A Quantitative Comparison of Female High School Students STEM Degree versus STEM Non-Degree Completion

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Abstract

Women remain underrepresented among degree completers in science, technology, engineering, and mathematics despite increased exposure to secondary-level enrichment programs. However, there remains a lack of empirical evidence examining whether participation in high school programs is associated with higher rates of science, technology, engineering, and mathematics degree completion. This study investigated the relationship between female participation in the FIRST Robotics project-based learning program during high school and subsequent completion of science, technology, engineering, and mathematics degrees. The study was guided by social cognitive career theory, which emphasizes the influence of learning experiences, self-efficacy, and outcome expectations on educational decision-making. A quantitative, correlational research design was adopted for this investigation. The participants included female students who participated in the FIRST Robotics program during high school and a comparison group of female students who did not participate. Archival data on postsecondary enrollment and degree completion were analyzed to address the research questions. Pearson's chi-square test revealed a statistically significant association between STEM degree completion and the two groups. The results indicated that female students who participated in the FIRST Robotics program were more likely to graduate with a degree in science, technology, engineering, or mathematics than non-participants. The findings have implications for high school project-based learning experiences, such as the FIRST Robotics program, in fostering readiness for college-level science, technology, engineering, and math, as well as degree-completion outcomes for female students. A future qualitative phenomenological study could examine the lived experiences of female students in higher education, exploring their personal stories of persistence, to identify best practices in curriculum design and guide the design of project-based learning structures.

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I want to thank my chair, Dr. Gary Walker-Roberts, for consistent support throughout this lengthy process. Dr. Gary's words, "Dee, continue to do something every day, you are almost there," sustained me as I struggled and stumbled along the pathway to the end. These simple words keep me from giving up when there is no end in sight. Additionally, I would like to thank my committee members, Dr. Scott Ebbrecht and Dr. Michael Shriner, for their support and guidance throughout this process.

This dissertation is dedicated to my husband, Curtis Wallace Sr.; my children, Curtis Jr., Christopher, and Cullen; and my mother, Bernice Henderson. My husband made sacrifices by adjusting his work schedule to accommodate my certification and subsequent pursuit of advanced degrees. My children have used my continuing education journey as a model to advance the next generation of learners in our family toward postsecondary degrees. I also want to thank my mother for the sacrifices she has made for me over the years and for her uplifting spirit, which has encouraged me to keep going despite the challenges I have faced.

I want to thank my sisters, Lucretia, Anita, Beverly, Terita, Rita, and Alicia, as well as my brother Albert Jr. They have teased and loved me over the years as I left the nest to gain more knowledge. I would especially like to thank my heavenly sister, Althea, and brother, Michael, along with my mother, Bernice, and father, Albert Sr., who have guided me on this path and continue to watch over me.

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Chapter 1: Introduction

The fields of science, technology, engineering, and math (STEM) are constantly evolving globally. The STEM workforce requires the United States to maintain a robust and diverse workforce (Nguyen, 2025). In the United States, 400,000 STEM bachelor's degrees are earned annually (Park et al., 2022). This increase in STEM degrees would be a welcome precursor to the United States keeping pace with the global STEM community. However, there is a significant gap between the number of female students who enter college as STEM majors and those who complete a STEM degree (National Science Foundation [NSF], 2020). Flack et al. (2021) described how the female STEM pathway may begin in career technology education (CTE) courses as early as middle school. Therefore, understanding the development of this pathway can help improve the equity of women who complete a STEM degree and enter the workforce.

Although the United States has made significant advances in STEM since landing on the Moon in 1969, there has been minimal improvement in diversifying the STEM workforce through the education system. In 1983, the National Commission on Excellence in Education released its report, *A Nation at Risk* (Finn, 2022). This report sent a shockwave across the United States, revealing that learners were being undereducated in science. Based on the findings, the United States science education system lacked a rigorous, high-quality curriculum that would increase the number of high school students majoring in STEM and graduating to fill new, sophisticated jobs (Finn, 2022). Additionally, the implications were that the United States had fallen behind Japan, South Korea, and Germany in technological advances in the automotive and steel industries. These differences were attributable to United States students' lack of preparation for college and careers beyond the high school level (Adamuti-Trache et al., 2020).

The Nation at Risk (Flinn, 2020) report emphasized the need for the United States to improve high school science education to maintain a strong STEM workforce. However, it was noted that the 1980s high school curriculum mirrored the industrial workforce rather than technological advances. Industry 1.0 introduced the steam-powered mechanical engine, Industry 2.0 introduced mass production and electricity, and Industry 3.0 introduced automation and computerization (Samiha et al., 2022). High school counselors offered learners two educational tracks: Career and Technical Education (CTE) and college preparatory. CATE classes, also known as vocational classes, consisted of individual trades such as plumbing, electrical, automotive mechanics, and heating, ventilation, and air conditioning (HVAC). The course design was developed for students with limited academic backgrounds who require hands-on, skills-based knowledge for immediate employment after high school. *The Nation at Risk* report emphasized the need for the United States to improve high school science education to maintain a strong STEM workforce.

The proposed prescription required each graduating high school student to complete either 4 years of math, 3 years of science, or a combination of 4 years of science and 3 years of math. Therefore, in the early 1990s, the National Science Foundation (NSF) formed the science, math, engineering, and technology (SMET) initiative in response to the 1983 *A Nation at Risk* Report (Lyons, 2020). In 2004, NSF rearranged the letters to form a new abbreviation. STEM represents an integrated curriculum of all four subjects (Lyons, 2020).

Manufacturing and job production are currently undergoing the fourth industrial revolution, which encompasses the digital transformation of jobs, including cloud computing, augmented reality, and cybersecurity (Samiha et al., 2022). The high school CTE curriculum, Education 4.0, has evolved in response to the increased use of digital technology in the classroom. In 2018, the 21st Century Act was passed by Congress to strengthen CTE, maintain a competitive global workforce, and support the high school curriculum (Dougherty et al., 2021)—indicating a focus on career pathways and the transformation of vocational trades through technology. An example of technology-enhanced reinforcement in a CTE course is the shift from drafting to computer-aided design (CAD) instruction (Yakimov, 2020). In the CAD course, students use software such as SolidWorks, Fusion 360, or OnShape to transition from two-dimensional drafting to working with surfaces and solids, enabling the creation of three-dimensional (3D) designs. These software packages are designed for use with 3D printers (De Souza Almeida et al., 2020).

The Department of Career and Technical Education (CTE) categorizes high school STEM courses. STEM CTE courses are integrated into a multi-year pathway that connects to college and careers, utilizing project-based learning and internships to enhance student engagement in STEM courses (Hemelta et al., 2018). Some STEM courses are dual-credit courses, in which students earn both high school and college credits (Cho-Baker et al., 2021). STEM coursework supports the development of essential skills for college and career readiness (Armstrong et al., 2021).

In 1989, Dean Kamen, the inventor of the Segway, founded FIRST (For Inspiration and Recognition of Science and Technology). The aim was to motivate high school students through STEM project-based learning (PBL) opportunities and to stimulate them to pursue future STEM college majors and careers (Dori & Yoel, 2022). Kamen's idea was to make STEM more relevant and attractive to the everyday lives of high school students by creating a robotics game for ninth through 12th graders (Dori & Yoel, 2022). FIRST programs develop the STEM skills of computational thinking, coding, technical skills, communication, and leadership (Fauber &

Becker-Blau, 2020). FIRST Robotics is an International Project-based learning program (Lim, 2021). FIRST has a family of programs, including FIRST LEGO League (FLL), FIRST Tech Challenge (FTC), and FIRST Robotics Competition (FRC). FIRST created a pathway of STEM project-based learning programs for learners from pre-K through 12th grade. FLL has three components: Discover (pre-K through 1st grade), Explore (2nd through 4th grade), and Challenge (5th through 8th grade). These early foundational programs support the more academically challenging middle- and high-school FIRST programs (Lim, 2021), as well as the FTC (for students in 7th grade through 12th grade) and the FRC (for students in 9th grade through 12th grade). FIRST is one of many project-based learning courses in the high school curriculum that prepares students to transition into a college STEM major (Armstrong et al., 2021).

Statement of the Problem

The problem addressed in this study was the disparity in the rate at which female college STEM students earn STEM degrees, which is lower than that among their male counterparts (Vooren et al., 2022). Female college STEM student dropout rates are 23% higher than the male STEM student dropout rate (Priulla et al., 2021). Dennehy and Dasgupta (2017) found that female college students entering STEM majors are significantly underprepared for these fields. The FIRST Robotics Project-based learning program academically prepares female high school students for STEM degrees. A continued trajectory of low completion rates among female college and university students in STEM coursework will harm the United States' STEM workforce by widening the diversity gap in the STEM workplace (De Gioannis et al., 2023; Jiang et al., 2020). This urgent matter requires attention to identify where leaks in the female STEM pipeline occur, preventing female students from completing STEM degrees (Vooren et al., 2022).

Since the late 1990s, the U.S. government has promoted greater equity in STEM education to increase the number of women pursuing STEM degrees. The STEM career pathway is also known as the STEM pipeline. Engineering is one of many STEM college majors that require students to have completed calculus and physics before entering an engineering course. However, females are less likely than males to enroll in advanced STEM courses in high school, such as calculus and physics (Dong, 2021). According to Dougherty et al. (2021), further research is needed to investigate how secondary STEM CTE vertical pathways courses contribute to the advancement and completion of college STEM degrees by females.

Purpose of the Study

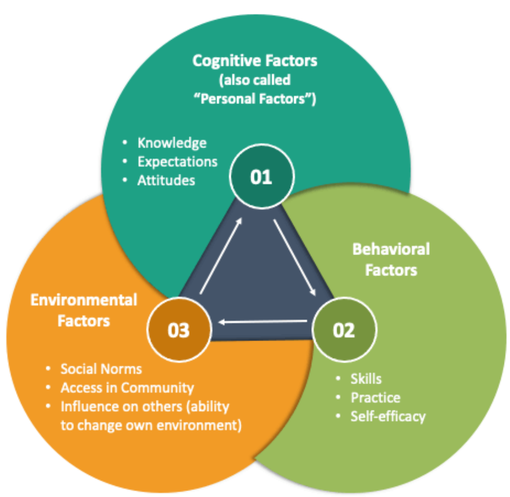
The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. Archival data, initially collected by Brandeis University, included 1,273 high school students across the United States and were used in this study. Brandeis University studied schools and organizations within the FIRST Robotics project-based learning program to determine how the program can increase the number of women completing STEM college degrees. Furthermore, understanding how project-based learning programs, such as FIRST, prepare female high school STEM students to transition into college STEM majors and complete their degrees would be a significant finding for this study. The independent variable in this study was female high school STEM students' participation in the FIRST Robotics project-based learning program. The dependent variable was the number of female students who completed a college STEM degree.

Introduction to Theoretical Framework

Albert Bandura's social cognitive theory (Bandura, 1977) served as the guiding framework for this study. Ion et al. (2022) noted that Bandura's framework addresses the understanding and change in human behavior, with a focus on cognitive concepts. Steward et al. (2020) stated that self-efficacy is central to Bandura's theory and that people's beliefs about their ability to perform a particular behavior or complete an academic course can influence the outcome of that behavior. Rachmatullah et al. (2022) stated that three principles underpin Bandura's theory: behavioral, environmental, and personal factors (cognitive, affective, and biological events). These principles provide academic knowledge or lead to behavioral changes through project-based program experiences. Researchers have emphasized that offering more rigorous high school STEM courses better prepares female STEM students to complete STEM degrees (Armstrong et al., 2020). According to this theory, a college student's readiness influences their likelihood of staying in college or dropping out over several years.

Figure 1

Bandura's Social Cognitive Framework



Introduction to Research Methodology and Design

This investigation adopted a quantitative method. A quantitative method is a research method rooted in the scientific process of discovering answers, involving the organization of data collection, analysis, and the interpretation of numerical data (Limberg et al., 2021). In a quantitative method, the researcher aims to quantify participant responses, analyze them using appropriate statistical tools, and subsequently interpret the numerical outcomes to inform decisions (Kiernan et al., 2022).

Quantitative methods generally fall into two main types: experimental and non-experimental. Experimental research determines cause-and-effect relationships, while non-experimental studies describe relationships between variables (Lodico et al., 2010). In a non-experimental investigation, the researcher collects data passively and does not control the subjects (Escudero-Mancebo et al., 2023). Escudero-Mancebo et al. (2023) emphasized how a non-experimental study examines the relationships between two variables.

A correlational study is one type of quantitative non-experimental research design. Researchers use a correlational design to examine associations among variables that cannot be manipulated or are not manipulated (Fitzgerald et al., 2004). Research Question

Research Q1

To what extent, if any, is there a relationship between female college STEM students who participated in the FIRST Robotics project-based learning program in high school and female college STEM students who completed a STEM degree?

Hypotheses

H10

There is no significant statistical difference in the likelihood of earning a college STEM degree among female college STEM students who participated in the FIRST Robotics project-based learning program in high school, compared to female college STEM students who did not participate in the FIRST project-based learning program in high school.

H1a

There is no significant statistical difference in the likelihood of earning a college STEM degree among female college STEM students who participated in the FIRST Robotics project-based learning program in high school, compared to female college STEM students who did not participate in the FIRST project-based learning program in high school.

Significance of the Study

The significance of this study lies in its contribution to understanding how to increase the number of female college students who complete their STEM degrees. In the study, female college STEM students who participated in the FIRST Robotics project-based learning program in high school and earned a college STEM degree were compared with those who did not participate in the program. Understanding the benefits of female participation in the FIRST Robotics project-based learning program was crucial to advancing women in STEM fields in higher education. The study's contribution could enhance college readiness by incorporating best practices in curriculum development and high school course selection. This study can provide STEM high school superintendents, principals, and career and technology education (CTE) directors with valuable insights for redesigning the current high school STEM project-based learning curriculum to increase the number of female college students pursuing STEM degrees.

The use of longitudinal archival data from Brandeis University could alter the culture of high school STEM course selection, STEM major expectations, and STEM college readiness for female high school students (Bryan et al., 2022). The study findings are beneficial for diversifying STEM careers by increasing the number of females entering the STEM workforce. The findings from the study can contribute to the literature on the expectation that female college students require additional STEM college-readiness skills and knowledge to select STEM majors, remain in STEM majors throughout their four years, and earn STEM degrees (Castellano et al., 2017).

Definitions of Key Terms

Career and Technology Education (CATE)

Career and Technical Education is a high school curriculum, initially funded by the Smith-Hughes Act of 1917, designed to prepare students for vocational trades (Giani, 2019; Halpern, 2012).

Career, Technology Education (CTE)

The Carl D. Perkins Act of 2006 subsidized the transition of vocational trades to Career and Technical Education pathways, which are grounded in technical education and workforce development (Flack et al., 2021; Giani, 2019).

College and Career Readiness (CCR)

The skills and knowledge needed to succeed in a college entry-level credit course or career pathway-oriented training course, without receiving remediation or developmental courses (Conley, 2012).

FIRST Robotics

For Inspiration and Recognition in Science and Technology is a STEM college- and career-preparatory program for kindergarten through 12th grade (Lim, 2021).

Project-Based Learning (PBL)

Project-based Learning is a STEM teaching method that helps students solve real-world problems in a classroom setting (Dori & Yoel, 2022).

Science, Math, Engineering, Technology (SMET)

The original acronym for the combination of the content areas of science, math, engineering, and technology (Lyons, 2020).

Science, Technology, Math, Engineering (STEM)

The National Science Foundation redefined the acronym to encompass the content areas of science, technology, engineering, and mathematics (Chang et al., 2023).

Science, Technology, Math, Engineering Career (STEM Career)

STEM careers encompass fields in science, technology, engineering, and mathematics (Almukhambetova et al., 2023).

Science, Technology, Math, Engineering Major (STEM Major)

STEM majors are college majors that encompass science, technology, engineering, and mathematics (Almukhambetova et al., 2023).

Science, Technology, Math, Engineering Pathways (STEM Pathways)

STEM pathways are a series of avenues for learners to explore in science, technology, engineering, and mathematics courses that lead to a STEM major or career (Hemelta et al., 2018).

Science, Technology, Math, Engineering Pipeline (STEM Pipeline)

The STEM pathway is a continuous sequence of science, technology, engineering, and mathematics courses that build on one another and lead to a STEM major or career (Hemelta et al., 2018).

