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Examining women's persistence in stem: a mixed methods study of autonomy, competence, relatedness, and sociocultural influences on women in science, technology, engineering, and mathematics

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EXAMINING WOMEN'S PERSISTENCE IN STEM: A MIXED METHODS STUDY OF AUTONOMY, COMPETENCE, RELATEDNESS, AND SOCIOCULTURAL INFLUENCES ON WOMEN IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

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Kay Davis, Ed.D. – Dissertation Chairperson

This dissertation, written by

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under the guidance of a Faculty Committee and approved by its members, has been submitted to and accepted by the Graduate Faculty in partial fulfillment of the requirements for the degree of

DOCTOR OF EDUCATION

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To my parents, Dr. Roy Hirofumi Saigo and Dr. Barbara Jean Woodworth Saigo, for being outstanding examples of scholarship and perseverance. To my children, Jade Toshiaki Saigo, Andrew Hirofumi Saigo, and Nico Midori Saigo, for their patience, love, and teamwork. To my siblings, Holly Harumi Saigo and Dustin Toshiro Saigo, for their unwavering support. I love you!

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I also thank Dr. Paul Sparks and Judge John Tobin for their encouragement and support during my time at Pepperdine. Finally, I give heartfelt thanks to my fellow students. It was a difficult journey, but I am glad we did it together.

VITA

HEATHER MIDORI SAIGO

EXPERIENCE

Adjunct Assistant Professor, Southern Oregon University, March 2017 – Present

- Teaching multidisciplinary environmental science courses, including biology and earth science labs.
- Connecting with students from diverse backgrounds using flexible, accessible teaching tools and methods.
- Designing new series of 400-level courses, featuring peer collaboration, immersive field activities, and service learning projects.
- Engaging students in traditional learning settings and online environments to meet learning objectives.

Consultant, November 2005 – Present

- Crafting innovative information products for education, nonprofit, and business clients.
- Building effective websites and customizing communications to teach and inform.
- Authored 20+ academic lessons published by Study.com, delivering understandable science information to online audiences.
- Designed and deployed content for social media audiences of 100,000+.

Director of Philanthropy, Communications, and Media, ScienceWorks Hands-on Museum, January 2020 – March 2021

- Developed and executed communications strategies to build relationships with constituent groups, including schools, patrons, donors, and journalists.
- Raised $50,000 to initiate ScienceWorks Everywhere, a program to distribute activity kits to students for remote hands-on science education during pandemic.
- Contributed science expertise to support museum programs, exhibits, grant proposals, and camp curriculum.
- Directed production of multimedia content to maintain online engagement during COVID-19 closure.

Membership Stewardship Manager, Oregon Shakespeare Festival, October 2019 - March 2020

- Implemented rolling renewal and marketing campaigns for 15,000 member households to support nonprofit theater.
- Instituted new tracking practice for 3-person team to streamline development projects.

Marketing Coordinator, National Geographic Toys/JMW Sales, November 2018 - October 2019

- Developed and launched company's first-ever content marketing and social media influencer program.
- Contributed science content expertise to development of 10+ products and STEM activity guides.
- Originated online content platform to support toy sales with downloadable science activities.
- Led three video production projects, including casting, on-set leadership, post-production.

Audience Development Manager, Oregon Shakespeare Festival, February 2018 - November 2018

- Cultivated relationships with 120+ influential community leaders to improve reach, representation, equity, and inclusion.
- Planned and hosted events for patron groups, including lodging, performances, conferences.

- Project-managed major crisis fundraising campaign, resulting in $2 million in contributions.

Website Services, Executive Assistant, Office Manager, Think Network Technologies, April 2015 - August 2016
- Delivered website creation services, social media management, project management, and bookkeeping.
- Ensured smooth functioning of office operations by streamlining processes, reducing costs.

Business Transcriptionist, Net Transcripts, September 2005 - July 2007
- Fulfilled transcription requests for meeting recordings with 99% accuracy within given time frame.

Dental Enrollment Coordinator, United Concordia Companies Inc., February 1998 - May 1999
- Processed applications to enroll patients into dental plans efficiently and effectively.
- Reduced time to complete process by developing customer enrollment templates.

Administrative Assistant, Temporary Staffing Agencies, October 1997 – February 1998

Client Services Manager, CML Financial Group, Inc., February 1997 - October 1997
- Developed processes to sell and service customer insurance and investment accounts efficiently.
- Established firm's online presence by creating its first website.

Graduate Assistant, School of Public and Environmental Affairs, Indiana University, August 1994 - July 1996
- Collaborated with faculty and staff to develop department's first website.
- Built website from the ground up using HTML.

Teaching Assistant, Biology, Willamette University, August 1993 - May 1994
- Assisted undergraduate biology students with dissections, microscopy, field work.
- Guided students to better understand biological concepts by leading labs and teaching core subject matter.

