apart from CST classes. The only learning context where graduates discussed self-efficacy was in CST classes.

**Successful failures.** As previously discussed, the project-based pedagogy in CST classes allowed students to develop personal self-efficacy.

**Pride/ownership in work.** Throughout the interviews, the graduates spoke of pride in their CST projects. They found purpose and meaning in their work as well as ownership and control in how their project progressed. Instead of passively consuming content in a traditional teacher-centered classroom, CST students were actively creating, designing, and implementing projects aligned to their personal interests. Each graduate reflected on how motivating it was to do novel work that contributed to science knowledge. Four out of eight graduates discussed pride in presenting their research projects either at a local university and/or at a regional STEM symposium. The practice of presenting work was aligned with the creation of a product, a common element in project-based learning (Buck Institute for Education, 2016; LaForce, Noble, & Blackwell, 2017; Savery, 2006). Three of the eight graduates discussed their pride in contributing to scientific journals. Their self-efficacy was enhanced by the satisfaction and confidence they gained from their projects. As a result of her ownership in her project, Emily reflected “it’s about being proud of what you are doing, and I didn’t have that before I came into the CST.” The pride students felt from their projects in CST classes directly enriched their self-efficacy.

**Problem solving.** Each graduate discussed how the project-based teaching and learning nature of CST classes gave them opportunities to “figure out how to solve our own problems” (Emily). Students had to figure out “why this didn’t work, and what can we do better” (Alexa). The CST graduates gained confidence to take the initiative to find their own answers. Problem
solving through project-based learning fostered a confident mindset and developed self-efficacy.

**Collaboration.** Every graduate, except Alexa, talked specifically about collaboration in the context of project-based learning. Graduates’ self-efficacy was developed as they gained skills to more productively work with others. The graduates expressed not having prior experience with collaboration until their CST classes. At first it was “intimidating to collaborate or speak up to people about your opinions but I learned how to communicate effectively and work together” (Zoe). Lily and Ryan “learned to understand how other people think, where they are coming from instead of just wanting to do it my own way” (Lily) and “it is more than just thinking you are right, it is about understanding where others are coming from and seeing where they might be right” (Ryan). Ryan also learned that “it is about how to really fight for what you believe in” while also “having respect for the knowledge of others, seeing where they are coming from, seeing the bigger picture of their idea, and how they might be right just in a different way than you.” Lily said, “The CST group work defiantly enhanced my listening ability and reduced my hardheadedness and my wanting to do it my way.” Through her CST classes Lily “learned to listen to other opinions and combine all of them so we can work together and have the best outcome and see everyone’s thought processes.” Ryan reflected, “it was a big lesson in conflict resolution and finding middle ground.”

Four of the eight graduates discussed how these collaboration skills have benefited them at their universities. Aiden, Lily, and Audrey talked about using their collaboration skills when they worked in a lab group (Aiden) or with a mentor on a research project (Lily and Audrey). Zoe mentioned generally that “...those [collaboration] skills have benefited me in college.” Audrey said learning to collaborate with her lab partners allowed her to gain project management skills. She would guide her partners by taking the lead in charting the course for their research.
Seeing the bigger picture of where they wanted their project to go and identifying the steps to get there “definitely gave me the confidence to manage a project on my own” (Audrey).

Collaboration skills gained through the context of project-based learning promoted self-efficacy as students gained confidence to successfully communicate in a work environment.

**Summary.** There were two significant findings regarding self-efficacy. The first is the impact of teachers. The second is the impact of students learning through projects.

The interview data suggests the teachers had significant influence on the development of students’ self-efficacy in the CST program. Three specific teacher characteristics were found: supporting students’ successful failures, unwavering belief in students’ abilities, and personal care for each student.

The second significant finding from the data suggests that project-based learning had a significant influence on students’ self-efficacy. The projects in this context fostered self-efficacy through allowing successful failures, student pride/ownership in work, confidence through problem solving, and confidence through collaboration skills. A teacher in another context might choose to adopt project-based learning pedagogy to promote the development of student self-efficacy. Figure 6 represents these relationships.
Academic Preparation Analysis

In attempting to answer my research question, “What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline,” I organized the analysis across graduates into three sections. Previously, the section on self-efficacy contained discussion of the quantitative self-efficacy results, characteristics of teachers in the CST program, and role of project-based learning. The current section regarding academic preparation contains discussion of academic preparation in high school with Advanced Placement (AP) classes and project-based CST classes. The following section will examine the relationship between self-efficacy and academic preparation and contains discussion on how
both factors, in the project-based context of the CST program, influenced graduates’ choice of and persistence toward a college degree in a STEM discipline.

Graduates’ experiences with higher education academics. Each of the eight graduates, who were identified as exemplars or outliers and participated in the interviews, found post high school academic success and were persisting in STEM degrees at their universities. Each interview participant reflected on their academic experience as freshmen.

The data suggested that for students with similar academic backgrounds such as Audrey, Aiden, Emily, and Ryan, the selectivity of the university was an important factor in the ease, or lack of ease, in their transition to university academics. The pattern emerged that the more selective the university the more difficult a graduate’s freshman year was. Aiden struggled his freshman year at his more selective university even though he was as academically prepared as Emily, Ryan, and Audrey, who all found ease in transitioning into their selective universities. Aiden took the introductory classes, even though he could have skipped them with his AP credits. He reflected, “From day one... it [academics] was for sure just a shock” (Aiden). He “really struggled for the first time. I really had to get help.” Additionally, Alexa referenced struggling her freshman year at her most selective university. Emily and Ryan, who attended selective universities, found the academics were “like a semester-long review (Emily),” and “they said it would ramp up but it didn’t. My first semester was a disaster” (Ryan). Table 22 summarizes the graduates’ academic experiences their freshman year.
Table 22

Graduates’ freshman academic experience, n = 8

<table>
<thead>
<tr>
<th>CST Graduate</th>
<th>Enter university with AP credits?</th>
<th>Skip intro science &amp; math classes?</th>
<th>University classification*</th>
<th>Freshman academic experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leah</td>
<td>No</td>
<td>No</td>
<td>Selective, liberal arts</td>
<td>Did not mention</td>
</tr>
<tr>
<td>Emily</td>
<td>Yes</td>
<td>No</td>
<td>Selective, R1</td>
<td>Too easy</td>
</tr>
<tr>
<td>Alexa</td>
<td>No</td>
<td>No</td>
<td>Most selective, R1</td>
<td>Struggle</td>
</tr>
<tr>
<td>Aiden</td>
<td>Yes</td>
<td>No</td>
<td>More selective, R1</td>
<td>Difficult</td>
</tr>
<tr>
<td>Audrey</td>
<td>Yes</td>
<td>Yes</td>
<td>Selective, R1</td>
<td>Ease, right challenge level</td>
</tr>
<tr>
<td>Zoe</td>
<td>No</td>
<td>No</td>
<td>More selective, R1</td>
<td>Struggle and ahead in science &amp; lab skills</td>
</tr>
<tr>
<td>Lily</td>
<td>Yes</td>
<td>Yes</td>
<td>Selective, R1</td>
<td>Did not mention</td>
</tr>
<tr>
<td>Ryan</td>
<td>Yes</td>
<td>No</td>
<td>Selective, R1</td>
<td>Too easy</td>
</tr>
</tbody>
</table>

* = Carnegie Classification of Institutions of Higher Education, 2018

High School Academic Preparation. Since each CST graduate had taken the CST courses, the variable was the number of rigorous AP classes they chose to take outside the CST program as part of the comprehensive high school. The exemplars were similarly academically prepared except for Alexa and Zoe, the outliers. As previously mentioned, Alexa and Zoe were included in the exemplar determination as outliers since they had lower self-efficacy scores and lower academic preparation and yet were persisting in STEM majors at a most selective R1 university and a more selective R1 university, respectively. The other six CST graduates had taken at least four AP science and or/math classes compared with only one AP class for Alexa and Zoe. A significant finding was the graduates perceived both AP and project-based learning as necessary for their academic success.