Summary

Increasing the representation of women in the STEM workforce is vital for the United States to remain competitive in the global STEM community. The details of Chapter 1 include the introduction, problem, and purpose of the research study by focusing on associations in earning a college STEM degree for female college STEM students who participated in the FIRST Robotics project-based learning program in high school versus female college STEM students who did not participate in the FIRST Robotics project-based learning program in high school. The research questions in Chapter 1, the study's significance, and the definitions of the terms can help clarify the issues faced by female college students in STEM fields. The literature review on female college students in STEM majors, along with an explanation of Bandura's social cognitive theory, is presented in Chapter 2.

Chapter 2: Literature Review

The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. Secondary data, initially collected by Brandeis University, included 1,273 high school students across the United States and were used in this study. Brandeis University studied schools and organizations within the FIRST Robotics project-based learning program to determine how the program can increase the number of women completing STEM college degrees. Furthermore, understanding how project-based learning programs, such as FIRST, prepare female high school STEM students to transition into college STEM majors and complete their degrees would be a significant finding for this study. The independent variable in this study was female high school STEM students' participation in the FIRST Robotics project-based learning program. The dependent variable was the number of female students who completed a college STEM degree. A Pearson’s Chi-Square test was used for data analysis in this study, with IBM Statistical Package for the Social Sciences (SPSS) version 23.

The problem addressed in this study was the disparity in the rate at which female college STEM students earn STEM degrees, which is lower than that among their male counterparts (Vooren et al., 2022). Female college STEM student dropout rates are 23% higher than the male STEM student dropout rate (Priulla et al., 2021). Dennehy and Dasgupta (2017) found that female college students entering STEM majors are significantly underprepared for these fields. The FIRST Robotics Project-based learning program academically prepares female high school students for STEM degrees. A continued trajectory of low completion rates among female college and university students in STEM coursework will harm the United States' STEM workforce by widening the diversity gap in the STEM workplace (De Gioannis et al., 2023; Jiang et al., 2020). This urgent matter requires attention to identify where leaks in the female STEM pipeline occur, preventing female students from completing STEM degrees (Vooren et al., 2022).

Since the late 1990s, the U.S. government has promoted greater equity in STEM education to increase the number of women pursuing STEM degrees. The STEM career pathway is also known as the STEM pipeline. Engineering is one of many STEM college majors that require students to have completed calculus and physics before entering an engineering course. However, females are less likely than males to enroll in advanced STEM courses in high school, such as calculus and physics (Dong, 2021). According to Dougherty et al. (2021), further research is needed to investigate how secondary STEM career and technical education (CTE) vertical pathways courses contribute to the advancement and completion of college STEM degrees among females.

The literature review in Chapter 2 begins with a description of Bandura’s social cognitive theory, which serves as the study's framework, and is followed by sections that explain several societal prejudices, educational settings, and preconceptions affecting female students pursuing STEM degrees. The Chapter concludes with a thorough examination of the impact of social pressure on female students' course choices, offering valuable insights into practical strategies to increase the number of females in STEM learning environments.

A literature review search was conducted using the National University (NU) online library and databases. Several factors contribute to the underrepresentation of women in STEM disciplines, including cultural stereotypes, a lack of role models, and academic environments that hinder female participation (Turner et al., 2022). The research literature for this study was completed online using databases such as EBSCOhost, ERIC, ProQuest, Google Scholar, PubMed, JSTOR, and SAGE journals. Only a limited number of articles retrieved via Google Scholar were verified as scholarly and peer-reviewed through the NU Library.

The library's Roadrunner search engine defines search boundaries, including full-text options for instructional articles, research studies, dissertations, and peer-reviewed academic literature. To maintain academic rigor and relevance, the ideal search strategy was to consult recent literature, focusing on peer-reviewed articles published within the last five years (2020 and 2025) to ensure alignment with contemporary educational contexts. This time frame captures recent empirical advancements, updated theoretical applications of SCT, and current policy-informed educational practices.

However, given the limited literature on project-based learning and female STEM graduation completion, the search parameters were extended beyond the five-year window. Additionally, Bandura's social cognitive theory and foundational studies published in the 1960s were included in the search. While foundational SCT works by Bandura predate this range, these seminal studies were included selectively through citation chaining to provide necessary theoretical grounding. Limiting the primary search to recent literature ensured that findings reflected current educational environments, technological integration, and post-pandemic shifts in STEM instruction.

The parameters input into the Roadrunner search engine included exploring gender inequality in STEM education and social cognitive theory. Boolean search strategies were tailored to each database while maintaining consistent core constructs. Search strings included combinations of keywords such as *gender inequality, STEM training, female representation,* *cultural biases, project-based learning, K–12 or postsecondary, academic environments, and women in STEM*. These terms were used to compile an extensive database of literature. Advanced filters were applied to include (and/or) the search terms. The searches were limited to peer-reviewed publications, English-language studies, and empirical or theoretical research within the defined date range.

Additionally, terms such as Albert Bandura and the social cognitive theory framework in academic settings, as well as the experiences of women in STEM, were included to examine the underlying factors contributing to female college students' failure to complete STEM degrees. The search targeted recent literature, focusing on the last decade to ensure relevance and alignment with modern educational contexts. The literature review drew on research studies and peer-reviewed articles to provide a robust, evidence-based examination of issues in female STEM education and college.

The following studies were excluded from the search: studies not grounded in SCT. Research focused exclusively on non-STEM disciplines. Studies centered on workforce outcomes without an educational context. Non-peer-reviewed reports, editorials, or opinion pieces and publications not available in English. Literature saturation was assessed through iterative searching, citation chaining, and repeated database queries. Saturation was considered achieved when additional searches yielded recurring authors, theories, and empirical findings without introducing substantively new concepts or applications of SCT.

Forward and backward citation tracking of key studies consistently led to previously identified sources, indicating conceptual redundancy. Additionally, repeated Boolean searches across databases resulted in diminishing returns, with new articles reinforcing established themes rather than expanding theoretical understanding. The convergence of findings across databases, coupled with consistent replication of SCT constructs such as self-efficacy, project-based learning, and STEM identity research, confirmed that the literature base was sufficiently saturated to support the study's theoretical framework.

Summary

My systematic literature search employed multiple complementary databases, rigorously defined Boolean search strings, and clearly justified methodological decisions to ensure comprehensive and up-to-date coverage of research on social cognitive theory and female STEM identity development. The use of explicit inclusion and exclusion criteria, alongside iterative saturation checks, strengthens the credibility and transparency of the review process.

Theoretical Framework

The evaluation of gender gaps in STEM education was supported by fundamental concepts that underpin this study. The study's assumptions are grounded in social cognitive theory, which explains how social and cultural contexts shape individuals' ideals, self-perceptions, and behaviors. Luo et al. (2022) converged by demonstrating how self-efficacy, a crucial concept in this paradigm, refers to an individual's confidence in their ability to solve a problem. Self-efficacy is crucial in STEM education because it influences scholars' confidence in their ability to succeed in technological fields and mathematics, which are essential to understanding science and engineering.

Albert Bandura's groundbreaking social cognitive theory, which emerged in the 1960s, serves as the theoretical framework for this study. According to Bandura's theory, cognitive features, behavioral patterns, and environmental factors influence human behavior (Ardianti et al., 2020). The concept of self-efficacy, which refers to a person's confidence in their ability to accomplish a specific task, significantly influences their motivation and behavior, and is crucial to this principle. This fundamental concept provided the framework for understanding how college students' STEM self-efficacy, influenced by external variables, was crucial to their pursuit of STEM majors.

The social cognitive theory paradigm has been employed in numerous studies to evaluate self-efficacy and motivational ideals in STEM training. Researchers Cwik and Singh (2022) conducted a longitudinal investigation of the motivational beliefs of male and female college students in the bioscience track enrolled in an introductory physics course. Their findings indicated widespread gender differences in self-efficacy, with female students exhibiting lower levels than male students. This result confirms how Bandura's theory remains applicable for analyzing gender variations in STEM subjects. Researchers Kalender et al. (2020) agreed on the impact of self-efficacy on physics students. They similarly converged on the effects of low self-efficacy and academic success. The study examined the critical role of self-efficacy beliefs in shaping and acquiring knowledge of outcomes in STEM disciplines, as proposed by social cognitive theory.

Scholars consistently highlighted the importance of the social cognitive theory framework and its associated concepts for yielding valuable insights into abilities and boundaries in STEM education. Their study demonstrates the enduring relevance of Bandura's theory in examining students' self-efficacy and motivational beliefs in STEM fields. Additionally, the alternative theoretical framework of social cognitive career theory was employed to inform this study on how female high school STEM students complete the FIRST Robotics Project-Based Learning Program and pursue STEM college degrees.

Origins of Social Cognitive Theory

Bandura’s Social Cognitive Theory (SCT) provides a valuable lens for understanding human learning as a fundamentally social and cognitive process rather than a simple result of behavioral conditioning (Bandura, 1977). During the mid-20th century, behaviorism was dominated by B.F. Skinner's work emphasized reinforcement, punishment, and environmental stimuli as determinants of learning (Bandura & Walters, 1977). Bandura’s Social Cognitive Theory (SCT) framework emerged as a substantive theoretical departure from the dominant behaviorist models of the mid-twentieth century, which conceptualized learning as a function of environmental stimuli and reinforcement (Koutroubas & Galanakis, 2022).

Bandura's findings rejected Skinner's notion of behavioral and reconceptualized learning as an inherently social and cognitive process in which individuals actively interpret, internalize, and reproduce observed behaviors (Bandura, 1963). Wei & Kinshuk's (2012) research supports Bandura’s framework, which challenges the foundational assumptions of behaviorism. According to their findings, observational learning demonstrates that individuals (children) could acquire novel behaviors through observation, imitation, and symbolic processing in the absence of direct reinforcement (Bandura et al., 1961). Bandura’s reconceptualization of the framework marked a paradigm shift in psychology and education. Lent et al. (1994) confirmed that Bandura's research laid the foundation for Social Learning Theory (SLT), which posits that cognitive processes, such as attention, memory, and decision-making, facilitate learning.

Collectively, Bandura’s body of research reframed learning as an active cognitive process rather than a product of rigid behavioral conditioning (Burney, 2008). Bandura challenged the assumptions of stimulus-response models and instead highlighted students' active role in their learning process (Bandura et al., 1961). Bandura’s findings support the view of learners as active participants who interpret, regulate, and shape their own learning within dynamic social environments (Wei & Kinshuk, 2012). Through this shift, Bandura established Social Learning Theory as a foundational framework for understanding the reciprocal relationships among cognition, motivation, behavior, and context across diverse educational settings (Martin et al., 2011).

Evolution and Expansion into Social Cognitive Theory

Bandura refined his early findings and increasingly emphasized the reciprocal interaction among personal, environmental, and behavioral factors. The concept became central to the rebranding as the Social Cognitive Theory (Bandura, 1986). Bandura, Ross, & Ross (1961) identified SCT as a groundbreaking social cognitive theory that emerged in the 1960s and serves as the theoretical framework for this study. SCT represented a significant theoretical expansion, embedding learning within the broader framework of human agency and self-regulation. Ardianti et al. (2020) confirmed that Bandura’s most influential contribution was the addition of self-efficacy to SCT. Schunk & DiBenedetto (2020) found that incorporating self-efficacy into SCT is a cornerstone of educational research, particularly in STEM and identity-focused studies, as it explains how students' perceived competence shapes their engagement, persistence, and success. Over time, SCT has been widely applied across disciplines, including health behavior, organizational psychology, teacher learning, and STEM education, due to its flexible yet rigorous framework for explaining how individuals navigate sociocultural contexts while exercising agency.

The social cognitive theory paradigm has been employed in numerous studies to evaluate self-efficacy and motivational ideals in STEM training. Researchers Cwik and Singh (2022) conducted a longitudinal study of the motivational beliefs of male and female college students in the bioscience track enrolled in an introductory physics course. Their findings supported the finding of widespread gender differences in self-efficacy, with female students exhibiting lower levels than male students. This result confirms how Bandura's theory remains applicable for analyzing gender variations in STEM subjects. Researchers Kalender et al. (2020) agreed on the impact of self-efficacy on physics students. Their findings similarly converged on the effects of low self-efficacy and academic success. These studies examined the critical role of self-efficacy beliefs in shaping and acquiring knowledge of outcomes in STEM disciplines, as proposed by social cognitive theory.

Scholars have consistently highlighted the importance of the social cognitive theory framework and its associated concepts for yielding valuable insights into abilities and boundaries in STEM education (Schunk & DiBenedetto, 2020). The expansion of SCT supports a deeper examination of equity and participation in STEM education (Britner & Pajares, 2006). SCT offers a framework for understanding how factors such as representation, instructional feedback (Kalender et al., 2020), and classroom norms shape students' beliefs about their competence and belonging in STEM fields. Studies applying SCT in STEM contexts have highlighted that exposure to relatable role models, supportive instructional practices, and authentic learning experiences can enhance self-efficacy and mitigate stereotype threat, particularly among students from historically underrepresented groups (Schunk & DiBenedetto, 2020).

Critiques and Limitations of Social Cognitive Theory

Despite its broad influence, SCT has faced several critiques and limitations. Scholars disagree that while the theory's breadth allows for broad applicability, it can also reduce conceptual precision, making SCT difficult to operationalize consistently across studies (Pajares, 1996). Brookfield (2017) found that the theory places substantial emphasis on individual cognition and agency at the expense of deeper structural, cultural, and contextual factors that shape human behavior, particularly within marginalized populations. Others note that constructs such as reciprocal determinism can be challenging to test empirically because the relationships among personal, environmental, and behavioral factors are complex and dynamic (Miller, 2011).

Additionally, although self-efficacy is one of SCT's most influential contributions, researchers caution against overextending the construct or treating it as a universal predictor of behavior without considering situational constraints (Usher & Pajares, 2008). Carlone & Johnson (2007), in their STEM education and identity research, highlight that SCT does not fully address systemic inequities, such as stereotype threat, institutional bias, and resource disparities, that constrain learning opportunities regardless of individual agency. While SCT remains one of the most widely adopted frameworks in education and psychology, these critiques underscore the importance of applying the theory alongside models that account for sociocultural, structural, and identity-based influences.

Alternative Frameworks

Expectancy-value theory (EVT) is one of several alternative frameworks investigated in this study. EVT is most prominent for emphasizing how individuals' beliefs about the likelihood of success (expectancies) and the value they assign to a task are primary drivers of engagement and achievement (Bong, 2001). Cole et al. (2008) confirmed that this framework is widely applied in educational research to explain academic choices, persistence, and performance, particularly in contexts where motivation is shaped by perceived utility, interest, and cost. EVT offers a parsimonious and empirically supported model for understanding why learners choose to engage in specific tasks (Schweigert & Harackiewicz, 2008).

While expectancy-value theory offers a robust framework for understanding motivational beliefs and task engagement, it provides a narrower account of how social environments, instructional practices, and behavioral feedback mechanisms shape students' ongoing academic trajectories (Zimmerman, 2000). As a result, EVT is valuable for examining task choice and motivational outcomes (Wigfield & Eccles, 2000). However, SCT is often better suited for studies that seek to capture the dynamic, socially embedded processes through which learning and behavior develop (Bandura, 1986, 1997). Social Cognitive Theory (SCT) offers a more comprehensive framework for understanding college STEM graduation by incorporating reciprocal interactions among self-efficacy beliefs, academic behaviors, and institutional contexts (Bandura, 1986, 1997). Thus, while EVT explains motivational choice, SCT more fully captures the dynamic, socially embedded processes that influence sustained engagement and successful graduation in college STEM programs.

The social cognitive career theory (SCCT) was the second alternative framework considered for this study. Lent et al. (1994) developed research grounded in Bandura's social cognitive theory by applying its principles to career development. Duong et al.'s (2024) study converges with the extension of Bandura's original framework by emphasizing how learning experiences, environmental influences, and personal beliefs shape an individual's career interests and choices. This expansion positioned SCCT as a model that accounts not only for personal cognition but also for the contextual factors that influence how individuals form career-related goals (Doğan et al., 2025). Researchers Litzler et al. (2014) found that past positive performance strengthens self-efficacy and outcome expectations. Lent & Brown's (2019) suggestions provide two core elements that guide individuals' future learning and career decisions.

SCCT has been widely used to understand career readiness, especially in STEM fields that require sustained confidence and exposure to complex learning environments (Lent & Brown, 2008). Rafidahet et al. (2019) found SCCT effectively captures how individuals develop career preparedness by linking their interests, abilities, and experiences to long-term pathways. Findings from several researchers underscore the theory's assertion that educational support and barriers significantly shape self-efficacy and, in turn, the likelihood of selecting and persisting in STEM career pathways (Ro, 2024; Mutseekwa, 2024). Nonetheless, Kiernan et al. (2022) argue that SCCT examines how environmental factors, such as academic climate, mentorship, and social support, may influence women's decisions to pursue STEM majors.