Summer Biomedical Research Assistant, University of Oklahoma Health Sciences Center, June 1993 - July 1993
- Conducted research activities including bacterial cultures, ELISA, and Western Blot tests.
- Maintained laboratory safety and sanitation, recordkeeping, and reporting processes.

EDUCATION

Master of Science in Environmental Science, Indiana University, Bloomington, Indiana
Bachelor of Science in Biology, Willamette University, Salem, Oregon
Doctor of Education in Learning Technologies, Pepperdine University, Malibu, California

PROFESSIONAL INVOLVEMENT

National Science Teaching Association
Association for Educational Communications and Technology
Center for Self-Determination Theory
Mensa International

ABSTRACT

Several decades of effort have improved the participation of women in science, technology, engineering, and mathematics (STEM), but the gender gap remains. Researchers have found diverse reasons for women's underrepresentation in STEM, but less is understood about factors supporting persistence. This study's purpose was to understand how women persist in STEM, through the lens of self-determination theory. Self-determination theory posits that persistence improves when one's needs for autonomy, competence, and relatedness are satisfied. This embedded mixed methods study provides evidence of how autonomy, competence, relatedness, and sociocultural factors influence women's persistence in STEM. Using network and snowball sampling, the researcher recruited 641 diverse women with 6+ years of STEM experience for an anonymous online survey. The instrument included the 24-item Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) and several open-ended questions. Statistical analyses resulted in findings of high satisfaction and low frustration levels of autonomy, competence, and relatedness among the STEM persisters. Competence was rated highest in satisfaction and relatedness rated lowest in frustration. Significant associations were found between persistence and the combined satisfaction of autonomy, competence, and relatedness, as well as for the satisfaction score for competence. Educational attainment level, race, living in a rural area, and occupation also showed significant associations with persistence. Thematic analyses of narrative responses revealed qualitative support for the BPNSFS results, including 17 satisfaction themes, with the most prevalent being social support, communal benefit, enjoyment, and self-efficacy. Ten frustration themes emerged, with the most prevalent being lack of relatedness and lack of knowledge. In addition to affirming the influence of autonomy, competence, and relatedness, participants' narratives indicated six sociocultural themes, including discrimination and bias, and career and money. By integrating quantitative and qualitative findings, four conclusions were determined. First, that women in the study were highly satisfied overall, and second, that they have persisted despite negative experiences with discrimination and bias. Third, organizations must support women's autonomy, competence, relatedness, and financial equity to promote persistence. Finally, there are career trajectory points where risk of attrition is more likely to occur. Recommendations include programs to promote women's interest, self-efficacy, and belonging in STEM.

Chapter One: Study Introduction

> I thought gender discrimination in STEM was an outdated idea. Now that I've progressed further… I've witnessed and experienced the fact that women are still at a disadvantage in STEM, and we need to fix this.
>
> — Study participant

Science, technology, engineering, and mathematics (STEM) education is vital for the United States' continuing productivity and leadership in research and innovation. The increase in jobs requiring STEM-capable workers creates demand for well-educated people in diverse economic sectors. STEM opportunities include jobs in traditional science and engineering industries as well as increasing numbers of entry-level and technical positions (National Science Board, 2018). Therefore, it is crucial to address the need for workers by retaining STEM-interested students from K-12 through college and into careers.

Improving women's persistence in STEM has benefits for individuals and society. Not only does STEM training result in better workforce preparation for employers, but it also provides higher-paying jobs for workers (Burke et al., 2022). STEM literacy is viewed as a measure of national future-readiness (Timms et al., 2018), and most developed countries are now prioritizing STEM knowledge and skills (Julià & Antolí, 2019). Internationally, the United Nations declares that inclusive, equitable, quality education is one of its 2030 Sustainable Development Goals (United Nations, n.d.-a), which were ratified by all members of the U.N. in 2015 (United Nations, n.d.-b). Clearly, there is broad agreement on the need for worldwide STEM education.

In the past few decades, the U.S. has implemented several programs intended to improve STEM education and training. For example, the American Association for the Advancement of Science (AAAS) presented *Project 2061: Science for All Americans* in 1989 with the broad goal of improving general science literacy (Rutherford & Ahlgren, 1990). Organizations such as the

AAAS, National Research Council (NRC), and National Science Teachers Association (NSTA) produced subsequent iterations of science education standards and benchmarks to encourage progress toward goals (National Research Council, 2012). In 2013, the state-led Next Generation Science Standards (NGSS) were introduced and adopted widely (National Research Council, 2012). These programs represent efforts at local and national levels to address the need to produce STEM-capable workers over the past several decades.