Advanced placement classes. Six out of eight exemplars took multiple AP math and
science classes. Alexa and Zoe only had one AP math class each and no AP science classes. It is important to note that in the interviews each graduate, including Alexa and Zoe, mentioned that they had taken AP courses besides math and science. They mentioned AP literature and composition, AP United States government, AP United States history, AP English language, among others. While these are not science or math classes, they have the same format, organizational structure, and pedagogy as science and math classes. When the graduates answered the interview question regarding their experiences in AP classes as compared to CST classes, they may have thought broadly across their AP classes.

In describing their AP classes, each graduate used phrases such as “more typical lecture based” and “these assignments, this test” (Leah). Emily described, “[an AP teacher] has got this calendar printed out of everything you need to have done everyday and it’s totally structured”. “It is definitely a lot more structured... you did what you were directed to do, there was no choice or independence” (Aiden). “AP classes were just cramming material for the test,” (Audrey) and they “were very much by the book, just very organized material coming at you” (Zoe). Ryan seemed to sum up his peers’ thoughts by saying that the AP classes are basically a linear pathway to the test: “information, A, is delivered to the students to prepare for the AP test, B.” Zoe said that besides her CST classes she saw, “high school as jumping through hoops with adults telling you what to do.” Alexa was the only graduate who said her AP classes seemed “focused more on getting kids into college versus just passing the AP tests.”

While the graduates discussed how AP classes were more structured, by the book, lecture based, and all in the service of passing the AP tests, each graduate also discussed the benefits of their AP classes. Emily said her “AP classes taught me how to process more information than a regular high school class.” She thought of “AP classes as twice the information of a regular class,
and a college class is twice the information of an AP class, so if you don’t take AP classes you’re trying to process four times the information at once.” Audrey and Lily felt the benefit of AP classes was to allow graduates the opportunity to earn high AP test scores in order to skip introductory level university classes. Even though Ryan knew AP classes were just moving him from point A, the information, to point B, the test, he reflected that his AP classes allowed him to “learn good information along the way, you know what you need to do, and you know how to get there.” Leah was the most positive of the graduates about her AP experience. She said “they were wonderful classes and I enjoyed taking them” (Leah).

**Project-based CST classes.** In contrast to the AP classes, each graduate discussed the CST classes very differently. Audrey reflected, “Pushing yourself and grit was really instilled in the CST, whereas in AP classes it was more ‘here’s your assignment, you have to get it done’.” In CST classes “you are not just being handed answers to remember” (Emily). Ryan reflected that “Mr. Martin fosters a culture where people take their skills, creativity, work ethic to get where they need to be, there’s not a point A to point B.” Lily said in taking CST classes you don’t learn so much book knowledge as you do skills and a thinking method, and so I think there is a lot more to learn from CST than AP credits.”

Each graduate talked about independence and problem solving in their CST classes. Leah said for her the CST classes were “fostering creativity, independent learning, and an acceptance that we don’t have all the answers - that we are working towards getting the answers.” In Emily’s experience, in CST classes, “you figure out your project on week one or the end of the year before, and we plan our own time out, and figure out how to solve our own problems.” Alexa “liked that it was very hands-on, very independent oriented study, and we had all the equipment to allow us to actually do the scientific research.” Mr. Martin “would make us question our
results, ask us why, and not just give us answers but make us about why this didn’t work, and
what can we do better” (Alexa). In contrast to Ryan’s reflection of AP classes as moving from
point A to point B, Aiden said “it’s completely dependent on the time you allocated to spend
time on research or experiments.” Being able to make decisions about her projects and work, Zoe
said, “we were seeing things happen, we did a lot of trial and error, it was just really cool and
unique.” Every graduate appreciated the pedagogy in his or her CST classes. Comments by Zoe
and Ryan sum up their peers’ thoughts. “CST is the best way to prepare for what you might
experience in college, even if you don’t pursue science, it’s deep thinking, it’s team work, it’s
challenging, exciting, and it’s really an awesome opportunity we have at LHHS” (Zoe). “When
your brain comes up with an idea and you see that it worked, almost worked, or even if it failed,
you figure out why it failed. I feel this is the best way a student could possibly learn” (Ryan).
Even though the CST graduates saw value in their AP classes, they consistently spoke of
learning more and gaining more benefit from their project-based learning CST classes.

**Summary**

The graduates perceived both AP and project-based learning as important for their
academic success. The data suggest that they saw themselves as more prepared in terms of facts
and work load with AP classes and more prepared in terms of self-efficacy, deeper science
knowledge, collaboration, passion, problem solving, project managing, and inspiration to pursue
a STEM major with the project-based learning CST classes. Each graduate perceived AP classes
as more structured, CST classes as project-based, and both AP and CST (project-based learning)
as beneficial.

Although research on school reform suggests that rigorous and college-aligned
curriculum, such as AP courses, is coupled with higher student outcomes (Duncan & Murnane,
the CST graduates described how AP courses alone were insufficient preparation for college success. A leader of a STEM charter school explained, “The reason our school started was because locals said, ‘we are getting these students that are great at calculus—they’re 4.0 students—but they can’t do anything in the work place, can’t actually apply it to the real world’” (Lynch, Burton, Behrend, House, Ford, Spillane, Matray, Han, Means, 2018). Students in project-based CST classes were learning the application of science concepts, how to collaborate, how to problem solve, and gaining the self-efficacy to persist when faced with academic challenges or failures. The graduates did not discuss these outcomes with regard to their AP courses.

CST students were preparing for college classes by developing socio-emotional proficiencies and behaviors associated with persistence in college and career success (Duckworth et al., 2007; Farrington et al., 2012; NRC, 2012; Partnership for 21st Century Skills, 2009). The strong sense of self-efficacy developed in CST classes is influential in students’ academic achievement in college STEM courses (Andrew, 1998; Lent, Brown, & Larkin, 1984; Multon, Brown, & Lent, 1991; Pietsch, Walker, & Chapman, 2003). As indicated in the qualitative data and in the research literature, academic preparation and self-efficacy seem to be inextricably connected, mutually reinforcing one another. Continued successful behaviors and performances on difficult or challenging tasks lead to greater academic achievement. This leads to even greater self-efficacy to accept further challenge and the cycle continues (Bandura, 1997). The CST project-based learning environment gave students practice overcoming academic challenges while developing their self-efficacy by viewing failure as a learning experience. CST students experienced the daily practice of academic challenge with successful failures.
The context of my study is relatively unique in that students had access to an inclusive project-based STEM program and rigorous AP courses. The research literature on STEM efforts in school reform predominantly focuses on either traditional comprehensive schools that offer rigorous courses such as AP or stand-alone project-based learning STEM schools. The study context at LHHS offers students both project-based learning and rigorous AP courses to maximize their academic preparation to persist in STEM majors. Figure 7 shows how both project-based learning and Advanced Placement classes contribute to the academic preparation of students in the CST STEM program.