Collectively, research on SCCT aligns with broader social cognitive principles and provides valuable insights into female students' experiences in college STEM fields (Rutherford et al., 2024). Because the SCCT framework concepts are specific to career decision-making and outcome trajectories, it did not fully align with this study's primary goals. The SCT framework was ultimately selected to examine the development of self-efficacy among younger female students participating in project-based robotics programs, in which factors influencing STEM confidence may differ from those at the collegiate level (Bandura, 1986, 1997). While SCCT highlights critical career-related processes, its emphasis on long-term career intentions and decision-making was insufficient to examine the early formation of STEM self-beliefs among pre-college female learners. Within this framework, SCCT was considered but ultimately rejected as the study's foundational framework(Schunk & DiBenedetto, 2020).

Social cognitive theory (SCT) is the most suitable framework for this study, as it directly addresses the central construct under investigation: self-efficacy. Individuals develop beliefs about their ability to succeed through interactions among personal cognition, behavior, and environmental influences (Bandura, 1993). These elements confirm my findings that the experiences of female students participating in the FIRST Robotics project-based learning program shape their confidence in STEM abilities and influence their decision to complete a

STEM degree. SCT provides the most transparent theoretical framework for understanding the relationship between project-based learning and its impact on academic choices, making SCT a natural fit for interpreting the program's impact on female students.

Additionally, SCT provides a robust lens for examining female STEM graduates. In educational settings, female students exhibit lower STEM self-efficacy than their male peers, despite comparable competence, and these disparities significantly contribute to their underrepresentation in STEM pathways (Luo et al., 2022). SCT enables researchers to examine not only individual beliefs but also how societal stereotypes, classroom climates, and learning environments shape those beliefs over time.

In summary, Social Cognitive Theory represents a transformative shift from behaviorist perspectives toward a more nuanced understanding of learning as an interplay between cognition, behavior, and social context (Walter & Wade, 2024). By demonstrating that individuals can acquire knowledge and skills through observation and symbolic processing without direct reinforcement, Bandura challenged the assumptions of stimulus–response models and highlighted learners' active role as agents in their environments (Bandura, 1986). Building on this framework, the concept of self-efficacy extends SCT by specifically examining individuals' beliefs in their capabilities to organize and execute actions necessary to achieve desired outcomes, highlighting the critical role of perceived competence in motivating behavior and learning (Simpson et al., 2025).

STEM Identity Formation Among Females

STEM identity formation among females is a multifaceted and dynamic process influenced by the interplay of personal beliefs, social interactions, cultural expectations, and educational experiences (Cavazos & Cavazos, 2025). At the core of Simpson, L. et al. 's (2025) research, STEM identity involves internalizing oneself as a capable and legitimate participant in science, technology, engineering, and mathematics (National High Magnetic Field Laboratory researchers, 2023). Researchers indicate that identity, beyond cognitive ability, significantly shapes interest, motivation, and persistence in STEM pathways (Bandura, 1997; Sonnert et al., 2025). These studies converge on the idea that female learners who develop a strong STEM identity often begin early and are reinforced by meaningful experiences that foster a sense of competence, belonging, and alignment with STEM goals. Conversely, negative experiences, including gender bias, underrepresentation, and societal stereotypes, can undermine identity formation and discourage participation in STEM (Yeldell et al., 2024).

A central factor in the formation of female STEM identity is self-efficacy, defined as an individual's belief in their ability to succeed in specific tasks (Bandura, 1997). Self-efficacy develops through mastery experiences, vicarious learning, social persuasion, and emotional regulation. Participation in hands-on, project-based learning activities such as robotics, coding challenges, or science competitions provides mastery experiences that reinforce competence and capability (Litzler et al., 2014). Zarrett & Malanchuk's (2021) findings are particularly influential because they enable women to observe tangible outcomes of their efforts, fostering the belief that they can overcome the challenges inherent in STEM learning. However, research shows that females frequently face disparities in access to such opportunities. Gendered expectations, unequal encouragement, and subtle social cues can diminish the perceived relevance of STEM and weaken self-efficacy, thereby creating barriers to the formation of a positive STEM identity (Wang et al., 2023).

Social and cultural contexts profoundly influence identity development by shaping perceptions of who belongs in STEM fields. Societal narratives often portray STEM as male-dominated, competitive, or intellectually exclusive, creating additional obstacles for females navigating these spaces (McKinney et al., 2021). In addition to these factors, positive social influences, including supportive teachers, peers, and mentors, help counteract these messages by providing affirmation, guidance, and examples of successful women in STEM. Belongingness, the sense of being valued, accepted, and represented within a learning community, is critical for identity formation. When females see themselves reflected in role models, mentors, or collaborative peer groups, they are more likely to internalize STEM as part of their self-concept and persist in STEM pathways (Jiang et al., 2024). Conversely, an educational environment that perpetuates stereotypes, isolates female learners, or fails to recognize their contributions can lead to identity conflict, in which female learners struggle to reconcile their interests with societal expectations (Wang et al., 2021).

The literature points towards a complementary role in shaping STEM identity among females. Exposure to successful women in STEM fields provides tangible proof that gender does not limit potential and fosters aspirational pathways (McKinney et al., 2021). Hazari et al. (2020) research on mentorship programs, guest speakers, and classroom curricula that highlight female STEM professionals normalizes women's presence in these fields. These research findings help women envision themselves as future STEM innovators (Steinke, 2017). The absence of such representation, by contrast, reinforces stereotypes and reduces women's ability to envision a long-term STEM trajectory.

Beyond individual mentorship, institutional structures, including curricula, program design, and extracurricular opportunities, further influence identity formation. Inclusive, inquiry-based curricula that emphasize problem-solving, collaboration, and real-world applications allow females to develop authentic STEM competencies (Zang et al., 2025). Zhao et al. (2024)

examined how these concepts reinforce confidence and engagement. Programs that intentionally address gender disparities through mentorship, equitable access, and supportive learning environments have demonstrated significant success in cultivating positive STEM identities (Mix et al.,2021).

In summary, the literature increasingly points towards female STEM identity formation being shaped by the integration of personal efficacy, social affirmation, and environmental support (McKinney et al., 2021). When females experience mastery, recognition, representation, and belonging simultaneously, they are more likely to internalize STEM into their self-concept, remain engaged, and envision future STEM careers (Bandura, 1997). Lent et al. (2001) argue that this process is critical not only for individual educational outcomes but also for addressing broader gender disparities in STEM fields. Overall, the evidence points to a clear path: to foster diverse perspectives in STEM, understanding and supporting identity formation among females is essential to cultivating a more innovative and equitable STEM environment.

Early Exposure and Pre-College STEM Pathway

Early exposure to STEM learning experiences plays a critical role in shaping students' interest, motivation, and eventual participation in STEM pathways prior to college. Research consistently demonstrates that engagement in STEM activities during elementary and middle school years significantly influences students' confidence in their abilities, the development of STEM-related identities, and their long-term educational trajectories (Dörterler, 2024). These experiences provide opportunities for children to explore fundamental concepts, develop problem-solving skills, and cultivate curiosity, all of which help lay a foundation for future STEM learning. In addition, researchers found that early exposure helps students develop self-efficacy, the belief in one's ability to successfully perform STEM tasks (Herbert-Berger, 2024;

Erol et at, 2025). These findings are strong predictors of persistence and success in subsequent academic endeavors (Zhao et al., 2024). When viewed together, these perspectives suggest that early engagement, particularly among students from underrepresented groups such as women and minority populations, may be hindered by barriers to recognizing their potential in STEM fields or to envisioning themselves as capable participants (Carlone & Johnson, 2007).

The quality and type of early STEM experiences are crucial in shaping pre-college STEM pathways. Hands-on, inquiry-based activities that emphasize experimentation, critical thinking, and problem-solving allow students to actively engage with STEM concepts rather than passively absorb information (Dörterler, 2024). Programs such as robotics clubs, science fairs, coding workshops, and mathematics competitions have been shown to foster not only skill acquisition but also intrinsic motivation, engagement, and enjoyment (Erol et al., 2023). For females and other underrepresented groups, these experiences serve an additional function by providing visible evidence that they can succeed in domains where stereotypes often suggest they do not belong (Capsi et al., 2019). Vongkulluksn et al.'s (2018) findings of makerspace research suggest that participation in collaborative STEM activities also cultivates social and communicative skills, reinforcing a sense of belonging and community within STEM spaces. Early exposure thus functions both as a mechanism for developing competence and as a context in which students begin to internalize a STEM identity (Denner et al., 2014).

Family and community environments significantly influence early STEM engagement. Parental attitudes, encouragement, and support strongly impact children's interest and persistence in STEM activities (Herbert-Berger, 2024). Baker et al.'s (2020) research converges with the finding that children whose parents emphasize curiosity, experimentation, and problem-solving are more likely to engage in STEM activities both inside and outside of school.

Similarly, access to informal out-of-school STEM learning environments, such as museums, science centers, after-school programs, and community-based workshops, enhances exposure and provides opportunities for experiential learning that formal classroom settings may not offer (Jenny & Ingber, 2025). The theme of early STEM exposure is further connected to exploratory, student-directed engagement, which reinforces autonomy and fosters self-directed learning. Both of which are critical components of STEM identity development and sustained interest (Caspi, 2019). Without such exposure, students may perceive STEM as abstract or inaccessible, limiting the likelihood that they will pursue rigorous STEM coursework in high school or consider STEM careers.

School structures, curricula, and instructional practices also shape pre-college STEM pathways. Schools that provide early access to rigorous STEM courses, differentiated instruction, and hands-on project-based learning foster students' confidence and skill development, laying the groundwork for advanced study. Early participation in STEM coursework, particularly in mathematics and science, is predictive of later enrollment in high school and college STEM programs (Capsi et al., 2019). Researchers agree that schools that integrate cross-disciplinary STEM experiences, such as combining mathematics, engineering, and technology in applied projects, encourage students to see the relevance of STEM in real-world contexts, promoting engagement and goal-directed learning.

Equity and access are central considerations in early STEM exposure and pathway development. Research consistently shows that underrepresented students often have fewer opportunities to participate in advanced STEM courses or extracurricular programs, which can create gaps in skills, confidence, and preparation for future STEM study (Rafidahet et al., 2019; Kiernan et al., 2022). Researchers at the National Academies of Sciences, Engineering, and

Medicine (2021) agree that addressing these disparities requires intentional interventions, such as targeted outreach programs, inclusive curriculum design, mentorship opportunities, and scholarships for STEM enrichment activities.

Longitudinal researchers Robnett et al. (2020) suggest that early STEM experiences have cascading effects on students' educational trajectories. Students who engage meaningfully with STEM prior to high school are more likely to enroll in advanced coursework, participate in STEM clubs, and consider STEM careers (Hazari et al., 2020). Litzler et al.'s (2014) research found benefits that extend beyond cognitive skills to include affective and identity-based outcomes, such as confidence, persistence, and a sense of belonging within STEM communities. Researchers Maltese & Tai (2011) believe these outcomes are critical to success in higher-level STEM learning and professional contexts. By fostering both competence and identity at an early stage, pre-college STEM pathways lay a foundation for sustained engagement and career readiness.

In summary, the body of work by de Moor et al. (2021) provides a foundation for examining how early exposure to STEM is a critical determinant of pre-college STEM pathways, influencing students' skills, self-efficacy, motivation, and identity development. Vongkulluksn et al.'s (2021) findings agree that hands-on, inquiry-based learning experiences, supported by families, communities, and schools, provide opportunities for meaningful engagement that can shape long-term trajectories. Equitable access to these experiences is vital for females and underrepresented students, as it mitigates the impact of societal stereotypes and structural barriers. By prioritizing early exposure and supportive pre-college pathways, educators and policymakers can cultivate a diverse, skilled, and motivated future STEM workforce. These pathways not only prepare students academically but also foster the self-concept and identity necessary to sustain long-term engagement in STEM fields (Maltese & Tai, 2010).

Societal Stereotypes and Bias Impacting Women In STEM

Merayo and Ayuso (2022) examined how persistent prejudice and cultural norms continue to affect women pursuing STEM majors. Beroíza-Valenzuela's (2025) study emphasized that longstanding societal beliefs often associate STEM disciplines with masculine characteristics, reinforcing the perception that women are inherently less competent or professional in these fields. Such stereotypes not only influence external expectations but can also be internalized by women, shaping their self-perception and confidence. This internalization of bias can create a self-fulfilling cycle in which diminished self-efficacy and self-belief hinder women's engagement, performance, and persistence in STEM pathways. Dunlap and Barth's (2023) findings underscore the importance of addressing implicit bias and challenging gendered assumptions to foster equity and inclusivity within STEM education and professions.

O'Connell and McKinnon (2021) similarly found that young women often exhibit lower motivation to pursue STEM degrees. Researchers further underscored the persistence of women's underrepresentation in STEM fields (Stout et al., 2011). Wilkins & Ma's (2003) research underscored the importance of addressing systemic bias and confronting deeply embedded societal preconceptions that shape students' educational choices and career trajectories. By challenging these structural and cultural barriers, education curriculum developers can help create more equitable opportunities that encourage sustained female participation and advancement in STEM disciplines (Stout et al., 2011; O'Connell & McKinnon, 2021).

García-Holgado and García-Peñalvo's (2022) research on preconceptions and biases toward women in STEM influences not only male and female perceptions but also shapes the broader academic and professional environments in which these perceptions persist. The societal belief that STEM is inherently male-oriented can be unintentionally reinforced through biased curricular materials, instructional practices, and institutional norms (Steffens & Jelenec, 2011). Cheryan's (2017) and Dunlap & Barth's (2023) findings distressingly show that STEM courses often create an unwelcoming environment for female students, contributing to feelings of isolation, inadequacy, and diminished belonging within STEM disciplines. Moreover, limited visibility of successful female role models in STEM perpetuates the perception that women’s presence in these fields is atypical rather than the norm (Jiang et al., 2020). This continued underrepresentation of women in STEM courses not only reinforces gender stereotypes but also poses challenges for recruiting, supporting, and retaining women as STEM majors (Dunlap & Barth, 2023).

Chen et al.'s (2023) results reinforced biases and stereotypes in STEM, findings supported by societal and media messaging. The findings of the National Academies of Sciences, Engineering, and Medicine (2021) converge on the notion that women do not inherently feel a sense of belonging in these disciplines, a notion supported by the frequent depiction of scientists, engineers, and mathematicians as predominantly male in popular culture. These media images strongly impact female perceptions of their talents and capacity for fulfillment in STEM fields (Ceglie, 2020). Therefore, tackling bias and stereotypes in STEM requires a multifaceted approach that contests media representations, promotes diverse and inclusive curricula, and develops environments that actively challenge harmful narratives (Steffens & Jelenec, 2011).

In summary, examining prejudice and stereotypes affecting women in STEM underscores the pressing need for targeted interventions and systemic reforms. According to Hunt et al. (2021), conditions for a more inclusive and equitable STEM instructional environment are created by spotting and confronting these deeply rooted cultural perspectives. However, Daniels and Robnett (2020) diverged from this approach by prioritizing diverse media portrayals, providing female students with role models, and fostering cultures of active anti-bias action. Ultimately, eliminating these prejudices and stereotypes was crucial for achieving gender equality and realizing the full potential of the STEM professions (Wang & Kenny, 2021).

Female College Students in a Two-Semester Physics Course

The motivational attitudes of female students enrolled in a two-semester primary physics pathway are examined in Cwik and Singh's (2022) case study. The researchers provided a closer look at the complex interaction between motivational factors and academic achievement in bioscience music. Riegle-Crumb et al. (2011) reported significant gender-based differences in total self-efficacy, a key construct in social cognitive theory. Researchers found that female college students had lower self-efficacy than their male counterparts, underscoring the need for targeted interventions to enhance their confidence and perceptions of their abilities in STEM fields (Wang et al., 2021; Zarrett & Malanchuk, 2021). This study highlights the desire to create a more inclusive learning environment by underscoring the long-lasting impact of societal prejudices and biases (Wang et al., 2021).

The bioscience track's focus was essential, as it speaks to a particular phase of college students in STEM majors. Given that bioscience professions are integral to the broader STEM disciplines, it was essential to acknowledge the motivational ideals of women in this field. Cwik and Singh's (2022) research provided an insightful analysis of studies of female college students seeking STEM degrees by examining bioscience music, offering a nuanced view of the factors that impact their academic trajectories. This focused method provides a more thorough understanding of the challenges and opportunities in STEM education, thereby informing effective plans to increase women's representation in these vital professions.