Despite these and other programs intended to improve STEM education, the U.S. Government Accountability Office reports that employers in 80% of local areas have had trouble finding qualified candidates for technical jobs (Government Accountability Office, 2013). After 40 years of STEM education improvements, the National Science Board reiterated an urgent call for investment in science and engineering in 2020, citing America's decreasing share in global research and development (National Science Board, 2020). While some of the talent deficit is being mitigated by employing foreign-born workers (National Science Board, 2020), there are great opportunities to meet that need with homegrown employees. As technologies evolve, new job types will be created, requiring employment-ready people, and STEM-supportive programs and policies. Providing solid foundational STEM education is part of the solution to the problems of STEM literacy and STEM-capable employees.

Women's Underrepresentation in STEM is a Complicated Problem

While progress has been made in curricular updates, there are continuing gaps in representation among women and minoritized groups in STEM (Kang & Kaplan, 2019). Women are underrepresented in STEM careers, which means they occupy a lower proportion of STEM jobs than expected, based on their proportion of the general population (National Science Board, 2020; Noonan, 2017). Although women hold nearly half of all jobs across the United States employment landscape, they occupy only one-quarter of jobs in STEM fields (Noonan, 2017; A. M. Petersen, 2014). For underrepresented minority women, the gender gap is even more pronounced. While underrepresented minority women compose 15% of the U.S. population, they hold only 4% of jobs in STEM (Guy & Boards, 2019). This disparity represents a barrier to career achievement and financial independence, since women in STEM jobs earn more money than women in other fields (Goris, 2020; Noonan, 2017). The lack of women also may hinder overall innovation and productivity at the national level due to women's attrition from STEM fields and the resulting loss of talent (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007; National Coalition for Women and Girls in Education, 2022; National Science Board, 2020). The National Science Board recommends nearly doubling the participation of women in science and engineering careers to achieve a representative workforce and meet the need for workers by 2030 (National Science Board, 2020). Achieving greater participation of women in STEM will require better retention throughout educational and career pathways.

To improve the persistence of women across STEM-related industries, it is critical to investigate factors that may help retain women in STEM. The process of developing STEM-capable employees from early education through career choices is commonly referred to as the STEM pipeline (Blickenstaff, 2005). The simple pipeline analogy imagines the intake of young people at one end, carries them through a career development track of schooling and credentialing, and releases them into STEM careers at the other end. Differences in group representation in STEM careers are then attributed to a "leaky pipeline," as though there are places in the process where some participants fall out. Other metaphors may be better descriptors for the process. For example, the STEM career development process may be referred to as a colander, which is designed to retain some while hastening the removal of others (Roulson, 2022). Another metaphor for STEM career development is a highway or path with multiple entrances and exits (Espinosa, 2011; A. J. Fisher et al., 2019). The language used to describe STEM career development reflects different assumptions about whether women belong in STEM and are underrepresented by accident (leaky pipeline), or whether the design of the system (colander) contributes to the outcome.

While young students seem equally capable in STEM subjects, the gender gap between boys and girls widens throughout the school years (Bindis, 2019; Wang & Degol, 2017). At the college and graduate school levels, women are more likely than men to earn degrees, but less likely to pursue STEM degrees (Amon, 2017). The disparity is remarkable among college graduates, with women holding only 30% of STEM degrees, despite graduating at almost the same rate as men (Noonan, 2017). In higher education leadership roles, the gap is more pronounced (Hill et al., 2016; Litmanovitz, 2011), with women occupying only 27% of department chair and dean positions (Amon, 2017). The gender gap in STEM leadership positions is not only evident in academia but is observed across corporate and industrial sectors (Noonan, 2017; Sterling et al., 2020). The presence of a STEM gender gap from early education through top levels of leadership invites investigation into the causes and effects of women's underrepresentation.

Understanding that boys and girls start school with similar abilities in STEM and soon show signs of diverging participation, researchers have asked what factors contribute to higher attrition among girls and women. Previous research attributes this disparity to several possible causes, including persistent gender biases favoring men (Amon, 2017; Andrus et al., 2018; Moss-Racusin et al., 2012, 2018), lack of self-efficacy among girls and young women (Orenstein

& American Association of University Women, 1994), lack of role models and mentors in STEM fields (Amon, 2017), and a lack of a sense of belonging in the STEM community (Dasgupta & Stout, 2014; Good et al., 2012; Goris, 2020; M. Z. Moore, 2020; Xu & Lastrapes, 2021). Research has found that gender discrimination contributes to women's underrepresentation, but its effects have lessened somewhat in recent decades (Ceci et al., 2014). Some studies show that women now achieve advanced degrees at greater rates than men in certain STEM subdivisions, narrowing the overall gender gap (Wang & Degol, 2017), and suggest that discriminatory practices are no longer the primary cause of underrepresentation (Ceci et al., 2014; Ceci & Williams, 2011; D. I. Miller & Wai, 2015). Despite making gains in fields such as life sciences, women are still steeply underrepresented and less persistent than men in math-intensive fields such as engineering and physics (Buse et al., 2013; Glass et al., 2013; Kahveci et al., 2006; Smith, 2011; Zeng & Duncan, 2007). Even with improvements in some areas of education and employment, there is still work needed to understand why women remain underrepresented in STEM.