Figure 7. Academic preparation for CST students included project-based learning and advanced placement classes

**Relationship Between Self-Efficacy and Academic Preparation**

In answering my research question, “What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline,” the analysis across graduates was organized into three sections. At the beginning of this qualitative analysis, the section on self-efficacy contained discussion of the quantitative self-efficacy results, characteristics of teachers in the CST program, and role of project-based learning. The previous section regarding academic preparation contained discussion of academic preparation in high
school with Advanced Placement (AP) classes and project-based CST classes. The following section will examine the relationship between self-efficacy and academic preparation and contains discussion on how both factors, in the project-based context of the CST program, influenced graduates’ choice of and persistence toward a college degree in a STEM discipline.

Previously, with discussions regarding self-efficacy and academic preparation, I presented how the two factors individually contributed to the CST graduates’ choice of and persistence toward a college degree in a STEM discipline. While each of the two factors contributed independently to graduates’ future academic choices, there was a common theme in both. The graduates frequently discussed both self-efficacy and academic preparation in the context of project-based learning in their CST classes. The analysis indicated that both self-efficacy and academic preparation influenced graduates’ choice of and persistence toward a STEM degree through the CST project-based learning context.

In the interviews, significant patterns emerged between academic challenges in the project-based learning CST classes and increased self-efficacy. In their interviews, none of the graduates referenced self-efficacy in the context of Advanced Placement classes. With regard to CST classes, graduates described how using science knowledge to procedurally and conceptually understand a complex experimental protocol, scoring well on an assessment, and completing a project promoted an increased sense of personal mastery. Britner and Pajares (2006) suggest that only mastery experiences significantly predict science self-efficacy. Throughout the interviews, graduates spoke of self-efficacy in terms of mastery experiences through finding answers to problems, successful failures, learning to collaborate, gaining confidence from finding results in their research projects, developing presentation skills, understanding journal articles, and contributing to journal articles. Figure 8 builds on Figure 7 to show that according to the
interview participants, self-efficacy was developed in the project-based learning classes as opposed to their Advanced Placement classes.

![Diagram showing the relationship between Academic Preparation, Project-based learning, Self-efficacy, and Advanced Placement.]

*Figure 8. Self-efficacy developed in the project-based context*

**Choice Of And Persistence Toward A STEM Degree**

The influence of project-based learning on CST graduates’ choice of and persistence toward a college degree in a STEM discipline was unexpected and interesting to me. Since every graduate, except Emily, reflected on how project-based pedagogy in CST classes inspired her or him to pursue a STEM major and persist towards that goal in college, this was a significant pattern. The pattern was aligned with research that suggests students who experience project-based learning or problem-based learning have increased positive beliefs about STEM and interest in pursuing STEM in college (Baran & Maskan, 2010; Berk, Muret-Wagstaff, Goyal, Joyal, Gordon, Faux, & Oriol, 2014; LaForce, Noble, & Blackwell, 2017; Mergendoller, Maxwell, & Bellisimo, 2006).

When discussing projects, each graduate except Emily discussed how project-based learning directly influenced his or her STEM career choice. Some graduates spoke of specific academic content of the project as a deciding factor. Alexa said she chose her university because
they emphasized cellular research similar to what she did in her CST projects. Audrey’s two projects on sea mammals “changed my career path so now I’m going to do veterinary medicine on marine mammals.” Other graduates discussed how the self-efficacy gained through their project(s) contributed to their choice of a STEM major. For Leah, “the CST was perfect, it fostered independence and allowed me to feel comfortable making my own path in the sciences.” Ryan’s projects in the CST “gave me confidence to go into a hard field like Chemical Engineering that has some of the most rigorous courses.” For Aiden and Zoe, “the CST has been pivotal to my passion for science (Aiden)” and “it made me feel passionate about what I was doing and in the career I am pursuing” (Zoe). In Lily’s case, the CST completely changed her mindset. Instead of thinking she would “get out of high school and get a job, it was like here’s what I can apply my brain to.” Lily said her “interest in science just exploded, I was interested in science but once I got to LHHS and the CST, it was ‘nope, that’s it’, that sealed the deal. I definitely made up my mind to go into science.”

It is important to note that when graduates reflected on how self-efficacy influenced their choice of a STEM major, they talked about their confidence in relation to academic mastery in the project-based context of CST classes. Figure 9 shows the relationships between the independent variables of academic preparation and self-efficacy and the dependent variable of graduates’ choice of and persistence toward a college degree in a STEM discipline.
Figure 9. Relationships between academic preparation and self-efficacy and graduates’ choice of and persistence toward a college degree in a STEM discipline

Analysis Grounded In Theoretical Framework

To provide further conceptual grounding of the centrality of project-based academics to the development of self-efficacy and resulting choice of and persistence toward a STEM major, I referred to my theoretical framework of Social Cognitive Career Theory (SCCT). Brown and Lent (1996) and Lent, Brown, and Hackett (1994, 2000) as pioneers of SCCT suggest that project-based learning, as found in the CST classes, have been found to impact career choices and persistence towards career goals (Carpi, Ronan, Falconer, & Lents, 2016). This summary shows how theoretical suggestions, based on study data, that the self-efficacy CST students developed in the STEM project-based context influenced their choice of and persistence toward a STEM career.
Choice Of And Persistence Toward A STEM Degree

Research studies employing the SCCT framework indicate that students’ career choices are developed to a significant degree by students’ self-efficacy beliefs as they successfully perform tasks aligned with career interests (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Bandura, 1986; Carpi, Ronan, Falconer & Lents, 2016; Lent, Brown & Hackett, 1994, 1996; Lent, Sheu, Gloster, & Wilkins, 2010; Wang, 2013). Project-based learning, in the CST context, was an environment where students were successfully performing STEM related tasks. These tasks included finding interesting results, producing a journal article, scoring well on an assessment, completing a project, presenting project results, or understanding a complex concept. These successfully completed tasks promoted an increased sense of personal mastery. Britner and Pajares (2006) suggest that only mastery experiences significantly predicted increased self-efficacy. In the project-based CST context, when a student received a disappointing score or experimental result, she/he recognized that there was meaningful learning in that therefore it was no longer seen as a failure that could negatively affect his/her self-efficacy. As a result, the student’s belief in her/his ability to master content or lab skills was promoted and sense of self-efficacy was further developed. As students learned not to accept anything as a failure but as a learning opportunity, they developed a sense of mastery that positively influenced their self-efficacy beliefs (Bandura, 1997).