In summary, Ferguson and Martin-Dunlop's (2021) findings emphasized the complexity of motivating ideals and their effect on academic performance. The investigators suggested the need for interventions that enhance self-efficacy and account for the societal context that shapes those attitudes (Beroíza-Valenzuela, 2025). By incorporating social cognitive theory, the study provided a well-established framework for examining the complex interplay among cognitive strategies, behavior, and environmental factors in STEM education (Govindaraju, 2021). Burney's (2008) and Hazari et al.'s (2020) observations are a crucial first step toward achieving a balanced representation of women in these critical fields by advancing inclusive and equitable STEM study environments.

Lack of Role Models for Females In STEM

Female goals and self-belief in pursuing STEM majors are significantly influenced by the scarcity of prominent female role models in STEM fields (Dyer et al., 2022). It was harder for young female college students to envision themselves succeeding in STEM majors when they had no prior experience in those fields. STEM-focused career roles serve as potent catalysts, demonstrating to women that fulfillment in STEM offers value (González-Pérez et al., 2020). Sulema Torres-Ramos et al. (2021) emphasized that having role models may make females feel more comfortable in the industry, thereby encouraging them to choose a STEM-related major. Due to gender stereotypes being strengthened, efforts to create a more diverse STEM network are hampered.

In addition, females interested in STEM may feel much less assured and confident due to the need for more female role models. According to Olaitan and Mavuso's 2022 research, students could only doubt their achievement propensities with concrete illustrations of successful women in STEM. This lack of representation contributes to cultural preconceptions that associate STEM fields with masculine traits, thereby discouraging female college students from pursuing these fields (Navarro et al., 2019). Young women may also find it challenging to pursue STEM education and careers, which can lead to reduced confidence and lower self-efficacy.

Zarrett & Malanchuk (2021) agreed that addressing the shortage of female role models was fundamental to achieving gender equality in STEM. To motivate and empower the next generation, improving the visibility of prominent women in STEM fields is critical (Idris et al., 2023). Cwik and Singh (2022) further stated that providing women with relevant STEM positions to pursue after graduation will significantly enhance their self-belief and aspirations, ultimately increasing the number of women entering STEM careers. The campaign to expand the focus on and representation of female students was an essential first step toward building a more diverse and equitable STEM network (Sáinz & Castaño, 2020).

Female dreams and self-belief in pursuing STEM education are significantly influenced by the scarcity of prominent female role models in STEM fields (Pilotti, 2021). It was more challenging for younger females to envision themselves succeeding in these fields when no applicable role models had been established. O'Connell and McKinnon's (2021) investigation converges on findings that role models serve as catalysts for lasting change. Tal et al.’s (2024) findings indicate that women's achievements in STEM are vital to fostering a positive outlook among younger women and preventing discouragement from pursuing STEM careers. In the absence of female role models, gender stereotypes are reinforced, and efforts to create a more diverse STEM community are hampered (Rocker & Dori, 2023).

In addition, Wu et al. (2022) upheld that younger females interested in STEM majors may feel less assured and confident due to the shortage of visible female role models. Without concrete illustrations of females in STEM, college students might doubt their potential for success. This loss of representation contributes to cultural preconceptions that associate STEM fields with masculine characteristics, thereby discouraging female college students from pursuing these fields (Devi et al., 2017). Young women may also find it challenging to pursue STEM majors and careers, which can diminish self-confidence and self-efficacy.

In summary, it was vital to address the lack of female role models to achieve gender equality in STEM. Sulema Torres-Ramos et al. (2021) reported findings indicating that motivating and empowering the next generation of technology initiatives could increase the visibility of outstanding women in STEM fields. Turner et al. (2022) found that female role models provide younger females with relatable role models to aspire to, which significantly affects their confidence and aspirations over the long term, ultimately increasing the number of females who pursue careers in STEM fields. An organized campaign to raise awareness and understanding was a vital first step in building a more diverse and equitable STEM community.

Teacher Expectations and Classroom Climate for Female Students

Teacher expectations and classroom climate play a pivotal role in shaping female students' academic outcomes, motivation, and engagement, particularly in STEM subjects. Researchers indicated that students' perceptions of teacher beliefs about their abilities strongly influence self-concept, academic persistence, and achievement (Bandura, 1997; Rosenthal & Jacobson, 1968). When teachers hold high expectations and communicate confidence in their students' capabilities, female students are more likely to internalize these beliefs, thereby increasing their self-efficacy and willingness to take on challenging tasks (Copur-Gencturk et al., 2023). Conversely, low or biased expectations can hinder female students' development, particularly in male-dominated subjects like science, mathematics, and technology, by reinforcing stereotypes and limiting growth opportunities (Kiernan et al., 2022). Teacher expectations are not merely perceptions; they shape instructional strategies, feedback patterns, and the distribution of attention within the classroom, all of which contribute to an environment that either supports or undermines female students' learning (Garcia, 2018).

Classroom climate, defined as the overall atmosphere and social-emotional environment of a learning space, interacts closely with teacher expectations to influence student outcomes. A favorable, inclusive classroom climate fosters a sense of belonging, psychological safety, and intellectual engagement, which are particularly important for female students navigating STEM subjects (Rafidahet et al., 2019). Litzler et al.'s (2014) findings agree that females are more likely to engage deeply and take intellectual risks in classrooms where they feel respected, supported, and valued. Rutherford et al.'s (2024) findings converge on the importance of collaborative learning environments that foster peer interaction, equitable participation, and respectful discourse, which have been shown to enhance female students' motivation, self-efficacy, and persistence in STEM-related tasks. In contrast, competitive, rigid, or gender-biased classroom climates can discourage female students from participating fully, eroding confidence and contributing to underrepresentation in STEM fields (Walter & Wade, 2024).

Teacher behaviors and instructional practices directly shape both expectations and classroom climate. Garcia (2018) agreed that teachers may unconsciously engage in differential treatment based on gender, such as calling on boys more frequently, providing more detailed feedback to male students, or assuming higher competence in male learners (Kiernan et al., 2022; Kinkopf & Dack, 2023). A natural extension of this discussion concerns behaviors that implicitly signal who is expected to succeed, thereby reinforcing stereotypes and limiting female students' access to challenging learning experiences. Conversely, deliberate practices that promote equity, such as providing balanced attention, encouraging risk-taking, emphasizing growth-mindset principles, and modeling inclusive language, can counteract stereotype threat and support the development of a positive academic identity among females (Carlone & Johnson, 2007). Teachers who adopt these practices create a classroom climate that communicates both high expectations and support, fostering an environment in which female students are more likely to engage in STEM tasks and view themselves as capable learners (Garcia, 2018).

The link between feedback and assessment practices is another critical component of classroom climate influencing female students. Constructive, specific, and growth-oriented feedback reinforces learning and encourages persistence, whereas generic or biased feedback may inadvertently signal limited potential (Rafidahet et al., 2019). Hazari et al. (2020) and Rafidahet et al. (2019) concur that when teachers highlight effort, strategy use, and problem-solving rather than innate ability, females are more likely to develop self-efficacy and maintain interest in STEM tasks despite challenges. Classroom practices that emphasize mastery over competition also create environments where risk-taking is safe, errors are normalized as learning opportunities, and all students, regardless of gender, can thrive academically (Zhao, 2024). These aspects of climate directly intersect with teacher expectations, as supportive and equitable classrooms reinforce the message that all students are capable of success.

Social-emotional support within the classroom further shapes female students' engagement and persistence. Teachers who cultivate a climate of encouragement, inclusivity, and mutual respect help students develop resilience and confidence in their abilities (Pilotti, 2021). Female students who experience supportive classroom relationships are more likely to participate actively, collaborate with peers, and persist in subjects traditionally dominated by male students (Litzler et al., 2014). Mentorship, peer modeling, and structured opportunities for leadership and decision-making enhance females' sense of agency, reinforcing both academic identity and STEM self-concept (De Gioannis, 2023). When combined with high expectations and equitable instructional practices, these social-emotional supports create a comprehensive climate conducive to female achievement and retention in STEM pathways (Herbert-Berger et al., 2024).

Finally, research emphasizes that teacher expectations and classroom climate have long-term implications for female students' educational trajectories. Researchers converge on findings that experiences in supportive, inclusive, and challenging learning environments increase the likelihood of sustained engagement, enrollment in advanced coursework, and the pursuit of STEM-related careers (Jenny & Ingber, 2025; Kiernan et al., 2022). Conversely, classrooms characterized by low expectations, gender bias, or unsupportive climates contribute to disengagement, diminished self-efficacy, and attrition from STEM pathways. By intentionally fostering equitable expectations and positive classroom climates, educators can mitigate structural and cultural barriers that disproportionately affect female learners, thereby promoting both academic success and gender equity in STEM fields (Jiang et al., 2020).

In summary, teacher expectations and classroom climate are critical determinants of female students' academic development and STEM engagement. High expectations, inclusive and collaborative climates, equitable instructional practices, constructive feedback, and social-emotional support collectively foster self-efficacy, motivation, and persistence among females (Usher, 2009). Conversely, low or biased expectations and unsupportive environments reinforce stereotypes, limit opportunities, and hinder identity development (Li & Singh, 2021). Understanding the interplay of teacher expectations and classroom climate is therefore essential for designing interventions and educational practices that empower female learners and promote equitable participation in STEM from the earliest stages of education (Bond & Blevins, 2020).

Longitudinal Patterns of Female Persistence in STEM

Understanding the longitudinal patterns of female persistence in STEM is critical to addressing gender disparities in these fields. Researchers Kiernan et al. (2022) and Litzler et al (2014) converged findings that female students often exhibit high interest and engagement in STEM during early education. Rafidahet et al. (2019) found that participation declines across successive educational stages, particularly in high school and college. This attrition is influenced by a combination of individual, social, and structural factors that interact over time, shaping women's decisions to continue or discontinue STEM pathways. Longitudinal studies provide essential insights into these patterns by tracking students across multiple years, highlighting not only when attrition occurs but also the factors that support sustained engagement (Jiang et al., 2020). These studies underscore the importance of early intervention, mentorship, and supportive learning environments in fostering long-term persistence among female STEM learners (Vooren et al., 2022).

One of the most consistent predictors of women's persistence in STEM is self-efficacy, defined as the belief in one's ability to succeed in STEM tasks (Bandura, 1997; Rafidahet et al., 2019). Longitudinal research demonstrates that self-efficacy established during middle and high school strongly predicts both course selection and sustained engagement in STEM-related activities. Females who develop confidence through mastery experiences, such as project-based learning, science competitions, or coding challenges, are more likely to persist in STEM throughout high school and into college (Litzler et al., 2014). Conversely, repeated exposure to failure, lack of encouragement, or environments that convey low expectations can weaken self-efficacy, contributing to attrition (McKinney, 2021). These patterns suggest that interventions designed to build competence and confidence at multiple points across the educational trajectory are essential for sustaining female participation in STEM.

Social and environmental factors, including classroom climate, teacher expectations, and peer support, also influence the longitudinal trajectory of female persistence. Studies show that female students are more likely to continue in STEM when they experience positive, inclusive learning environments and when teachers maintain high expectations for all students (Rafidahet et al., 2019; Kiernan et al., 2022). Dennehy & Dasgupta's (2017) peer research further shapes persistence, as collaborative learning and supportive peer networks foster engagement, motivation, and a sense of belonging. Conversely, environments characterized by gender bias, isolation, or stereotype threat contribute to early disengagement, even among students with strong ability and interest in STEM (Steffens & Jelenec, 2011). Longitudinal evidence suggests that these social and environmental influences are cumulative, with negative experiences compounding over time and increasing the likelihood of attrition in later educational stages (Cwik & Singh, 2022).

Curricular and institutional factors also play a critical role in shaping longitudinal patterns of female persistence in STEM. Access to advanced mathematics and science courses in high school, exposure to STEM-related extracurricular activities, and availability of mentoring programs have been consistently associated with sustained participation (Litzler et al., 2014; Rafidahet et al., 2019). Female students with repeated opportunities to engage in authentic, challenging STEM experiences demonstrate greater resilience and persistence, as these experiences reinforce both skill development and identity as STEM learners. Furthermore, longitudinal studies indicate that early exposure to STEM is necessary but insufficient; ongoing reinforcement, scaffolding, and guidance are required to sustain engagement through the transition from middle school to high school and, subsequently, to college.

Longitudinal research also highlights the importance of identity formation and STEM self-concept in predicting persistence. Female students who view themselves as capable STEM learners are more likely to select challenging coursework, participate in STEM competitions, and pursue postsecondary STEM opportunities (Kiernan et al., 2022). Cumulative experiences of mastery, recognition, mentorship, and belonging shape identity development. Longitudinal studies show that early disruptions in the formation of STEM identity, whether through negative classroom experiences, social discouragement, or a lack of role models, can have lasting effects, leading to decreased engagement and eventual departure from STEM pathways. Conversely, interventions that reinforce female students' STEM identity across multiple developmental stages contribute to resilience and sustained participation.

Mentorship and representation are additional factors influencing longitudinal patterns of female persistence. Access to female role models, whether teachers, university students, or professionals, provides critical social proof that women can succeed in STEM fields (Litzler et al., 2014; Kiernan et al., 2022). Mentorship helps students navigate academic challenges, develop coping strategies, and envision future STEM careers, reinforcing motivation and persistence. Dong et al. (2021) longitudinal studies indicate that sustained mentorship across middle school, high school, and college has a cumulative effect, increasing retention and encouraging the pursuit of advanced STEM coursework and professional pathways. Without continued mentorship, even competent female students are at increased risk of disengagement, highlighting the importance of long-term, structured support networks.

Finally, longitudinal studies reveal disparities in persistence across demographic and contextual factors, emphasizing the need for equity-focused interventions. Females from underrepresented racial, ethnic, or socioeconomic backgrounds often face compounding challenges, including limited access to resources, lower expectations, and fewer role models (Rafidahet et al., 2019). These structural barriers interact with individual and social factors to influence attrition patterns. Evidence suggests that targeted programs—such as STEM enrichment camps, dual-enrollment courses, and scholarships for underrepresented students—can mitigate these effects, fostering sustained engagement and promoting equitable representation in STEM fields over time.

In summary, longitudinal patterns of female persistence in STEM reflect the interplay of self-efficacy, identity development, social influences, classroom climate, and structural factors. Early mastery experiences, supportive classroom environments, mentorship, and representation collectively promote sustained engagement, whereas negative experiences, bias, and structural barriers contribute to attrition (Garcia, 2018). Buckle et al.'s (2022) research diverges from earlier longitudinal studies, which treat the study as a single factor or intervention, rather than as a cumulative outcome shaped by multiple experiences over time. Understanding these patterns is essential for educators, policymakers, and program designers seeking to foster sustained participation and success among female STEM learners (Copur-Gencturk et al., 2023). By addressing both individual and structural factors, interventions can create pathways that support females' long-term engagement, ultimately contributing to a more diverse, innovative, and resilient STEM workforce (Park, 2022).

Educational Environment Discouraging Female Participation in STEM

Colleges and universities unintentionally foster a culture that discourages women's participation in STEM disciplines across several educational settings. Previous coaching strategies and discriminatory curricular materials can be sustained by the concept that STEM fields are better suited to men. LaForce et al. (2019) suggested that female students may feel insufficient and alienated. Furthermore, Schnitzler et al. (2020) found that when energetic engagement was not recommended, women might feel even more excluded from these fields. The self-belief and sense of belonging of female college students in STEM fields may need improvement due to the lack of supportive, inclusive environments in study spaces and lecture rooms (Veldman, 2022).

These demoralizing settings have effects that move beyond the classroom. González-Pérez et al. (2020) found that when female college students perceive STEM fields as unwelcoming, it may affect their sense of competence and belonging in these fields. In an unreceptive STEM classroom, female college students' educational trajectories and career goals may be adversely affected in the long term by this lack of self-assurance (Zhang, 2025). Additionally, it perpetuates the underrepresentation loop by reinforcing the widespread assumption that masculine characteristics are dominant in STEM fields (Herrmann et al., 2016). It was crucial to recognize and address these problems to create an effective environment that nurtures self-assurance and provides the network experience female students need to pursue STEM (Rachmatullah et al., 2022)

There was a pressing need for inclusive teaching methods that actively encourage female engagement in STEM to lessen the demoralizing effects of tutorial environments (Rachmatullah et al., 2022). This involves using contemporary, objective curriculum materials that represent the diverse viewpoints and contributions of the STEM professions. Additionally, Morton (2020) emphasized that educators should aggressively promote and assist female college students' participation in STEM majors. Women who explore STEM fields may benefit significantly from opportunities for hands-on learning, projects from STEM-focused women's organizations, and exposure to female role models (Armstrong et al., 2020). By creating a welcoming and supportive environment that fosters awareness of their surroundings, we can enable women college students to pursue STEM coursework and explore promising careers in these essential fields (Dangur-Levy, 2024).