Increased self-efficacy beliefs influenced the graduates’ choice of a STEM degree as well as their persistence in college STEM degrees. There is a robust body of studies, which employed SCCT, that indicate the influence of increased self-efficacy on persistence towards STEM-related degree pathways (Betz & Hackett, 1983; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; Hackett, Betz, Casas, & Rocha-Singh, 1992; Lent, Lopez, & Bieschke, 1993; Lent,
Lopez, Lopez, & Sheu, 2008; Wang, 2013). Additionally, researchers identified that learning to cope with failure and frustration, as common in project-based learning, is an important predictor of persistence in STEM majors (Harsh, Maltese, and Tai, 2011; Hernandez et al., 2013; Laursen et al., 2010; and Lopatto, 2007).

**Summary**

A significant finding from the quantitative and qualitative analysis was how self-efficacy and academic preparation, developed in the project-based context of CST classes, influenced the graduates’ choice of and persistence toward a college degree in a STEM discipline. Learning through projects helped students develop robust perceptions of self-efficacy and fostered graduates’ choice of a STEM major.

In summary, the self-efficacy CST students developed in the STEM project-based academic context influenced their choice of a STEM career and their persistence in STEM majors. A significant result was the centrality of the project-based learning experience in the lives of CST graduates. The academic project-based learning context in CST classes contributed to the development of self-efficacy that influenced their choice of a STEM major and persistence toward a college degree in a STEM discipline.
CHAPTER FIVE DISCUSSION

Introduction

The purpose of the study was to understand what, if any, influence a specific inclusive high school STEM program that emphasized self-efficacy and academic preparation had on graduates’ choice of STEM degree pathways and their persistence toward a college degree in a STEM discipline. While academic preparation and self-efficacy were two separate constructs (independent variables), the concept of graduates’ choice of and persistence in a STEM major were one construct (dependent variable). The unit of analysis was the graduates from an inclusive high school STEM program.

Research Question

My study was guided by the following research question:

“What influence, if any, did an inclusive high school STEM program’s emphasis on self-efficacy and academic preparation have on graduates’ choice of and persistence toward attainment of a college degree in a STEM discipline”?

My study utilized a mixed methods approach by analyzing qualitative and quantitative data from students who graduated from an inclusive STEM program, the Center for Science and Technology (CST), situated within an urban comprehensive high school. The mixed methods design included an initial survey followed by semi-structured interviews. The CST STEM program graduates responded to survey items related to self-efficacy and academic preparation as well as items related to their post-high school academic choices. The survey data was analyzed to inform participant selection for the interviews. Of the 52 CST graduates who participated in the survey, eight were selected as exemplars for interviews based on their self-
efficacy scores and academic preparation as described in Chapter 3. These CST graduate exemplars exhibited a “particularly intense or highly developed manner” of self-efficacy and academic preparation (Bronk, King, & Matsuba, 2013, p.1). The participants of the study were men and women who graduated from the CST program between the years of 2010 and 2016.

**Summary of Findings**

The results of my study were intended to illuminate whether the emphasis on self-efficacy and academic preparation in the Center for Science & Technology program at Lake Hills High School influenced graduates’ choice of and persistence toward college degrees in STEM disciplines. The results suggest that the project-based learning context in CST classes significantly contributed to the development of self-efficacy that influenced the graduates’ choice of and persistence in STEM majors. The understanding of these relationships, as represented in Figure 9, answered my research question.

**Understanding the CST STEM Program**

With an increase in STEM focused programs and stand-alone STEM schools in the United States, it is important to understand constructs that may contribute towards the success of their graduates. According to Means, Confrey, House, and Bhanot (2008), 63% of STEM schools were either charter or public stand-alone schools and 38% were schools/programs-within-a-school. While Inclusive STEM High Schools (ISHS) have captured some research spotlight (LaForce, Noble, King, Century, Blackwell, Holt, Ibrahim, Loo, 2016; Lynch, Peters-Burton, Behrend, House, Ford, Spillane, Matray, Han, & Means, 2017; Means, Wang, Young, Peters, & Lynch, 2016; Weis, Eisenhart, Cipollone, Stich, Nikischer, Hanson, & Dominguez, 2015), comparatively little is known about STEM programs situated within comprehensive high schools. This study furthered the understanding of the specific Center for Science and
Technology (CST) STEM program context within an urban comprehensive Lake Hills High School (LHHS). While each context is unique, and my findings are not generalizable, the application of findings and implications may relate to readers situated in or interested in similar contexts. In my journey to understand the nuances of this STEM program, specifically if the variables of academic preparation and self-efficacy influenced the variable of graduates’ continuing STEM education, I uncovered project-based learning as a connecting factor between the three variables (see Figure 9). The results suggested the project-based learning experiences in CST classes had a significant and central influence on the development of self-efficacy that influenced their choice of and persistence toward college degrees in STEM disciplines.

The study context of the CST program within LHHS provided an interesting frame to attempt to understand the relationship between academic preparation through AP classes and project-based learning classes. The research literature on Inclusive STEM High Schools (ISHSs), and on comprehensive high schools attempting transformation, frequently mentions STEM focused curriculum or rigorous curriculum and only occasionally specifically refers to Advanced Placement classes (Weis et al., 2015; Lynch et al., 2017; Lynch, Peters-Burton, & Ford, 2014; Means et al., 2016). Since LHHS did not fit either research context: ISHS or transitioning comprehensive school it provided an unusual scenario where students have access to ISHS type project-based learning in CST classes while accessing general and AP classes within the standard comprehensive high school. The study findings suggest that the CST graduates benefited academically from both AP classes and project-based CST STEM classes. This aligns with research indicating that a rigorous and college-aligned curriculum, such as Advanced Placement classes, is associated with higher test scores, high school graduation rates, and college-going rates (Duncan & Murnane, 2014; Rutledge, Cohen-Vogel, Osborne-Lampkin, & Roberts, 2015;
Lynch et al., 2018). In addition, research suggests substantial academic gains from project-based learning in ISHSs (Weis et al., 2015; Lynch et al., 2017; Lynch, Peters-Burton, & Ford, 2014; Means et al., 2016). My study suggests students benefited academically from both Advanced Placement classes and project-based learning classes.

The findings from my study show that an inclusive pedagogical approach where project-based learning and AP classes mutually exist in a comprehensive school has benefits for students. The data suggests that even though graduates viewed AP classes as traditional, lecture-based, teacher-centered, and structured, they found them valuable for learning facts, internalizing rote knowledge, managing information, and for skipping entry-level university classes. The project-based nature of teaching and learning in the CST classes promoted increased self-efficacy by allowing for and supporting successful failures, student pride/ownership in their work, problem solving, and collaboration. The results show that self-efficacy was cultivated in a project-based environment where mistakes and failure due to academic challenge were viewed as learning experiences. The results show that these elements were not developed in AP courses. A conspicuous finding from the qualitative data suggests a significant impact on student self-efficacy when students learn through projects.

Even though the project-based pedagogy in the CST classes developed graduates’ self-efficacy it is important to note how the teachers’ characteristics supported the emphasis of self-efficacy. Figure 6 showed the inter-connected relationships between project-based learning and the characteristics of the CST teachers in promoting self-efficacy in the CST program. The CST teachers nurtured the concept of successful failures as students experienced challenges through their projects while concurrently expressing an unwavering belief in the abilities of students and
personal care for each student. These characteristics in the context of project-based learning boosted the graduates’ development of personal self-efficacy.

**For Further Inquiry**

While the results of my study are interesting, they are incomplete. To more fully understand the nuances of this inclusive STEM program, a comprehensive critical narrative inquiry or ethnographic study with rich contextual descriptions may be beneficial. A detailed qualitative study would enhance our understanding of project-based teaching and learning, specific stages in the evolution of students’ personal self-efficacy within project-based experiences, and details about how and why students choose (or do not choose) to pursue post-secondary STEM education. A qualitative study that explores specific CST program-level practices and characteristics may further our knowledge regarding STEM programs within comprehensive high schools. Such a study might include analysis of student work, classroom observations, document and curriculum analysis, interviewing current students and faculty, examining the relationship between the STEM program and the comprehensive high school, documenting the influence of AP classes, analysis of the inception and evolution of the CST program, and understanding the role of school district support and funding structures. In a National Research Council report (2011), the authors suggested examining school-level practices beyond student learning outcomes to more fully understand the effectiveness of the STEM school (or STEM program). Optimally, a future study would explore a combination of student learning outcomes, including choice of and persistence toward STEM degrees, with practices from the STEM program, the comprehensive high school, the school district, and the community.

**STEM program demographic.** Additionally, my study was not conducted through the lens of opportunity structures. Neither my survey nor my interviews asked graduates
demographic questions such as ethnicity, gender, or family income because those factors were not a focus for my study. Since LHHS is an urban comprehensive high school that serves approximately 1,500 students with equal gender ratios, 35% of students are non-white, and 53% of students live in low socio-economic families, including 25% from extreme poverty situations, a social justice perspective might yield valuable findings. Many questions arise related to the context of an inclusive STEM program within an urban, ethnically diverse, higher poverty comprehensive high school. Are the students in the inclusive STEM program representative of the population in the high school? Which students enroll in the STEM program and why? Are there cultural barriers related to or perceptions of the STEM program that hinder non-white students and/or students of poverty? Even if underrepresented minority students are participating in the STEM program, research suggests their intent to pursue STEM careers is not as influenced by experience with STEM classes as compared with their white peers (Wang, 2013).

Additionally, of the 52 graduates of the CST STEM program who participated in the survey, 100% participated in post high school education with 83% attending a four-year college (see Table 2) and a majority, 73% of graduates, pursued a STEM major in college (see Table 3). Although this high rate of graduates who chose and are persisting toward STEM degrees aligns with the interviews regarding how the CST program influenced their choice of and persistence toward STEM degrees, it raises other questions. Were these underrepresented minority students? Were they students of poverty? Did the 73% of graduates pursuing a STEM degree persist to attain their degree? What careers did these graduates enter? Why did these students pursue STEM degrees and the other 27% did not? An ethnographic or other critical qualitative study through a social justice lens may aid in our understanding of this fairly unknown context and
suggest findings that may be relatable to similar contexts of STEM programs within comprehensive high schools.

**Implications for Schools**

Since most of the students in the United States are educated in traditional comprehensive high schools, it is important to understand how our schools could increasingly promote self-efficacy and academic preparation, inspire students to pursue STEM majors, and build their capacity to persist towards STEM degrees. This study provided research findings that, although not generalizable, may inform comprehensive high school leaders of the potential student benefits a developing a project-based STEM program. Even if the implementation of a STEM program is not feasible, the study findings suggest other potential areas of application for schools.

These areas of application include the potential implementation of project-based learning pedagogy whether in a STEM program or modifying STEM instruction in one classroom or many classrooms. The study results suggest a significant influence of project-based learning on students’ self-efficacy and their choice of and persistence toward a college degree in a STEM discipline. Implementation of project-based learning pedagogy requires teacher professional development. Beyond pedagogy and the teaching and learning of project-based curriculum are affective components of teachers that were shown in my study to enhance student self-efficacy. The CST graduates suggested that CST teachers’ support of successful failures, their unwavering beliefs in students’ abilities, and personal care for each student promoted their self-efficacy (see Figure 6). The positive influence of teachers communicating personal care was also noted in an ISHS case study (Morrison, Roth McDuffie, & French, 2015).
Even though the research literature suggests that well-prepared STEM teachers, those with STEM degrees and strategies such as project-based learning, are influential for student success (Ball, Lubienski, & Mewborn, 2001; Lynch et al., 2017; Means et al., 2016), another finding is the quality of student-teacher relationships correlated with positive STEM achievement outcomes (Bryk, Sebring, Allensworth, Luppescu, & Easton, 2009; Lee, 2011; Subotnik et al., 2013; Means et al., 2016). In a study of one inclusive STEM High School (Lynch et al., 2018), they found that hiring STEM teachers who had personally overcome challenging circumstances could help students develop “grit” to persist in a STEM college prep classes and apply that mindset later in college. Further study is necessary to understand teacher preparation and professional development with regard to project-based learning and the promotion of student self-efficacy.

The results from my study suggest a deeper level of specificity with regard to the influence of self-efficacy through successful failures than I found in the research literature. It would be interesting to conduct further research into the specific, daily, “in the moment” opportunities teachers have to support students’ development of self-efficacy. Within the project-based settings, teachers may have opportunities to promote student self-efficacy through successful failures because students encounter academic challenges, pivots, and setbacks as they develop their projects. Additionally, future studies could consider investigating student achievement outcomes, high school graduation rates, test scores, and persistence in college as a result of increased self-efficacy through successful failures.

While there is much research to do, my study results may have potential application to other comprehensive school contexts. The influence of project-based learning in a STEM program within a comprehensive high school could have application as many school districts
around the country are seeking and implementing teaching and learning pedagogies such as project-based learning in various ways. Many school districts have chosen to develop ISHSs as “a viable alternative to large comprehensive schools for inspiring and preparing students for STEM and STEM-related careers” (Lynch et al., 2018). These authors recommend that, “school districts well might consider the creation of specialized STEM schools” (Lynch et al., 2018).

While ISHSs are increasingly common, there are also examples of comprehensive high schools that have attempted to transform into ISHSs (Eisenhart et al., 2015). The results of my study suggest that instead of transforming a traditional high school into an academy model or ISHS, school districts might consider the implementation of a project-based STEM learning within the school to compliment already existing college-prep classes such as AP. A teacher or principal in a school comprehensive school context might choose to implement project-based learning pedagogy to promote the development of student self-efficacy as a complement to traditional methods and curriculum. Teachers or school leaders within any school context could choose to implement project-based learning methods into classes or could develop a discrete program such as CST. It would inform the research field to seek to understand schools such as LHHS that are “positive deviants” from the norm (Bryk, 2015, p. 472).

Even though my study provided findings that may help inform whether or not leaders of comprehensive schools or STEM programs within schools may choose to implement project-based learning academics, the application of my study resides in whether the reader determines my findings are informative to their particular context and life experiences (Morse, 1991; Morgan, 2007).
Recommendations for Research

While there are a multitude of concepts, contexts, structures, and questions to fuel further understanding, I will present two areas for potential future research focus. One potential foci is the context of STEM programs within comprehensive high schools including teacher preparation and professional development regarding project-based learning. A second focus is further qualitative studies utilizing Social Cognitive Career Theory (SCCT) to understand affective factors such as self-efficacy with students and adults. First, I will discuss future research focuses regarding STEM programs within comprehensive high schools followed by research concerning affective factors through a qualitative SCCT lens.