Additionally, the school environment can unintentionally contribute to the gender gap in STEM (Litzler et al., 2014). An environment that felt different was likely due to outdated coaching strategies, biased curricular materials, and a lack of encouragement for female college students to participate actively. Wang et al.'s (2021) research findings converge on the finding that younger women may feel isolated or inadequate, discouraging them from pursuing STEM majors and careers. To create an inclusive educational environment that supports the achievement of all college students, regardless of gender, it is crucial to recognize and overcome institutional barriers (Li & Singh, 2021). This study aims to investigate these complex issues and determine the extent to which focused initiatives, such as the FIRST Robotics project-based learning program, can mitigate their consequences and foster a more inclusive and equitable educational environment (Evans, 2017).

Black Women's Persistence in STEM

Morton (2021) provided an in-depth analysis of the impact of undergraduate study opportunities on the persistence of Black women in STEM fields. The researcher explores the lived experiences and contextual factors that shape the instructional trajectories of Black women in STEM through a phenomenological and ecological lens (Eisenhart & Allen, 2020). Clarifying the purpose of this dual analysis helps readers understand how it facilitates a comprehensive exploration of individual experiences and environmental influences (Wilkins-Yel, 2022). Many researchers converge on the more significant structural and environmental factors that determine the persistence of Black women in STEM by incorporating an ecological perspective (Morton, 2021; Eisenhart & Allen, 2020). In STEM training, this dual framework provides an intensive lens for exploring the complex interplay between private reports and environmental settings (Wilkins-Yel, 2022).

The information about the vital role that undergraduate research experiences play in supporting the persistence of Black women in STEM was central to Morton's (2021) observation. Practical study opportunities provide students with a transformative platform to apply their instructional knowledge in real-world settings (Samiha et al., 2022). Although African American women's technical expertise is advanced, studies also indicate that it affords them a sense of control and ownership over their scientific endeavors (Dori & Yoel, 2022). This empowerment was essential for African American women, who may face additional barriers and structural challenges in STEM education (Eisenhart & Allen, 2020). Morton's (2021) study employs a phenomenological method to capture the diverse and complex perspectives of these students, illuminating how research reports motivate their perseverance and success in STEM fields.

In summary, Morton's (2021) studies highlighted the cost of creating welcoming and inspiring environments for Black women in STEM. The ecological perspective emphasizes structural factors that positively impact their educational experiences, including mentorship, institutional support, and culturally responsive pedagogy (Cristina Neri-Cortés, 2021). Eisenhart & Allen's (2020) findings are crucial for recognizing and addressing contextual variables if Black women are to persist and succeed in STEM fields. Morton's (2021) examination provides a comprehensive understanding of the complex dynamics shaping the academic experiences of Black women in STEM by combining a phenomenological exploration of personal stories with an ecological evaluation of extrinsic contextual factors, ultimately offering valuable insights for fostering a more inclusive and equitable STEM community.

Peer Pressure Deterring Women from Choosing STEM Fields

Ferguson and Martin-Dunlop (2021) found that peer pressure can significantly influence the decisions of younger females, particularly regarding their academic and career choices. In STEM fields, gender stereotypes and cultural conventions may also pressure female college students to pursue interests and goals that conform to stereotypical female roles (Flack, 2021). The researcher's findings may serve as a strong disincentive for college students pursuing STEM education, as their genuine enthusiasm for these fields may be overshadowed by fear of deviating from prevailing social norms (Pilotti, 2021). Peer pressure can be an effective deterrent for females from pursuing the numerous opportunities STEM fields offer.

Peers have a significant impact and long-lasting effects on a female's educational and employment choices in STEM fields. Once enrolled in STEM courses, peer stress may also impact instructional dreams (Sherry et al., 2023). Female college students may experience isolation and self-doubt as they navigate a campus where they are in the minority (Jiang, 2020). The pressure to conform to standard norms in these male-dominated sectors can intensify this sense of alienation. A few women may also pursue new educational pathways to take advantage of the life-changing opportunities STEM education can provide (Steffens & Jelenec, 2011).

In summary, Starr et al. (2019) and Wu et al. (2022) reported convergent findings on how to combat peer stress among female STEM students; proactive measures must be implemented to expand networks of guidance and empowerment. The destructive effects of societal expectations can be mitigated by providing spaces for women to interact, exchange reviews, and inspire one another (Wu et al., 2023). Both Starr et al. (2019) and Wu et al. (2022) further agreed that building a culture that encourages women to pursue their STEM-related hobbies requires a combination of mentoring programs, peer support networks, and inclusive social environments. Individuals can help females overcome the challenges posed by peer stress and ultimately enable them to succeed in STEM subjects by fostering a sense of belonging and providing opportunities for collaboration and support (Hazari et al., 2022).

Parental Influence on Daughters' Pursuit of STEM

Parents' attitudes significantly influence women's career choices in STEM professions (Rachmatullah et al., 2022). A female's interest in these disciplines may be motivated by early exposure to instructional materials, video games, and sports related to the STEM fields. Additionally, parents who actively participate in conversations about STEM opportunities nurture their daughters' curiosity and self-assurance (Evans et al., 2017). Parents can cultivate a lifelong passion for STEM by creating a welcoming environment that fosters discovery and inspires their daughters to consider these topics as potential career paths.

Abdullah et al. (2020) argued that parental influence may serve as a robust counterbalance to strain, both reinforcing and thwarting its outcomes. When parents provide consistent support for their daughters' STEM endeavors, they foster strong self-confidence. Abdullah et al.'s (2020) investigation suggests that parents' internal commitment enables girls to withstand external pressures more effectively, thereby encouraging them to pursue STEM careers. In comparison, if a mother and father have misgivings about their daughters' entering industries with a preponderance of guys, their impact can also unintentionally coincide with peer stress and discourage females from pursuing STEM (Li & Singh, 2021), and creating an environment where women are encouraged to pursue their hobbies calls for acknowledging and resolving these traits.

A female parent's expectations and critiques significantly influenced her STEM instructional and career choices. (Eisenhart & Allen, 2020). Parents with preconceived notions about how women should be dealt with in STEM fields or who underrate their daughters' potential can be a chief impediment. Similarly, Kim et al. (2018) found that parents who support their daughters' interest in STEM professions are more likely to provide the guidance and resources they need. These central ideas shape a woman's self-perception, influencing her self-worth and motivation to pursue STEM education and employment. It was essential to reshape parental attitudes to ensure that younger women have an equal opportunity to succeed in STEM disciplines.

In summary, unlocking a woman's STEM potential requires creating a supportive and enabling ecosystem within the family. Kalender et al.'s (2020) study found that, in addition to fostering a love of learning, parents who actively involve their daughters in STEM-related activities and discussions foster a sense of autonomy and capability. Developing students' problem-solving, critical thinking, and interest in STEM fields paves the way for their confident exploration of STEM fields (Kim et al., 2018). Parents play a crucial role in breaking down barriers and building a future in which women thrive in dynamic STEM fields by actively participating in their daughters' educational decision-making (Fairlie et al., 2020).

Mentoring Programs and Support Networks

The barriers to peer pressure faced by female college students in STEM disciplines have been overcome through mentoring and female support networks. Ion et al.'s (2020) findings confirm that mentoring and female aid networks serve as a critical lifeline, providing younger women with direction and a secure environment in which to address problems in male-dominated settings (Wu et al., 2023). Cristina Neri-Cortés (2021) research provides female college students with a sense of network and empowerment by matching them with informed female mentors who can relate to their unique experiences. Mentors provide female college students with the fortitude and self-assurance they need to stand up and overcome the demanding situations that could otherwise prevent them from pursuing STEM education and careers through everyday interactions and individualized guidance (Wu et al., 2022).

Atadero et al. (2014) explained that mentorship was a robust accelerator for female STEM students, increasing their self-confidence and broadening their professional opportunities. Mentors offer insightful advice by sharing their knowledge and understanding, which can be transformative for young women trying to establish themselves in a competitive field (Fairlie et al., 2020). The advice provided was practical for improving their technical abilities and building their self-belief, enabling them to speak up in both instructional and expert settings. Herrmann et al. (2016) also examined how women’s connections with other women affect academic achievement and persistence in STEM courses. Wu et al. (2022) reported outcomes that illustrated the benefits of female mentors, highlighting the role of social interactions in developing interests and STEM identities. Additionally, mentors regularly provide mentees with a broader perspective on potential professional alternatives, helping them visualize a STEM career that aligns with their goals and objectives (Giani, 2019).

Evans et al. (2017) concluded that the beneficial effects of mentoring programs on women's participation and success in STEM are well demonstrated by numerous case studies and exemplary practices. Female contributors in programs such as "Girls Who Code" and the "Society of Women Engineers" have achieved remarkable outcomes, including improved retention rates and increased self-confidence. (Cwik & Singh, 2022). These women-empowered programs employ individualized mentoring, peer-assistance programs, and targeted talent-development publications (Vongkulluksn, 2018). The inclusion of women has effectively mitigated peer pressure by fostering a supportive, welcoming environment that enables younger women to pursue STEM careers (Wu et al., 2023).

In summary, networks of aid and mentoring programs are critical for empowering the next generation of female STEM students (Devi et al., 2017). It was impossible to overestimate the power they have to reduce the harmful effects of peer stress, boost self-confidence, and expand professional opportunities. These applications play a crucial role in transforming the landscape of female involvement and success in STEM disciplines by highlighting exceptional case studies and best practices (Agunloye, 2019). Efforts for a more inclusive and equitable future wherein female students are not only welcomed but additionally recognized within the exciting disciplines of science, technology, engineering, and mathematics, as we continue to put money into and develop these mentorship programs (Wu et al., 2022).

Female Psychological Resilience and Coping Strategies in STEM

For female students, navigating peer pressure in male-dominated disciplines such as STEM can pose specific psychological challenges. Atadero et al. (2014) findings converge that female college STEM students might struggle with impostor syndrome, feelings of exclusion, and loneliness. Social pressures and preconceptions may also exacerbate these emotional stressors(Dennehy & Dasgupta, 2017). Internal difficulties, compounded by the stress of adhering to social norms, could harm a woman's self-worth and self-confidence (Ion et al., 2020). It was essential to understand and address these psychological issues to foster an environment where both female and male STEM students can succeed (Rachmatullah et al., 2022).

Female STEM students adopt coping mechanisms and resilience-building strategies to lessen the effects of peer stress. Dennehy and Dasgupta (2017) found that seeking mentors and guidance, participating in self-affirmation activities, and actively engaging with communities that value diversity are crucial to the mental health of female college STEM students (Castellano et al., 2017). Another effective coping method was to adopt a mindset that emphasizes developing and improving fixed skills. O'Connell and McKinnon (2021) found that setting plausible objectives and acknowledging small victories can boost confidence and provide a sense of accomplishment, helping people cope with the stresses they encounter.

For women in STEM, developing mental resilience has far-reaching implications. According to analysis, individuals who practice strength can better cope with the difficulties they face in college, leading to higher achievement (Wu et al., 2022). As a result of their confidence in their ability to overcome demanding situations, individuals with higher levels of mental resilience also tend to have more ambitious professional goals (Armstrong et al., 2021). This proactive attitude may foster greater tenacity in pursuing STEM management roles and in postgraduate settings (Bryan et al., 2022).

Building psychological resilience extends beyond success in STEM majors and STEM careers. Resilient women with effective coping mechanisms generally score higher on measures of preferred mental well-being. Schnitzler et al. (2020) highlighted that female STEM students and workers can cope with stress and are more likely to engage in inclusive practices within STEM fields, thereby supporting the creation of a more inclusive and supportive society for future generations. By focusing on the mental fitness of female STEM students, we enable them to achieve instructional and professional success most effectively while also leading fulfilling, satisfying lives in their communities (Dökme et al., 2022).

Summary

In summary, this literature review synthesizes current research on the complex relationships between self-efficacy and academic achievement among female college students majoring in STEM fields (Ion et al., 2020). The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. Key areas of investigation included fostering motivation, confidence, and persistence among female college students (Jiang et al., 2020). The literature review emphasized that the absence of supportive, equitable learning environments for female college students reduces their motivation and persistence in pursuing STEM degrees (Jiang et al., 2024). Therefore, this study would contribute to the literature on how high school project-based learning programs, such as FIRST Robotics, can increase the likelihood of female college students completing a STEM degree (Evans et al., 2017).

The literature review emphasized the need for a framework that effectively supports female college students in pursuing STEM degrees. Bandura's social cognitive theory is best suited to this study and aligns with the literature review, supporting the attainment of STEM degrees by female college students (Bandura, 1986). The adoption of this framework would enhance the body of knowledge on how to increase the proportion of female college students who complete STEM degrees (Bryan et al., 2022). These literary conclusions set the stage for Chapter 3, which presents the research design and methodology employed to investigate the relationship between participation in project-based learning programs and female students' attainment of STEM degrees.

Chapter 3: Methodology

The *Nation at Risk* report sounded the alarm about the decline in the number of United States high school students who transition into STEM college graduates and professionals relative to the number of open STEM jobs (Finn, 2022). The problem addressed in this study was the disparity in the rate at which female college STEM students earn STEM degrees, which is lower than that among their male counterparts (Vooren et al., 2022). The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. The study's methodology and design are paramount, as they underpin the entire research project. By using this methodology and design, the study addressed the following question:

Research Methodology and Design

The decision to use a quantitative methodology was appropriate for this study, given its emphasis on examining statistical differences in the completion of STEM college degrees between two groups of female students. This method involved selecting mathematical data and conducting statistical analysis, thereby providing a structured framework for addressing the research questions (Rustambek Kuldoshev et al., 2023). This study compared the outcomes of female college STEM students who participated in the FIRST Robotics project-based learning program in secondary school with those of students who did not. Quantitative methodology enables the researcher to draw precise, objective conclusions based on statistical evidence.

The study was non-experimental and did not involve variable manipulation. Instead, it exploits naturally occurring contrasts and events. I did not select the independent variable in this study. Utilizing a correlational research design further improved the study's appropriateness. In this design, the researcher dissected the effects of an independent variable on a dependent variable (Jung, 2020). The independent variable was participation in the FIRST Robotics project-based learning program, and the dependent variable was the completion of a college STEM degree. Correlational research involves quantifying the relationship between independent and dependent variables. The examination offers significant insights into potential relationships between the two variables.

The chosen research methodology and design are closely aligned with the study's problem, purpose, and research questions. The issue centers on understanding how the FIRST Robotics project-based learning program affects the transition of female students from secondary school project-based learning programs to STEM degree attainment (Zawacki-Richter et al., 2020). The purpose was to evaluate the association between college STEM degree completion and program participation among students who participated in the program and those who did not. The research question and the associated hypotheses directly pertain to this comparison.

When embarking on a research endeavor, it was crucial to consider alternative methodologies and designs and evaluate their suitability for the research problem, purpose, and questions. This study's quantitative correlational research design was appropriate for examining the association between college STEM degree completion and participation in the FIRST Robotics project-based learning program among female students (Luetke et al., 2021). Notwithstanding, a few alternative methodologies and designs were considered but ultimately deemed less appropriate for multiple reasons.

A phenomenological qualitative approach would have been an alternative, particularly for exploring the experiences and perceptions of female college students. However, the data for this study were received from Brandeis University in numerical form. Using this alternative qualitative method would not yield the statistical data necessary to address the research question effectively. Additionally, a causal-comparative design examines the causal relationship between the two variables (Möller, 2022). A correlational design was appropriate for examining whether meaningful associations in outcomes emerged between the groups, while acknowledging that definitive causal claims could not be established. Brandeis University provided archival data used in this study.

The quantitative correlational research design was appropriate for investigating the distinctions in college STEM degree completion between female students who participated in the FIRST Robotics project-based learning program and those who did not (Dori et al., 2022). The method and design closely align with the study's problem, purpose, and research questions, providing a robust framework for generating critical insights into the impact of project-based learning programs on the academic and professional trajectories of female students in STEM fields.