STEM Program Context

As previously stated, little is known about STEM programs situated within comprehensive high schools. I did not find other contexts similar to CST in the research literature. There is a need for a qualitative critical inquiry or ethnographic study of the CST program to more fully understand the nuanced nature of students developing self-efficacy and choice of and persistence toward STEM degrees in a project-based learning context. A research focus is needed regarding how traditional comprehensive high schools might implement project-based learning either as a STEM program or within existing class(es). What are best practices for traditional non-STEM focused schools to spark reform-oriented change (Morrison, Roth McDuffie, & French; 2015)? There is also a need to understand this context through a social justice perspective.

Many research questions could be framed to investigate this implementation process. What should be emphasized in teacher professional development? What are the benefits and risks of developing a project-based STEM program versus implementing project-based learning
in science and/or math classrooms or in non-STEM classrooms? How would a comprehensive school best leverage opportunities for students to take Advanced Placement and other general non project-based classes concurrently with project-based classes? What affective teacher characteristics influencing student self-efficacy, such as personal care for students, support of successful failures, and unwavering belief in students’ abilities, are needed to support a project-based classroom culture? How would a school leader develop those affective characteristics in her teachers?

**Affective Factors**

This second section expands on the need for qualitative research focused on affective factors such as self-efficacy through a SCCT framework in general and specifically to the STEM program context. Even though the importance of affective factors such as self-efficacy is becoming recognized, Vedder-Weiss and Fortus’ (2011) quantitative study suggested there is a lack of research on motivation and persistence in STEM. Additionally, Fortus’ (2014) editorial suggests not only is there a lack of research on affect (motivation, identity, interest, self-efficacy and attitudes), but also there is a severe shortage of qualitative and mixed methods research on affect. My study attempted to enrich the literature by providing a mixed methods perspective.

In addition, research using the SCCT framework to understand high school students’ STEM career interest and motivation was conducted almost entirely quantitatively (Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; Dika, Alvarez, Santos, & Suárez, 2016; Falco, 2016; Garriott, Hultgren, & Frazier, 2016; Garriott, Raque-Bogdan, Zoma, Mackie-Hernandez, & Lavin, 2017; Shin, Ha, & Lee, 2016). Of these quantitative studies using SCCT, only a few investigated students’ self-efficacy beliefs (Garriott et al., 2016; Garriott et al., 2017; Shin et al., 2016).
Further qualitative research regarding affective factors, such as self-efficacy, qualitative research utilizing the SCCT framework, and using the SCCT framework to understand self-efficacy is needed. Additionally, the research field is wide open regarding the understanding the contexts of STEM programs operating within comprehensive high schools.

**Conclusion**

The results of my study provided understanding of whether the emphasis on self-efficacy and academic preparation in a STEM program located within a comprehensive high school influenced graduates’ choice of and persistence toward college degrees in STEM disciplines. The results suggest that the project-based learning context in CST classes significantly contributed to the development of self-efficacy that influenced the graduates’ choice of and persistence in STEM majors as shown in Figure 9.

The findings of my study were limited in generalizability resulting from the specific STEM program context and the epistemological approach of my study. Even though there are other STEM programs within comprehensive schools, each has its own unique context. My study context may be similar to other STEM programs in some ways, but each will differ from another in other ways. It was my intention to understand my research question within the specific CST STEM program context, not to produce generalizable findings. While not generalizable, it is possible that the findings of my study may be relevant depending upon the context and lived experiences of the reader.

I understand that even with protections to ensure validity and reliability, knowledge gained through research will always be imperfect and fallible (Phillips & Burbules, 2000). Research conducted with unique humans interacting in complex situated communities (Lave & Wenger, 1991) that are continually interacting, adapting, changing, and experiencing full, rich,
multifaceted experiences every moment of every day cannot be generalized. Since each student is unique and is impacted differently by an infinite number of varying experiences, it is nearly impossible to attribute any outcome to any particular single construct, factor, or combination of connecting factors. As discussed in Chapter 1, my epistemological choice to reject a positivistic claim of producing generalizable knowledge is supported by a multitude of researchers (Guba & Lincoln, 2005; Mertens, Bledsoe, Sullivan, Wilson, 2010; Tashakkori & Teddlie, 2010). I acknowledge that “objective reality can never be captured” (Lincoln, Lynham, & Guba, 2011, p. 99) and that research is “not ever truly objective” (Hughes, King, Rodden & Andersen, 1994). Since research is never truly objective, findings are not generalizable to diverse contexts.

Even though my study findings are not broadly generalizable, they may be meaningful to researchers, teachers, school or district leaders who have an interest in STEM programs within comprehensive high schools. Ultimately, it is my desire to advance knowledge that promotes improved outcomes for students. It is conceivable that as more research is conducted on STEM programs within comprehensive high schools and the findings are implemented, the outcomes for many students currently educated in traditional high schools may improve. It is possible for more students to discuss learning the way the CST graduates did. It is my hope that more students will have the opportunity to learn academics through projects, increase their self-efficacy, and be inspired to choose and persist toward attainment of college degrees that will open doors for them into fulfilling careers.
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APPENDIX
Development of a 16s Bacterial rRNA Sequence Library for Apis Mellifera

Introduction

Our project focuses on Apis mellifera populations across the nation and in creating a genetic 16s library. The 16s sequences were obtained from individual organs (e.g., intestines) to centralize the origin of the bacteria. To reduce the chance of damaging the 16s sequence during recombination into pUC19, the use of restriction enzymes had to be eliminated due to the unknown target 16s sequence. PCR was used to create and amplify shear pUC19 and to sequence the amplified 16s sequences into the plasmid. Transforming the recombined plasmids into competent E. coli will allow each distinct 16s fragment to be isolated and sequenced in order to determine what bacteria are present in the bee.

Purpose

The Apis mellifera (European Honey Bee) 16s genomic library has not yet been developed. By establishing this library, we will be able to compare different hive populations for uniformity and look for any differences in the microbiota that would highlight abnormality in a regional bee population. Bees account for the pollination of over 70% of the food and crops we consume annually, and a larger understanding of bees is necessary to help in their conservation and protection.

Method

• PCR Mediated Plasmid Linearization and Amplification

PCR mediated plasmid linearization and amplification relies on the use of extended length 16s primers containing reverse complements to the pUC19 linearization primers (Fig 1, 2). When the amplification is synthesized from the 16s sequence, Taq polymerase completes the strand to the end of the primer, incorporating the reverse complement of the non 16s annealing sequence (Fig 3). The incorporated reverse complements on the 3' end of the 16s fragment are identical to the pUC19 linearization primers allowing the recircularization of the pUC19 plasmid, using the 16s insert as the primer for the completion of the recircularization. In order to assure that the 16s primer complements to pUC19 primers can't anneal to the circular pUC19, only linearized pUC19, a six base pair "overhang" is added to the pUC19 linearization primers and six complimentary base pairs are present in the 16s primers. These six base pairs and their complements do not anneal anywhere else in the recircularization. When recombining the plasmid, this 16s band acts as a primer to initiate the extension of the remaining plasmid (Fig 4).

Literature Cited


Expected Results

We expect to find Bacillus sp. to verify and expand upon the findings of Martha Gilliam in Identification and Roles of Non-Pathogenic Microflora Associated with Honey Bees, by using genomic evidence as opposed to selective media. Our sequences will give us greater confidence in identifying the different bacteria present in Apis mellifera.

Acknowledgements
Analysis of Interspecific Hybridization of Leuciscinae in Cottonwood Creek

Introduction
A major conservation problem and evolutionary issue among cyprinid fishes is interspecific hybridization due to loss of gene flow in confined tributaries. In the Pacific Northwest, tributaries and run-offs are converted for irrigation purposes, which have caused the natural flow patterns of the streams to become altered or destroyed. Damming, among other changes to the rivers, have lowered the water quality to poor conditions. In this study we used a 1.6 kb PCR product of the 125 and 165 regions to analyze possible divergence or introgression of the redside shiner (Richardsonius balteatus) and spooked dace (Rhinichthys osculus) in Cottonwood Creek, a tributary of Latah Creek, which runs into the Spokane River. Analysis of the cyprinid sequences will further explain the genetic introgression or genetic diversity in tributaries of the Spokane area.

Materials & Methods
Sample Collection: Samples were collected at several locations along Cottonwood Creek, a tributary of Latah Creek. The samples were collected using electroshock fishing and tagged based on species.

DNA Tissue Extraction - QUIAGEN DNA extraction kit (DNeasy Tissue Kit 250) and Phire Animal Tissue Direct PCR Kit (Catalog # F-1405). The QUIAGEN protocol was followed to standard except for the addition of 100 ul of AE at step 7 of the QUIAGEN protocol. The Phire Animal Tissue extraction was followed directly to protocol.

PCR: Forward and reverse primers were designed using IKBBI for both R. osculus and R. balteatus. Forward Primers: 5’TACAGCGTACAGGGGGAAAAAG 3’ Reverse Primer: 5’TGTGCTGCGGACAGGCAAGTCT 3’

Results
Electropherogram Results of 5 Minnows

References

Acknowledgements

The redside shiner being very closely related to the Rainbow Trout is studied here. Inhabiting shallow waters during the day and deeper waters at night and in winter seasons, they make seasonal migration and routinely move in patterns, often in congregating bodies numbering thousands. Between early May and early August, males become pigmented in scarlet and gold, spawning in groups amounting between thirty and forty. The spooked dace is the first fish to disperse into the upper Columbia post-glacial. Spawning occurs over a period of time from June to August in fish over two years of age. Males acquire a red spawning color, while females produce a multitude of 4000 eggs within a season.

Preliminary comparisons with NCBI databases shows a SNP at base 437 on the portion of our PCR product. Further comparisons will reveal further divergence in the genomes of minnows in areas surrounding Spokane to those already uploaded on NCBI's website. "Hot" reactions will be re-sequenced with a longer capillary to be able to sequence the entire 1.6 kb instead of the 500 we obtained in our results so far. Also, more minnows must be extracted and sequenced to verify the validity of SNP's found.

Redside Shiner (Richardsonius balteatus)

Spooked Dace (Rhinichthys osculus)
An Intra and Inter Herd Genetic Study Using SNP Analysis of Mule Deer (Odocoileus Hemionus) in Washington State

Abstract

Today in Colorado the mule deer population is estimated to be below 60,000 individuals. This is drastically less than the estimated peak population in the 1960s. Preliminary Colorado's mule deer population has decreased to half the size it was in the 1960s. This same pattern continues throughout the mule deer's native range. In some cases, the population has decreased by 90% or more. In Washington State, there is also the potential for a decline in genetic diversity. Using single nucleotide polymorphisms (SNPs) our research team is looking at intra and inter herd diversity within a population around eastern Washington. Capturing DNA from blood samples using clingen Blood and Tissue kit, we are sequencing DNA from the C1 gene and the extraneous U loop DNA to look for single point mutations.

Methods and Materials

Sample Collection

Mule deer blood samples were collected from multiple havens within multicellular tissue. Each sample had specific frequency numbers placed on multiple deer in the known herd. Periodically throughout the year, the deer were caugly as they could be collected. The samples and information collected from each deer were stored by frequency number on their tagging device and by herd. The blood samples were stored at refrigeration at below 5°C. Each sample was represented by at least ten different deer was selected for further testing.

Extraction

Using the QIAamp DNA Blood Kit (Qiagen, Valencia, CA) and the Qiagen protocol, we performed the extraction process. The extracted DNA was stored at −20°C. The DNA was then used for PCR amplification and sequencing using 351 SNP collection software version 3.0.0.

Results

Cycle Sequencing

Cycle sequencing primers were prepared for both the U loop primer and the C1 primer. The U loop primer was made to have a gradient. TUT, GUT, and UUT were made to be combined with a total of 10×, 20×, and 30×, respectively. The C1 primer was made with the same gradient. Both the primers were run through cycle sequencing.

Cycle Sequencing Cleanup

The cycle sequencing products were purified using the QIAQuick PCR Purification Kit from Qiagen. The purification was performed to maximize yield, and the efficiency of the purification was determined by electrophoresis. The purified products were then sequenced using the ABI Prism 3100 Genetic Analyzer.

Capturing Sequencing

The samples were rehydrated using InvaSyn enzyme and loaded into an ABI Prism 3100 Genetic Analyzer. The data were analyzed using a Bioedit software version 1.0.

Acknowledgments

Currently in our research, we have made progress in some different areas. Using the U loop primers, we have found SNPs in the genome sequence. These SNPs are reported in this paper. A total of 10,000 SNPs were found in this research. We were able to use the process of cloning and sequencing and successfully take the data into sequencing. All the data appears to show that we can correlate DNA differences in the mule deer, and we have probed our methods and materials now we will continue to extract DNA and routinely sequence to increase our understanding. We will give enough results to draw a clear conclusion soon.

References


APPENDIX B

Self-efficacy Survey Items per Bandura’s Self-efficacy Constructs

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<td>Earn good grades in IST classes</td>
<td>Work at understanding confusing/challenging material until &quot;I got it!&quot;</td>
<td>Communicate well with my lab partners or classmates</td>
<td>Be motivated by working with other students or partners</td>
<td>Be motivated by my teacher’s verbal encouragement</td>
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APPENDIX C
Survey of CST Program Graduates

Alumni Survey

Q1 Hi Alumni who were in Mr. Martin's science classes (recently called CST classes),

Since he is retiring this spring, we are partnering with WSU to more fully understand the impact he had. I am looking forward to hearing from you!

*I'd appreciate 6-7 minutes of your time to complete this phone friendly survey.*

Thanks in advance, Sarah Pooler

Q2 Your contact information will only used by research staff to share CST related information with you. Your responses will be used in a general sense without linking them to you personally. For example, we may say "90% of CST graduates went on to higher education". This generalized anonymous group data will be part of a research study with WSU that allows us communicate about the success of the CST program. Fine print: Your participation in this study by completing the alumni questionnaire is voluntary. You may choose not to participate. All data is stored in a password protected electronic format. If you have any questions about the study please contact Sarah Pooler at sarah_pooler@wsu.edu. Electronic consent: Clicking on the "agree" button below indicates that: you have read the above information, you voluntarily agree to participate, and you are at least 18 years of age. If you do not wish to participate, please decline by clicking the "disagree" button.