Population and Sampling

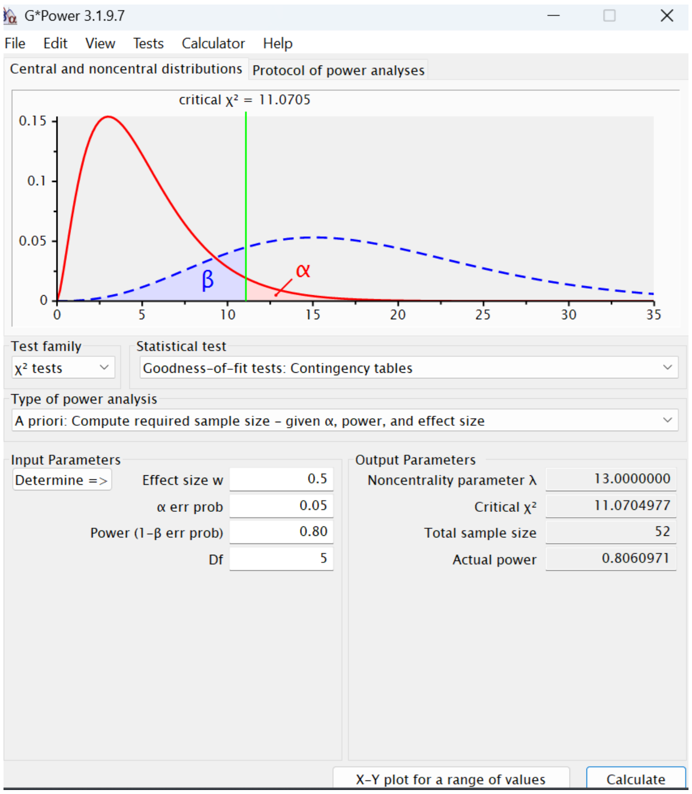
The archival data population for the FIRST study originally consisted of 1,273 nationally recruited students who participated in a longitudinal study. A Brandeis University researcher distributed more than 15,000 survey packages; however, the study included 922 participants in FIRST Robotics project-based learning programs and 451 comparison students (Meschede et al., 2022). The students in the comparison group were recruited from math and science classes at the same schools as those participating in the FIRST Robotics project-based learning program. Participants in both groups were surveyed over ten years, beginning in 2012. After ten years, 922 participants (518 males and 404 females) remained in the study. The population was represented by rural, suburban, and urban areas. The FIRST participants ' population consisted of 21.4% Asian, 7.4% Black/African American, and 65.6% White. The comparison group's ethnic composition was 9.4% Asian, 5.9% Black/African American, and 84.6% White.

However, the study sample comprised female high school students participating in the FIRST Robotics project-based learning program and female students in the comparison group. A random sampling method was used to select a comparison group similar to a FIRST Robotics project-based learning program. 46% of female high school students participated in the FIRST Robotics project-based learning program, whereas 54% were in the comparison group. A G*Power 3.1.9.7 analysis was calculated. Sommet et al. (2023) highlighted best practices for quantitative research methodologies that require hypothesis testing. Acceptable statistical power software, such as G*Power, indicates the likelihood that results can be replicated. Baranger et al. (2023) concurred that power analysis should be a staple in a researcher's toolkit and that reliability was essential.

The G*Power analysis software provided several computational results for quantitative researchers. The sample size was one of the computationally critical results needed to determine whether the relationship between the variables was significant. Researchers Fowler and Lapp (2019) explained the significance of a researcher not knowing the correct sample size, which could result in insufficient data to support the hypothesis. Similarly, Kang (2021) stated that using G*Power to determine sample size reduces the likelihood of false-conclusion errors. The G*Power 3.1.9.7 calculation yielded a sample size estimate (effect size = 0.5, power = 0.80, alpha = 0.05). An estimated minimum sample size of 52 was required. A visual representation of the G*Power analysis is provided in Figure 2.

Figure 2

A Prioi Sample Size Calculation



The data from this study could provide insight into whether the FIRST Robotics project-based learning program increases the likelihood that female college STEM students participating in the program will obtain a STEM degree. The sample was appropriate for this study because it was directly related to the problem statement, the study's purpose, and the research question. The sample population enables the investigation to determine whether female high school STEM students participating in the FIRST Robotics project-based learning program are more likely to become female college STEM students who earn STEM degrees.

Instrument

Brandeis University developed a FIRST Robotics project-based learning STEM career and interest survey. Brandeis' goal was to document the long-term impacts of youth participation in FIRST programs, with three guiding questions: What are the short- and long-term effects of FIRST participation on participants? What was the relationship between program experience and effect? To what extent are there associations in experiences and impacts among key subpopulations of FIRST participants? However, the Brandeis investigators followed the students for ten years and collected data from the participant groups. The participants completed a 40-question survey at the end of their first year of college. The questions were in five domains with five subscales:

Table 1

FIRST Survey Longitudinal STEM Career and Interest Survey Questions

Domain	Subscale
STEM interest	How interested are you in science, technology, engineering, and/or math (STEM)? On a scale of 1 (not interested) to 5 (very interested).
Involvement in science and technology activities	Outside of school, how much do you enjoy the following? On a scale from 1 (Not interested at all) to 7 (Very interested).
STEM careers	How interested are you in each of the following jobs related to STEM (science, technology, engineering, and mathematics)? On a scale, how much do you agree or disagree with the following?
STEM careers, science, math, technology, identity	We will now ask you a few questions about your beliefs regarding mathematics and science. How much do you agree or disagree with the following?
STEM understanding and pathways	We are interested in learning about how you think about yourself and your future. On a scale from 1 (Not True at All for Me) to 7 (Very True for Me)

The survey combined Brandeis University-generated questions with questions adapted from the United States Department of Education's High School Longitudinal Study of 2009 and the Barker, Nebraska 4-H study (Meschede et al., 2022). The combined survey used modified Likert-type scale items with multiple-choice responses. The Brandeis researcher assessed the reliability and validity of each test question using Cronbach's alpha. Cronbach's alpha is a measure of the internal consistency of survey items, and a minimum acceptable value is 0.70 (Laerd, 2018).

Validity and Reliability of the Data

Collecting data using psychometric characteristics ensures validity and reliability. Validity measures the accuracy of the questionnaire used in the study (Statistics Solution, 2023). Cronbach's alpha coefficient was calculated using the International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) version 23 to assess reliability (Laerd, 2023b). Sevinc and Alparslan (2022) stated that a Cronbach's alpha coefficient has a low to high range (0.0 – 1.0), with a value of less than 0.69 (low reliability), 0.70 to .79 (acceptable), and a value of 0.80 – 1.0 (high reliability). Therefore, Cronbach's alpha values of 0.70 or higher indicate good internal consistency or reliability for a study.

Researchers at Brandeis University collected data from this study. The survey combined questions developed by Brandeis University with modified items from the United States Department of Education's High School Longitudinal Study of 2009 and the Barker, Nebraska, 4-H study. (Baker & Meier, 2006). The combined survey questions were known as the Project-Based Learning STEM Career and Interest Survey. The survey was administered to both FIRST and non-FIRST female high school participants. The researchers used the International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) to calculate Cronbach's alpha to assess the reliability of the Project-Based Learning STEM Career and Interest Survey. The developed instrument's Cronbach's alpha coefficient was 0.81. The Cronbach's alpha coefficient of 0.81 indicates high reliability. The coefficient indicates that the questionnaire has both a high correlation and internal consistency.

Operational Variables

This quantitative, non-experimental study employed an independent variable. The independent variable was the female high school STEM students who participated in the FIRST Robotics, which was coded as 1, and the independent variable for female high school STEM students who did not participate in the FIRST Robotics was coded as 0. The dependent variable in this study was the number of female students completing a college STEM degree in each group.

Study Procedures

Archival data from the Center for Youth and Communities at Brandeis University's Heller School for Social Policy and Management were used to investigate whether the FIRST Robotics project-based learning program increases the number of high school female students who participate in the program and pursue college degrees in STEM fields. The researcher needed approval requests from the Center for Youth and Communities at Brandeis University's Heller School for Social Policy and Management and from the IRB at National University. Upon approval from both departments at Brandeis University, the raw data from the longitudinal study were downloaded into an Excel spreadsheet. The data did not include any personal identification information (PII). A password-protected device was used to store all the information from the archival database.

Data Collection and Analysis

Once final approval was granted by the National University IRB and Brandeis University, the Brandeis University researcher provided the archival materials. The raw data was provided through a secure link at Brandeis University. Two files were provided: an Excel spreadsheet and an International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) syntax data document. The Excel spreadsheet contained the study survey variables and their labels. The SPSS data file contained the study participants' responses. The Brandeis SPSS data file was imported into the International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) version 23. The first statistical test selected was an independent t-test, which is used to determine whether there is a difference between two groups within a population (Laerd, 2018). However, upon examining the data, it was determined that Pearson's Chi-Square test was more appropriate than an independent samples *t*-test.

Although both the Pearson's Chi-Square test and the independent samples *t*-test are quantitative analyses designed to compare two subject groups, they differ in the type of data each test analyzes and the questions they address. The independent-samples *t*-test is used when the dependent variable is continuous, and the researcher aims to test differences between the two groups (Welsh, 2022). The test also assumes that the data are typically distributed, that the variances across groups are equal, and that the observations are independent.

In contrast, according to Elliott and Woodward (2020), Pearson's Chi-Square test is used when the data are categorical, and the aim is to determine whether there is a significant association between two groups. The two independent groups in this study are female high school STEM students who participated in the FIRST Robotics program. The second value was the female high school STEM students who did not participate in the FIRST Robotics program.

To fulfill the aims of this study and help answer the research questions, a Pearson's Chi-Square analysis was performed using International Business Machines' (IBM) SPSS software, version 23.

It is necessary to check three assumptions prior to performing a Pearson's Chi-Square analysis. In quantitative research methodology, Pearson's Chi-Square test compares two groups to assess whether the statistical distributions associated with each group and the frequencies of outcomes differ significantly (Vankelecom et al., 2024). Assumption number one: The one independent variable had two independent groups. Assumption number two: No relationship exists between the two groups. Assumption number three: All cells must contain more than five counts. Once these assumptions were validated, the Pearson's Chi-Square test was performed.

The condition of the application of a Pearson's Chi-Square test involved the two independent groups for this research: the female high school STEM students who participated in the FIRST Robotics program and the female high school STEM students who did not participate in the FIRST Robotics program. The second assumption for Pearson's Chi-Square test was that there was no relationship between the two groups. The female students in each group had different STEM experiences. One group participated in the FIRST Robotics program, while the other group's STEM experience took place in a science class. The third assumption for a Pearson's Chi-Square test is that each cell has a count of five or more. The cell count for the FIRST Robotics program was 60, and the cell count for the non-FIRST Robotics program was 46. All three assumptions were met, and the statistical test was performed using the International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) software version 23.

The raw archival data from female high school STEM students participating in the FIRST Robotics project-based learning program reveal that females are underrepresented in the program. The calculated Pearson's Chi-Square Statistic is a measure of statistical significance, known as the *p*-value (Bonate, 2000). If the *p*-value was < 0.05, the result was statistically significant, and the null hypothesis would be rejected. The *p*-value from this study was used to answer the research question: To what extent, if any, are there significant statistical associations in earning a college STEM degree for female college STEM students who participated in the FIRST Robotics project-based learning program in high school versus female college STEM students who did not participate in the FIRST Robotics project-based learning program in high school.

Assumptions

This study used archival data; therefore, the following assumptions were made. Initially, the researcher followed all procedures to ensure that every female high school student selected as a national participant was eligible to participate. Therefore, all female high school students participating in the FIRST Robotics project-based learning program, as well as those enrolled in math and science classes, were invited to participate in the study. Secondly, the FIRST Robotics project-based learning program was similar across all locations. This assumption assumes that all instructors have universal training experience.

Limitations

The emphasis of this study was to determine whether female high school STEM students participating in the FIRST Robotics project-based learning program correlates with higher numbers of female college STEM students earning STEM degrees. A multi-year study was conducted, and the archival data from the investigation were used for this research. The limitations of this investigation include potential weaknesses, biases, or factors beyond the researcher's control (Almalki, 2016). The first limitation of this study was the data-collection method. Therefore, the researcher did not collect the data and had no control over how archival data was originally collected. If participants do not complete the survey, the resulting data will be invalid and cannot be replicated.

The data collection process should be standardized to maintain the integrity of the results (Katyal et al., 2021). Secondly, the original investigators' potential biases could affect the raw data used in this investigation. This bias could skew the study's results. The third potential limitation was that the data were collected over ten years, during which some participants may have had missing or incomplete data.

Delimitations

Delimitations are important boundaries deliberately set by the researcher to define the scope of the research and can influence the study's parameters (Theofanidis & Fountouki, 2018). The researcher's acknowledgment of the delimitations also provides transparency about the survey. This study was limited to the FIRST Robotics project-based learning program to investigate whether female high school STEM students participating in the FIRST Robotics project-based learning program correlate with higher numbers of female college STEM students earning STEM degrees. Other similar project-based robotics programs exist for high school female students in the United States, but were not examined in this study.

Ethical Assurances

In research, addressing ethical issues is essential. The outline for addressing these ethical issues was crucial to maintaining the study's integrity. The Belmont Report requires researchers to observe each participant by respecting the person, acting in a beneficent manner, and adhering to the principles of justice (Fisher, 2011). The data received from the original researcher in the Brandeis study were archival in nature.

This study did not involve direct communication with the female participants, thereby mitigating the risk of harm to them. The encrypted data file received from the surveys did not contain Personal Identification Information (PII) for the participants. The data was shared in a de-identified form. Therefore, the raw data received were anonymized and kept confidential for female participants. I had no conflict of interest with the Brandeis University researcher, the participants, the participating organizations, or the administration at the time of data collection. The encrypted data file was transferred to a USB flash drive, and hard copies were stored in a secure location accessible only to the researcher for up to three years.

Summary

The selected quantitative correlational research design was tailored to this study's research problem, purpose, and questions. Both ethical and practical considerations were taken into account for this study, which investigated the differences in college STEM degree completion between female students who participated in the FIRST Robotics project-based learning program and those who did not. The alternative phenomenological methodology and causal-comparative design mentioned above were considered less suitable because they would not have provided crucial quantitative analysis or presented ethical, logistical, or conceptual difficulties that would have rendered them unsuitable for this research. The International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) software version 23 was used to perform a Pearson's Chi-Square test for this study's two independent variables (female high school STEM students participating in the FIRST Robotics project-based learning program and female high school STEM students not participating in the FIRST Robotics project-based learning program). Chapter 4 provides additional details and findings for the results of this study.

Chapter 4: Findings

The problem addressed in this study was the disparity in the rate at which female college STEM students earn STEM degrees, which is lower than that among their male counterparts (Vooren et al., 2022). Female college STEM student dropout rates are 23% higher than the male STEM student dropout rate (Priulla et al., 2021). Dennehy and Dasgupta (2017) found that female college students entering STEM majors are significantly underprepared for these fields. The FIRST Robotics Project-based learning program academically prepares female high school students for STEM degrees. A continued trajectory of low completion rates among female college and university students in STEM coursework will harm the United States' STEM workforce by widening the diversity gap in the STEM workplace (De Gioannis et al., 2023; Jiang et al., 2020). This urgent matter requires attention to identify where leaks in the female STEM pipeline occur, preventing female students from completing STEM degrees (Vooren et al., 2022).

The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. The independent variable in this study was female high school STEM students' participation in the FIRST Robotics project-based learning program, coded as 1 for participation and 0 for non-participation. The dependent variable was the number of female students who completed a college STEM degree. The study hypotheses are as follows:

H10

There are no statistically significant associations in the likelihood of earning a college STEM degree among female college STEM students who participated in the FIRST Robotics project-based learning program in high school compared to female college STEM students who did not participate in the FIRST Robotics project-based learning program in high school.

H1a

There are significant statistical associations between earning a college STEM degree and participating in the FIRST Robotics project-based learning program in high school among female college STEM students, compared with female college STEM students who did not participate in the FIRST program in high school.

All analyses were conducted using the International Business Machines (IBM) Statistical Package for the Social Sciences (SPSS) software version 23. The statistical analysis was evaluated using a p-value of 0.05. The assumptions required for data analysis of the Pearson's Chi-Square test are provided for the study. Finally, this chapter concludes with an evaluation of the findings and a summary of Chapter 4.

Chi-Square ($\chi 2$) **Statistical Assumptions**

Three assumptions must be satisfied before a Pearson's Chi-Square ($\chi 2$) test can be performed to yield valid results and reliable conclusions (Hu & Plonsky, 2021; Laerd, 2015). The first data assumption for Pearson's chi-square test of association is that the independent and dependent variables are nominal or ordinal (Laerd, 2023b). In the present study, both STEM degree graduation status (dependent variable) and FIRST versus non-FIRST participation (independent variable) were nominal-level variables. As a result, the first assumption was met. The second assumption was that the observations must be independent and not reliant on previous trials (i.e., they should not be related to one another). Each female high school student was enrolled in either the non-FIRST program or the FIRST Robotics project-based learning program. The female high school students were enrolled in two independent programs. There was no relationship between the independent groups in the study, and the students were unaware that they were participating. Therefore, the second assumption was met. The third assumption states that at least five counts must be represented in each cell. In Table 2, the counts for FIRST Robotics non-graduates and graduates were 126 and 60, respectively. The counts in Table 2 also include 46 counts for non-FIRST graduates and 172 counts for the number of students who did not graduate. Each cell in Table 2 represents more than five counts. Therefore, the third assumption was met.

Table 2

*FIRST or Non-FIRST (Comparison) * Graduates and Non-Graduates Crosstabulation*

Comparison	Non-Graduate Count		Graduate Count		Total Count
	Count	Expected Count	Count	Expected Count	
FIRST	126	137.2	60	48.8	186
Non-FIRST	172	160.8	46	57.2	218

Results

The Brandeis University researcher provided raw data from the FIRST Robotics longitudinal study in an Excel Spreadsheet, an SPSS syntax file for courses taken, and an SPSS data file. The de-identified data from the FIRST Robotics longitudinal study included information on the college outcomes of the 922 participants who remained in the study after 9 years. The dataset included information on gender, program affiliation, race, geography, honors classes, type of post-secondary school, questions regarding interest in STEM majors, and completion of declared STEM majors.

Descriptive Statistics

This study investigates 404 female high school STEM students participating in the FIRST Robotics project-based learning program; therefore, males were excluded from the analysis. A descriptive frequency statistics analysis for gender was conducted in SPSS. The males' data were filtered and excluded from the data set. This removed 518 male participants, as indicated in Table 3. This resulted in 404 female participants.

Table 3

Total FIRST and Non-FIRST Participants Across the Ten-Year Study

Participants by Gender	**N**	**%**
Female (used in the present analysis)	404	43.8
Male (excluded from analysis)	518	56.2
Totals	922	100

Note. Males were excluded from the current analysis. Total number of participants = 922. Total percentage = 100%.

After 10 years, 404 female participants remained in the study. Among these participants, 106 reported having completed a degree in the STEM field. However, a subset of 298 participants did not indicate in their survey whether they had obtained a college-level STEM degree, as provided in Table 4.

Table 4

Total FIRST And Non-FIRST Female STEM Degree Indicator

Degree Indicator	N	%
Indicated STEM Degree, Graduate	106	26.2
Did not indicate a STEM Degree	298	74

As shown in Table 5, 106 participants completed a STEM degree. This study includes both graduates from the FIRST Robotics project-based learning program and the non-FIRST comparison group. Sixty female high school students who enrolled in the FIRST Robotics project-based learning program went on to complete STEM degrees. In the non-FIRST comparison group, 46 female high school students graduated with STEM degrees.

Table 5

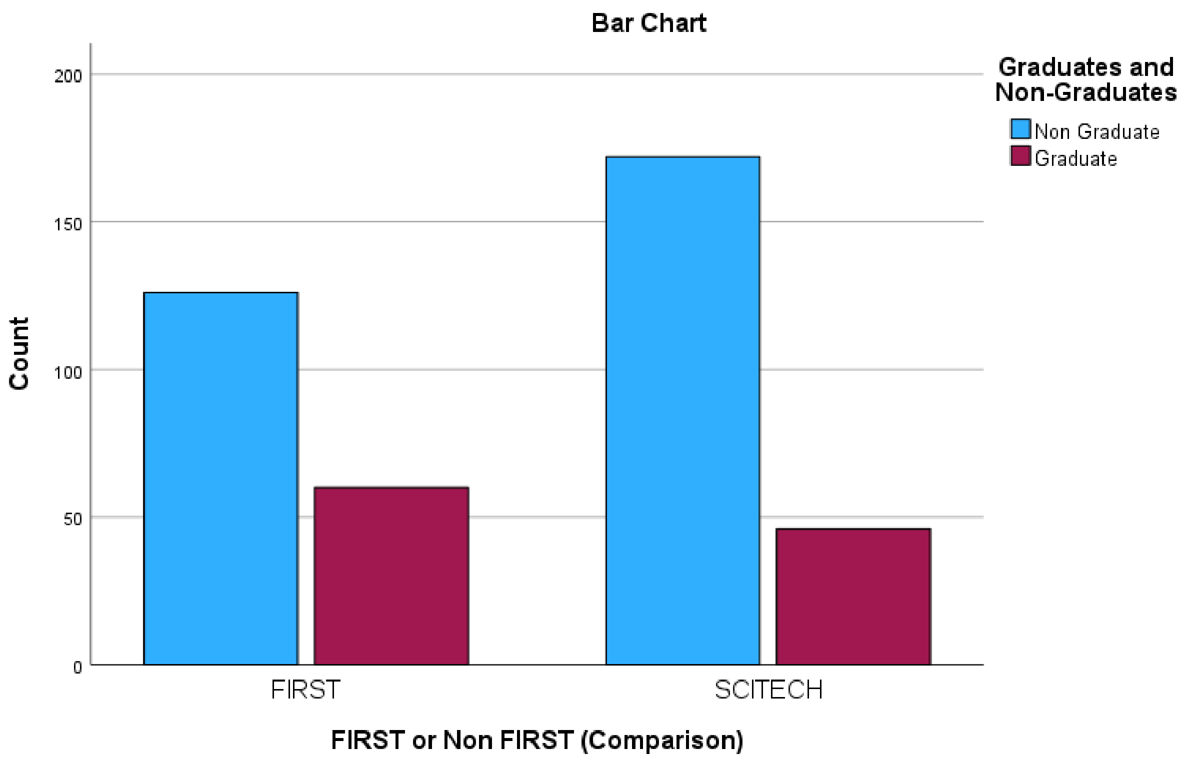
Female Demographics of FIRST and Non-FIRST STEM Degree and Non-Degree population

Degree and Non-Degree Population	FIRST	Non-FIRST
STEM Degree	60	46
Non-Degree	126	172

The FIRST STEM graduate group exceeded the calculated G* Power threshold. There were 60 female FIRST STEM graduates, which surpassed the calculated value of 52. In the non-FIRST participant group, only 46 female students completed a STEM degree, which was below the calculated minimum sample size of 52. However, 106 STEM graduates completed STEM degrees, exceeding the predicted value from the G*Power analysis. A visual representation of the female STEM graduates and non-graduates is provided in Figure 3.

Figure 3

Female FIRST and Non-FIRST Graduates and Non-Graduates



Pearson's Chi-Square Crosstabulation & Hypothesis Testing

This study aimed to determine whether there were significant associations between the number of earned STEM degrees and female students' participation in a high school FIRST Robotics project-based learning program, compared with those who did not participate nationwide. The following presents the crosstabulations, Pearson's Chi-Square statistic and its significance, the associated effect size, and risk estimates.

Graduates and Non-Graduates Crosstabulation. A cross-tabulation was performed for female high school STEM students who participated in the FIRST Robotics project-based learning program and those who did not participate (non-FIRST), along with the number of STEM graduates. Participants representing the FIRST Robotics project-based program included 186 female students. Participants in the exposed group were coded as 1 in SPSS for the Pearson chi-square test. The participants in a non-FIRST Robotics project-based program included 281 female students. Participants in the non-exposed group were coded as 1 in SPSS for Pearson's chi-square test. Female students in the graduate group were coded as 1, and female participants who did not complete a STEM degree were coded as 0. SPSS for Pearson's Chi-Square analysis.

Among the exposed participants, 60 of 186 (32.3%) earned a STEM degree, whereas 46 of 218 (21.1%) of the non-exposed participants did. The analysis confirms a higher percentage of STEM graduates among female participants in the exposed group. Additionally, Table 6 shows that the exposed female participants earned more STEM degrees than the non-exposed female participants. This association was statistically significant at the .05 alpha level (χ^2 (1) = 6.46, p = .01). Therefore, the null hypothesis was rejected. This indicated that participation in FIRST is significantly associated with completing a STEM degree. The results of Pearson's Chi-Square hypothesis test are provided in Table 6.

Association between Independent and Dependent variables. Table 6 presents the analysis of the strength of association between the two variables (exposed vs. non-exposed) among female STEM students and the number of female STEM students who complete a college STEM degree. The phi coefficient for the study's analysis was .126. The phi coefficient measures the strength of the association between two variables (Cui et al., 2016). A phi coefficient of 0.10 is considered a small association, 0.30 represents a medium association, and 0.50 represents a strong association. Pearson's Chi-Square analysis suggests an association between the two variables; the strength of this association is relatively weak, although significant at the .01 alpha level, which surpasses the a priori alpha level of .05. In other words, there was a weak positive association between participation in FIRST and subsequent graduation in a STEM degree. This association is statistically detectable; however, its practical impact may be limited. According to the phi estimate, about 1.6% of the variance in one variable is explained by the other. This confirms a minimal association, accounting for only a small proportion of the variation in STEM degree attainment. However, this is a noteworthy finding that warrants further investigation, as this study is the first of its kind to the researcher's knowledge.

Table 6

Pearson's Chi-Square Crosstabulation, Significance, and Effect Estimate

			FIRST and Non-FIRST Graduates		
Group	STEM Graduate N (%)	Non-Graduates N (%)	(χ2)	p-value	Phi
FIRST (N =186)	60 (32.3)	126 (67.7)	6.5	.01**	.126**
Non-FIRST (N =281)	46 (21.1)	172 (78.9)			

**Significant at the .01 alpha level

Risk Estimate. This study analyzed the association between female college students' exposure to the FIRST Robotics project-based learning program and their completion of a STEM degree. The risk estimates were calculated to compare graduation rates between the two participant groups. The risk estimates, including the odds ratio (OR), are presented. The odds ratio compares the probability of STEM graduation in the exposed group with that in the non-exposed group. The exposed group comprised the FIRST participants, and the non-exposed group comprised the non-FIRST participants. The odds ratio (OR) was 1.53 (95% CI: 1.10, 2.13), indicating that female students in the exposed FIRST program were approximately 53% more likely than females in the control group to graduate with a STEM degree. The confidence interval indicates that this relative increase could plausibly range from 10% to 113%. The risk estimates for the present study are provided in Table 7.

Table 7

Risk Estimate

Odds Ratio (OR)	Value	95% Confidence Interval	
		Lower	Upper
Exposed Graduate Group	1.53	1.1	2.13

Summary

The analysis yielded a Pearson chi-square statistic of 6.46 (p = 0.011), indicating rejection of the null hypothesis. Therefore, a significant association was found between the number of STEM degrees earned and female students' participation in the FIRST Robotics project-based learning program. The findings indicate that female participants in the FIRST Robotics project-based learning program in high school are more likely to graduate with a STEM degree. The results from this study demonstrate that participation in the FIRST Robotics program is positively associated with the fulfillment of STEM degrees. Chapter 5 summarizes the study, discusses the implications of the findings, and offers recommendations for practice and future research on how high school interventions can reduce barriers and increase female representation in STEM careers.

Chapter 5: Discussion, Recommendations, and Study Summary

The problem addressed in this study was the disparity in the rate at which female college STEM students earn STEM degrees, which is lower than that among their male counterparts (Vooren et al., 2022). Female college STEM student dropout rates are 23% higher than the male STEM student dropout rate (Priulla et al., 2021). Dennehy and Dasgupta (2017) found that female college students entering STEM majors are significantly underprepared for these fields. The FIRST Robotics Project-based learning program academically prepares female high school students for STEM degrees. A continued trajectory of low completion rates among female college and university students in STEM coursework will harm the United States' STEM workforce by widening the diversity gap in the STEM workplace (De Gioannis et al., 2023; Jiang et al., 2020). This urgent matter requires attention to identify where leaks in the female STEM pipeline occur, preventing female students from completing STEM degrees (Vooren et al., 2022).

The purpose of this quantitative correlational research design was to examine whether there are significant associations between the number of earned STEM degrees and participation in a high school FIRST Robotics project-based learning program, as well as those who did not participate in the FIRST Robotics project-based learning program across the United States. The study employed a non-experimental design and used secondary data from the Brandeis University study. The Brandeis University study originally included 1,273 high school students across the United States.

I obtained secondary statistical data from the Brandeis University study, which included numerical data on 106 female STEM graduates who participated in the FIRST Robotics project-based learning program and on those who did not. Concurrently, a quantitative methodology was selected over a qualitative methodology because it aligns with the analysis of statistical data. A correlational design enabled examination of associations between program participation and STEM degree completion.

While this study provides valuable insights into the association between participation in the FIRST Robotics project-based learning program and female STEM degree attainment, it is limited in its ability to establish causal relationships. The establishment of significant associations precludes causal inferences. Therefore, it cannot be determined whether participation in the FIRST Robotics project-based program directly influences the likelihood that female students attain a STEM degree. Therefore, the results should be interpreted as evidence of an association rather than a definitive causal effect.

The study's findings and implications for both theory and practice are provided in Chapter 5. The chapter begins with a concise review of the study's key findings, highlighting the statistical associations identified between participation in the FIRST Robotics project-based learning program and the attainment of STEM degrees among female college students. The interpretation of the results is presented in the context of the existing literature, explaining how the findings support, extend, or challenge prior research. The chapter concludes with a discussion of the study's limitations, implications for educational practice, and recommendations for future research to promote female participation and success in STEM fields.

Discussion

The study's results provided insight into the potential impact of participation in the FIRST Robotics project-based learning program on female students' attainment of STEM degrees. Analysis of the archival data indicated a positive association between program participation and the completion of a college STEM degree. The odds of program participants earning a STEM degree were higher than those of nonparticipants. Specifically, Pearson's chi-square test revealed a statistically significant association between STEM degree completion and the two groups, indicating that engagement in project-based learning experiences, such as the FIRST Robotics program, was a factor in this outcome. These results align with prior research emphasizing the value of project-based learning opportunities in fostering STEM interest and increasing persistence in completing a STEM degree among female students (Jung, 2020; Vooren et al., 2022).

The statistical significance of higher STEM completion rates among female FIRST participants has meaningful implications for the existing literature and for Bandura's theoretical framework. The study's results align closely with the stated problem and purpose. Pearson's Chi-Square test indicates that female FIRST participants are more likely to obtain STEM degrees than non-FIRST participants, which is a step forward toward addressing the study's problem and purpose. This alignment between the results and the study's problem and purpose supports the trajectory of female students receiving STEM degrees at the same rate as their male counterparts.

Research Q1

To what extent, if any, are there significant statistical associations in earning a college STEM degree for female college STEM students who participated in the FIRST Robotics project-based learning program in high school versus female college STEM students who did not participate in the FIRST Robotics project-based learning program in high school?

Hypotheses

H1a

There are significant statistical associations in the likelihood of earning a college STEM degree among female college STEM students who participated in the FIRST Robotics project-based learning program in high school, compared to female college STEM students who did not participate in the FIRST program in high school.

The higher STEM degree completion rates among female participants in the FIRST Robotics project-based learning program identified in this study have several implications and connections to existing research and theory. The findings align with the study's Research Question and the associated alternative hypothesis, which examined the statistical association between participation in the FIRST Robotics project-based learning program during high school and the likelihood of earning a college STEM degree among female students. Additionally, the results are lockstep with the alternative hypothesis, indicating a statistically significant association between program participation and STEM degree completion; therefore, the null hypothesis was rejected.

However, surprisingly, the association with the FIRST Robotics project-based learning program was relatively weak. The relatively weaker association observed in this study aligns with findings from previous research discussed in Chapter 2. Litzler et al.'s (2014) findings are parallel in that they address how a school's academic environment can unintentionally contribute to the gender gap. Additionally, Kalender et al. (2020) reported that low self-efficacy and modest college academic success are associated with female students. This surprising finding suggests that while participation in project-based learning programs, such as FIRST, may positively impact female STEM degree attainment, further research is needed to investigate additional factors that influence female students' intentions and persistence in completing STEM degrees. A detailed explanation of each implication derived from the study's conclusions is provided in the following table. The implications presented in Table 8 are structured around the research question and alternative hypothesis that underpinned the study.

Table 8

Implications

Research Questions	Implications
RQ: To what extent, if any, are there significant statistical associations in earning a college STEM degree for female college STEM students who participated in the FIRST Robotics project-based learning program in high school versus female college STEM students who did not participate in the FIRST Robotics project-based learning program in high school?	A. Female high school students are more likely to graduate from college with a STEM degree when they have participated in a project-based learning program similar to FIRST Robotics. B. Project-based learning programs similar to FIRST Robotics in high school are important for increasing the STEM degree attainment for female students.

Implication A: The study's findings align with the importance of providing female high school students with access to project-based learning experiences, such as the FIRST Robotics program. The program fosters STEM readiness for college-level STEM courses. Participation in project-based learning programs appears to enhance female students' confidence, problem-solving abilities, and technical skills, all of which are critical to success in postsecondary STEM education. This type of secondary educational experience highlights the value of project-based learning programs in high school curricula. Ensuring that female students are not only exposed to theoretical concepts of project-based learning programs but also have opportunities to apply their learning in real-world contexts.