- Agree (1)
- Disagree (2)

Q3 Your Name (First/Last)

Q4 Maiden or Former Name (leave blank if this doesn't apply to you)

Q5 Year You Gradated from Lake Hills High School

Q6 Phone number you use

Q7 Email you check
Q8 After graduating from Lake Hills High School (check all that fit you)

I started attending a Community College  (1)

I started attending a 4 year University  (2)

I attended a Community College and transferred to a 4 year University  (3)

I didn't go into higher education  (4)

I joined the Military  (5)

I am on my way towards a degree from a Community College  (6)

I am on my way towards a degree from a 4 year University  (7)

I am on my way towards a degree in a STEM field (science, technology, engineering and/or math)  (8)

I did some higher education but stopped before earning my degree.  (9)

I earned a degree from a Community College  (10)

I earned an undergraduate degree from a 4 year University  (11)

I earned a degree in a STEM field (science, technology, engineering and/or math)  (12)

I am on my way towards a graduate degree  (13)

I am on my way towards a graduate degree in a STEM field  (14)

Q9 What College or University are you attending or did you attend? (leave blank if this doesn't apply to you)

Q10 What is/was your major(s) and any minor(s)? (leave blank if this doesn't apply to you)

Q11 What degree did you earn or are you working towards? (leave blank if this doesn't apply to you)
Q12 If you graduated with a degree, what was your GPA? (leave blank if this doesn't apply to you)

Q13 What profession or area of work do you see yourself in or are you currently in?

Q14 What non-CST science classes did you take at LHHS? (like Chemistry, AP Physics etc.)

Q15 What math classes did you take at LHHS? (like Algebra II, Pre-Calc, Stats etc.)

Q16 What was your career goal when you were in the CST program?

Q17 What was your GPA when you graduated from LHHS?

Q18 You are 50% done already!

Q19 For the following items please reflect back to when you were a student in CST at LHHS. The questions relate to CST classes.

Q20 I felt like I could communicate well with my lab partners or classmates.

Q21 I felt I could do research that made a real-world impact.

Q22 I felt I could prepare the correct chemical solutions for labs.

Q23 I felt inspired by another student's success.

Q24 I felt confident using professional online databases (such as NCBI).

Q25 I felt I could figure out what my unexpected lab results meant.

Q26 I felt I could conduct an experiment accurately (such as following complex protocols).

Q27 I felt I was motivated by working with other students or partners.

Q28 I felt relaxed in class.

Q29 I felt I could work at understanding confusing/challenging material until "I got it".

Q30 I felt I was motivated by my teacher's encouragement.

Q31 I felt I was motivated by my teacher's encouragement.

Q32 I felt I could analyze experimental data to form conclusions.
Q33 I felt I was motivated by meeting professionals working in STEM careers.

Q34 I felt confident in my answers in my CST classes.

Q35 I felt I could help classmates with their experiments.

Q36 I felt pride in my work in CST classes.

Q37 I felt pride in my work in non-CST classes (history, english, math, etc.).

Q38 I could earn good grades in CST classes.

Q39 I could earn good grades in non-CST classes (history, english, math, etc.).

Q40 Would you like to be involved with current CST students? (talk about college and career options or help in the CST)

  ○ Yes, let's talk about when I might be available to visit (1)

  ○ No, it just won't work out (2)

Q41 Anything else you'd like to share? (achievements, life events, awards)

Q42 Anything you'd like to share with Mr. Martin? (thank you, impact he made in your life)
APPENDIX D

Alumni Questionnaire Pilot

Information for students:

“We are partnering with WSU on a research project about CST graduates. We’d appreciate your help testing the survey. The survey is written for CST graduates, so pretend you have already graduated when you take this. Answer as if you were a few years into the future.

Please let Mr. Martin or Mr. Shaw know right away if you come across anything that is confusing or you are not sure how to answer.”
Hello Lake Hills High School CST Graduate,

We are reaching out to connect about life after LHHS and to ensure that you receive an invitation to upcoming events (including Randy Martin’s retirement party in June!)

There is a link to a 5-minute survey about your experience at CST and after CST. Completing it will help us connect with you and know more about the influence of CST in your life.

We are looking forward to hearing from you and sending you information about CST and Mr. Martin’s retirement party!

Link Here

Best,

Steve Berg, Randy Martin, Dan Shaw and Sarah Pooler
APPENDIX F

Semi-Structured Interview Questions
(reflecting back to when you were a student in CST at LHHS)

- = Primary questions
• = Probing questions

- How did your CST experience impact your life after high school? (general opener)
  • If she/he mentions something related to SE such as social, psychological, mastery or vicarious or related to AP such as classes or rigor, I will repeat that portion of his/her answer and ask him/her to please expand on that or tell me more about that.

- What experiences have contributed to how confident you are that you would be successful in college (or if not college, in other post-high school pursuits)? (SE mastery)
  • If a comment is about the CST program, I will repeat that portion and ask him/her to please expand on that or tell me more about that.
  • If I receive a basic or limited answer, I’ll probe with:
    • Were there people at school or at home or elsewhere in your life that contributed to your confidence?
    • Were there certain experiences you had at school, home, community, travel that contributed to your confidence?

- How have other people influenced how you thought you would do in college? (SE social)
  • If a comment is about the CST program, I will repeat that portion and ask him/her to please expand on that or tell me more about that.
  • If I receive a basic or limited answer, I’ll probe with:
    - Were there people at school or at home or elsewhere in your life that contributed to your confidence?
    - Were there certain experiences you had at school, home, community, travel that contributed to your confidence?
o When thinking about college how did you feel? *(SE psychological)*
  - If a comment is about the CST program, I will repeat that portion and ask him/her to please expand on that or tell me more about that.
  - If I receive a basic or limited answer, I’ll probe with:
    - What emotions did you feel? Excited, nervous, apprehensive, doubtful, confident, scared? Why did you feel that way?
    - Have your feelings changed since then?

o Has your experience in CST courses influenced your academic success such as content knowledge, lab skills, taking on challenges, persistence, and confidence? *(AP & SE mastery)*
  - If I receive a basic or limited answer, I’ll probe with:
    - Could you name a time you used a skill you learned, or knowledge you gained or confidence you developed when you were in CST?
    - Is there a specific class or a specific experience, activity, field work, challenge you overcame that impacted you?

o How did the culture of successful failures at the CST prepare you to persist even through challenges? *(SE mastery & social)*
  - If I receive a basic or limited answer, I’ll probe with:
    - Do you remember what successful failure was in CST?
    - Could you remember a time you faced failure and reminded yourself of successful failures to not be discouraged?
    - Has the mindset of successful failures encouraged you?

o Is there anything else about how CST impacted your life after high school that you’d like me to know? Do you have any additional thoughts in general? Any questions for me? I’ll send you a transcript of our conversation that you can check for accuracy. Feel free to contact me anytime. We’ll be in touch. Thanks for your time!
Hello LHHS CST Grad,

Thanks for completing the survey. Based on your responses, we’d like to follow-up with you for a short phone interview. Would next Thursday at 5:30 work for you? If not, please suggest a different time.

I look forward to talking with you 😊

Thanks,
Sarah Pooler for Steve Berg, Randy Martin & Dan Shaw