Implication B. My study's findings also align with the idea that intentionally enrolling female high school students in a four-year, project-based STEM program, such as FIRST, plays a crucial role in preparing them for STEM college readiness. These actions are essential for female students to ultimately achieve a STEM degree. The research results affirm that participation in high school project-based learning programs contributes to female students' persistence in completing STEM degrees. Similarly, a female student's intention to complete a STEM degree is influenced by her prior high school project-based programs. These programs reinforce the importance of early structured STEM engagement in high school.

Contribute to Existing Literature.

The study's contributions to the existing literature by enhancing our understanding of how structured high school STEM experiences, particularly through programs like FIRST Robotics, impact long-term academic outcomes for female students pursuing STEM degrees. While earlier research has acknowledged the importance of female mentorship, bias in STEM courses, and early exposure to advanced academic classes in shaping STEM interest, few studies have provided empirical evidence on how project-based learning experiences associated with STEM degree completion are linked. By demonstrating a significant association between participation in the FIRST Robotics project-based learning program and persistence in STEM majors, this study offers a new perspective on gender and STEM degree completion in the literature. Evidence indicates that a STEM course with project-based learning opportunities not only increases interest in STEM but also has lasting effects on college success and degree attainment.

A significant difference in earned STEM degrees was observed between females who participated in a high school FIRST Robotics project-based learning program and those who did not participate in the FIRST Robotics project-based learning program. The results support Bandura's social cognitive theory. Wu and Cai's (2023) research aligns with the study's findings that female students who complete STEM-related degrees exhibit higher self-efficacy in project-based programs.

Litzler et al.'s 2014 research on high school females' interest in STEM courses aligns with this 2025 study, which incorporated a project-based learning pedagogy. This lockstep agreement has lasting effects on the college success and degree attainment of female students. Additionally, Hemelta et al. (2018) concluded that students who enrolled in consecutive courses in science, technology, engineering, and math (STEM) are more likely to choose a STEM major. However, the 2025 findings from this study extend Hemelta et al.'s contribution to the literature by showing that female students participating in high school project-based programs are more likely to pursue STEM degrees.

Recommendations for Practice

The findings from my study emphasize that high school project-based STEM experiences, when combined with targeted educational support systems, can significantly impact the academic trajectories and success of female students pursuing STEM degrees. Implications were drawn from my study's findings, leading to specific practice recommendations. Table 9 displays the suggested recommendations for the study's implications. A detailed explanation for each recommendation, which educators can access for ongoing evaluation in the design and implementation of high school project-based learning programs to support meaningful and sustained participation among female students.

Table 9

Implications and Recommendations for Practice

Implications	Recommendation for Practice
A. Female high school students are more likely to graduate from college with a STEM degree when they have participated in a project-based learning program similar to FIRST Robotics.	1. High schools should have project-based learning programs, such as FIRST, on a nationwide scale.
B. Project-based learning programs similar to FIRST Robotics in high school are important for increasing the STEM degree attainment for female students.	2. Superintendent, principals, and Career and Technology Education (CTE) directors should develop mandatory professional development to ensure all counselors and educators are aware of project-based learning programs.

Recommendation 1, based on Implication A, suggests that my findings highlight the importance of providing female high school students with access to project-based learning programs, such as FIRST Robotics, which is critical. The program provides a means of fostering STEM readiness in preparation for college-level STEM courses. Kalender et al. (2020) reaffirm the continued relevance of Bandura's social cognitive theory in analyzing female college students' self-efficacy and motivational beliefs regarding the attainment of a STEM degree. Participation in project-based programs appears to enhance students' confidence, problem-solving abilities, and technical skills, which are critical for success in postsecondary STEM education. Increasing the number of female high school students exposed to project-based programs increases the likelihood of addressing the study's problem of the low number of females completing STEM degrees.

Recommendation 2, based on Implication B. Implication B includes professional development for high school district administration. The high school district administration collaborators include area superintendents, principals, and Career and Technical Education (CTE) directors. The development of mandated professional development for high school educators and counselors highlights the importance of incorporating project-based learning programs, such as FIRST, into high school curricula. The high school district-level collaborations provide the first link in the pipeline for increasing the recruitment of female high school students into project-based learning programs. Hunt et al.'s (2021) findings support Recommendation A, indicating that targeted changes in STEM classrooms can increase the likelihood of future STEM academic success among high school female students. This exposure to project-based learning programs not only introduces theoretical STEM concepts but also provides opportunities to apply their learning in real-world early STEM settings.

Training educators to effectively implement project-based learning and support female students in STEM can enhance program outcomes and foster a supportive learning environment. Continuous evaluation of these programs is recommended to assess effectiveness and to inform improvements. By systematically analyzing participation data and academic achievement, district collaborators can refine curricula to maximize student engagement, skill development, and persistence in achieving a STEM degree.

Recommendations for Future Research

This study offers valuable insights into the association between participation in the FIRST Robotics project-based learning program and female attainment of STEM degrees. However, several recommendations are proposed for future research, thereby contributing to the existing body of knowledge on this topic. The first recommendation is to use a qualitative methodology with a phenomenological design. The second recommendation is to use a qualitative methodology with an action research design. The final recommendation for future research is to use a quantitative methodology with a causal-comparative design. Table 10 outlines the recommendations for future studies based on the findings from my study. The table includes the methodology, design, and purpose for each type of future study.

Table 10

Recommendations for Future Research

Methodology	Design	Purpose
Qualitative	Phenomenological	The researcher collects the lived experiences of female students in higher education, exploring their personal stories of persistence as STEM majors and their success.
Qualitative	Action Research	The researcher collaborates with High School superintendents, principals, and CTE directors, as well as with institutions of higher education, to implement and evaluate interventions that increase female participation and persistence in STEM degree completion.
Quantitative	Causal-Comparative	The researcher examines causal relationships between participation in project-based learning programs and STEM degree attainment, providing more substantial evidence of program effectiveness.

Qualitative Methodology with Phenomenological Design. A phenomenological qualitative study enables the researcher to explore the lived experiences of female students participating in project-based programs, such as FIRST Robotics. By focusing on students' personal experience, perceptions, and reflections, this design can provide deeper insight into how participation in project-based learning shapes their interest, confidence, and decision-making regarding completing a STEM degree. Understanding these experiences from the students' perspectives may reveal nuanced factors, such as mentorship, study dynamics, and problem-solving opportunities, that contribute to persistence in completing a STEM degree. The findings could inform educators and curriculum developers on strategies to enhance female engagement and success in STEM education.

Qualitative Methodology with an Action Research Design. An action research design would enable researchers to collaborate with institutions of higher education and high school district administrators to implement targeted interventions to improve female participation and retention in project-based programs. This design emphasizes iterative cycles of planning, action, observation, and reflection, which allows researchers to evaluate the effectiveness of specific strategies in real-world educational settings. By integrating research and practice, action research can help identify best practices in curriculum design and guide the design of project-based learning structures. This research design directly supports STEM outcomes for female students while also contributing to the broader evidence base.

Post-secondary experiences have implications for STEM degree retention and completion. Universities and colleges may benefit from establishing transition programs or bridge courses that build on prior project-based learning experiences, through mentorship, tutoring, and STEM-focused extracurricular opportunities to support female students as they navigate the demands of post-secondary education. Collaborative partnerships between high schools and higher education institutions can further enhance completion rates for female students by providing applied experiences that reinforce classroom learning and sustain their engagement in STEM courses.

Quantitative Methodology with a Causal-Comparative Design. A quantitative experimental causal-comparative design allows researchers to rigorously examine the causal link between participation in project-based learning programs and female attainment of STEM degrees. Experimental research enables the random assignment of participants to intervention and control groups, allowing for the testing of independent and dependent variables. By randomly assigning participants to intervention and control groups, this approach can control extraneous variables and offer strong evidence of program effectiveness. Such research could evaluate outcomes like STEM course performance, degree completion, persistence, and self-efficacy in problem-solving and teamwork. Results from these studies would provide valuable evidence to support recommendations for educators, program managers, and policymakers seeking to increase female representation and success in STEM fields.

Study Summary

The problem addressed in this study was the disparity in how female college STEM students earn STEM degrees, which occurs at a lower rate than among their male counterparts (Vooren et al., 2022). Female college STEM student dropout rates are 23% higher than the male STEM student dropout rate (Priulla et al., 2021). Studies show that female college students entering STEM majors are significantly underprepared. The FIRST Robotics Project-based learning program academically prepares female high school students for STEM degrees. A continued trajectory of low completion rates among female college and university students in STEM coursework will harm the United States' STEM workforce by widening the diversity gap in the STEM workplace (De Gioannis et al., 2023; Jiang et al., 2020). This urgent matter requires attention to identify where leaks in the female STEM pipeline occur, preventing female students from completing STEM degrees (Vooren et al., 2022).

The study's investigation was critical in understanding the association between participation in the FIRST Robotics project-based learning program and the attainment of STEM college degrees among female students in the United States. Utilizing a quantitative correlational research design, the study identified a statistically significant association between program participation and STEM degree attainment. Female students who participated in the program were more likely to earn a STEM degree than their peers who did not participate, highlighting the potential benefits of experiential, hands-on STEM learning opportunities during high school.

The findings contribute to the existing literature on gender disparities in STEM education by providing empirical evidence that targeted project-based learning programs can support female students in pursuing and completing STEM degrees. The study also offers practical implications for educators, administrators, and policymakers seeking to foster equitable STEM pathways through accessible and engaging programs.

Although limitations related to the study design, data source, and generalizability were acknowledged, the results provide a foundation for future research exploring causal mechanisms, program components, and the long-term outcomes of STEM interventions. Overall, the study highlights the importance of project-based learning experiences in promoting female participation and persistence in STEM fields, underscoring the need for ongoing support of programs that empower female students in STEM education.

Overall, the study's findings highlight the potential of targeted, project-based learning programs to narrow gender disparities in STEM degree attainment, suggesting that high school participation in such programs may have a lasting impact on college outcomes. The continued, systemic inclusion of project-based learning programs in high school curricula increases the odds that more female students will attain STEM degrees and help address the gender gap in STEM professions.

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Appendix A

IRB Approval (Notice of Exemption)

National UNIVERSITY

9388 Lightwave Ave.
San Diego, CA 92123
irb@nu.edu

Notice of Exemption

November 4, 2024

To: Deetrice Wallace

Project Title: A Quantitative Study of a Comparison Between Female High School STEM Students Completing the FIRST® Robotics Project-Based Learning Program and Earning a STEM College Degree
NU IRB Number: IRB-FY24-25-49
Determination: Exempt from further review 45 CFR 46.101 Category 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Status: Active - Research activities may begin as of November 4, 2024

Dear Deetrice Wallace:

The study referenced above has been reviewed by the National University IRB. The IRB has determined your research is exempt from further review under 45 CFR 46.104, which means you will not need to renew your study and may begin your study effective immediately. However, if you find the need to change your study in any way, you will need to submit a modification to the IRB prior to implementing the changes. This will allow the IRB to determine whether or not the study still meets exemption criteria.

Please review your Post Approval Responsibilities here: Approved Documents Guidelines

For any questions regarding your protocol, please reach out to the IRB at irb@nu.edu.

Sincerely,

Dr. Joseph Marron, IRB Chair

Dr. Brianne Mongeon, Director, HRPP & IRB

Jenessa Eberhardt, Associate Director, HRPP & IRB

Appendix B

Brandeis University Data Sharing Document

Brandeis | THE HELLER SCHOOL FOR SOCIAL POLICY AND MANAGEMENT Institute for Economic and Racial Equity

FIRST Longitudinal Study – Use of Data Requirements

Data from the final year of the 10-year FIRST Longitudinal Study (see the detailed variable list in the Appendix) may only be used for the purposes of the following project:

> A study comparing female high school STEM students completing the *FIRST*® Robotics project-based learning program with those earning a STEM college degree.

Any other use is not permitted without the prior written agreement of Brandeis University and *FIRST*.

If Dee Wallace (the requestor) wishes to publicly disseminate any materials that are prepared using these data, the requestor must first receive prior written (email) approval from Brandeis University and *FIRST*.

- The *FIRST* Longitudinal Study shall be cited as the data source in all materials, and the requestor shall be cited as the source of any interpretations and calculations. The requestor shall include the following excerpt with any public release using *FIRST* Longitudinal Study data.
    - *"The research presented here utilizes confidential data from a multi-year longitudinal study measuring STEM-related impacts conducted by Brandeis University Center for Youth and Communities in partnership with FIRST. The views expressed here are those of the author(s) and do not necessarily represent those of Brandeis University or FIRST, or other data contributors. Any errors are attributable to the author(s)."*

Required attachments:

- List of specific variables to be shared and year of data collection

Data would only be shared in de-identified form.

Dee Wallace 11/14/2024

Dee Wallace, Requestor Date

T. Meschede November 13, 2024

Tatjana Meschede, Principal

IERE

Brandeis | THE HELLER SCHOOL FOR SOCIAL POLICY AND MANAGEMENT Institute for Economic and Racial Equity

Investigator Date

Appendix 1: Variable List

Variable	Label
ID	Serial Number
SCITECH	FIRST or SciTech (Comparison)
Gender	Gender
income	Income
Race	Race
Asian	Asian dummy var
Black	Black dummy var
White	White dummy var
non_white_minus_asian	Non White not including Asian
hispanic	Hispanic Origin
ESL	ESL status
honors	Any honors courses during HS
pa_geogr1	Would you describe the place where your child generally lives as urban, suburban, or rural?
Q114	Which of the following best describes your situation
Q117	What type of institution is this school?
Q119	Did you attend college on a full-time or a part-time basis? (please check one)
Q193	What was your student status
Q154_1	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Arts and Humanities (Art, English, History, Music, Theater, etc.)
Q154_2	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Biological Sciences (Biology, Biochemistry, Environmental Science, etc.)
Q154_4	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Business (Accounting, Finance, Marketing, etc.)
Q154_3	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Computer Science/ Programming

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Q154_5	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Education
Q154_6	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Engineering (Civil, Chemical, Electrical, Mechanical, etc.)
Q154_7	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Health Professions (Nursing, Medicine, Pharmacy)
Q154_8	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Mathematics
Q154_9	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Physical Sciences (Astronomy, Chemistry, Physics, etc.)
Q154_10	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Social Sciences (Anthropology, Economics, Psychology, Sociology, etc.)
Q154_11	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Technical/ Vocational (Building trades, drafting, mechanical trades, etc.)
Q154_12	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Other Professional Fields (Architecture, Law, Criminal Justice)
Q154_13	What types of courses did you take this year? Please check the subject areas in which you took at least one course (select all that apply) Did not take any of these courses
Q157_1	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Arts and Humanities (Art, English, History, Music, Theater, etc.)
Q157_2	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Biological Sciences (Biology, Biochemistry, Environmental Science, etc.)
Q157_4	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Business (Accounting, Finance, Marketing, etc.)
Q157_3	You indicated you took courses in the following areas, please tell us the number of courses you completed. -

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	Computer Science/ Programming
Q157_5	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Education
Q157_6	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Engineering (Civil, Chemical, Electrical, Mechanical, etc.)
Q157_7	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Health Professions (Nursing, Medicine, Pharmacy)
Q157_8	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Mathematics
Q157_9	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Physical Sciences (Astronomy, Chemistry, Physics, etc.)
Q157_10	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Social Sciences (Anthropology, Economics, Psychology, Sociology, etc.)
Q157_11	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Technical/ Vocational (Building trades, drafting, mechanical trades, etc.)
Q157_12	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Other Professional Fields (Architecture, Law, Criminal Justice)
Q157_13	You indicated you took courses in the following areas, please tell us the number of courses you completed. - Did not take any of these courses
Q128_1	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Arts and Humanities (Art, English,F40.2
Q128_2	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Biological Sciences (Biology, BiocF40.2
Q128_3	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Business (Accounting, Finance, MarF40.2

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Q128_4	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Computer Science/ Programming
Q128_5	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Education
Q128_6	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Engineering (Civil, Chemical, ElecF40.2
Q128_7	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Health Professions (Nursing, MedicF40.2
Q128_8	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Mathematics
Q128_9	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Physical Sciences (Astronomy, ChemF40.2
Q128_10	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Social Sciences (Anthropology, EcoF40.2
Q128_11	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Technical/ Vocational (Building trF40.2
Q128_12	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Robotics
Q128_13	How interested are you in majoring in each of the following fields in college? Please mark one response in each row using the scale from 1 (Not interested at all) to 7 (Very interested) or "Already declared this major". - Other

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Professional Fields (ArchiteF40.2

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