To understand the full context of women in STEM, it is important not only to consider their underrepresentation, but also to investigate the conditions that support their persistence. The changing proportions of women earning degrees and continuing in STEM careers invite additional research into possible explanations for women's persistence and success. It is not known why some women persist in STEM education and careers and others do not. The existing literature reveals competing and contradictory explanations for women's underrepresentation in STEM, but there are fewer studies offering explanations for women's successful persistence in STEM careers. There is an incomplete understanding of how the constructs of Ryan and Deci's (2020) self-determination theory -- autonomy, competence, and relatedness -- converge with extrinsic influences to enable some women to persist while others fail. By studying women who persist, the researcher aims to understand factors contributing to their successful persistence. The findings may then help educators and organizations to create more supportive systems for women in STEM.

Problem Statement

While reasons for the degree and causes of women's underrepresentation continue to be debated, there is agreement on the existence of a gender gap between men and women in STEM. Although there are signs of improving gender parity, women – especially underrepresented minority women – still obtain fewer advanced degrees and hold fewer leadership positions than men (Ong et al., 2011). A recent report found that even in STEM subfields where women are not underrepresented, such as biology, they may face cultural obstacles and receive fewer leadership appointments (McCullough, 2020; National Coalition for Women and Girls in Education, 2022).

The goal of this study is to quantitatively assess whether autonomy, competence, and relatedness are associated with women's persistence in STEM. Deci, one of the founders of self-determination theory, suggests it is more valuable to create environments in which people will develop intrinsic motivation, rather than devise external motivational controls (Ryan & Deci, 2020; TEDx Talks, 2012). In other words, instead of trying to create better external rewards and controls, research is needed to learn what environmental conditions allow women to create their own motivation to persist. Toward that end, the data gathered in this study will be used to determine whether autonomy, competence, and relatedness are factors in persistence for the participants. By combining the scale measurements of these factors with demographic data, the researcher will learn whether these variables are connected.

This study will also provide insight into the lived experiences of women who persist in STEM. By collecting and analyzing narrative data from participants, the researcher will gain understanding of what it is like to be a woman persisting in a STEM field. Since participants are all women who study or work in STEM, the results will shed light on how they manage to defy the odds and stay in STEM. The study will also allow women to share what obstacles they encounter and strategies they use to overcome them. Learning about the participants' challenges may highlight areas of attrition risk, which will be useful in helping others prepare for and navigate their own professional pathways. The findings of this study will be valuable to women in STEM and the educators, administrators, industry leaders, and policymakers who influence the STEM landscape. They may use the insights from this study to create environmental conditions that foster better persistence for women in STEM.

Research Purpose and Research Questions

The aim of this study is to explore career persistence among women currently in STEM jobs or those who have experienced at least six years within STEM education or work. This is to include women who complete an undergraduate degree in STEM, and who are continuing in graduate education or a career in a STEM field.

Research Questions

- RQ1: What are the levels of autonomy, competence, and relatedness of women who have persisted in STEM?
- RQ2: What experiences and influences contribute to women's persistence in STEM?
- RQ3: How do women explain various sociocultural influences on their persistence in STEM?

- RQ4: How do women's experiences align with their levels of autonomy, competence, and relatedness?

Methodology and Design

A concurrent, embedded mixed methods design (Creswell & Creswell, 2018) was used to collect both quantitative and qualitative data using one survey instrument. The quantitative data collected includes items from the *Basic Psychological Need Satisfaction and Frustration Scale* (Chen, Van Assche et al., 2015; Chen, Vansteenkiste et al., 2015), to measure the three constructs of autonomy, competence, and relatedness, as they relate to career persistence. The qualitative data included open-ended items asking participants to share their lived experiences in STEM careers. The reason for collecting both quantitative and qualitative data was to gain a better understanding of factors affecting women's persistence in STEM careers. The quantitative data show how participants perceive their levels of autonomy, competence, and relatedness as women who persist in STEM careers. The qualitative data provide context for the quantitative data, providing insight into how persisting women experience autonomy, competence, and relatedness in their STEM careers.

Mixed methods studies are conducted by researchers taking a pragmatic worldview. Pragmatists tend to focus on finding solutions to problems, using a flexible approach to gathering data and understanding situations (Creswell & Creswell, 2018). Instead of using just one type of data, a researcher may combine methods as necessary to gain the most complete understanding of a problem. In this study, the pragmatic inquiry approach (Morgan, 2014) allowed the researcher to use quantitative data to analyze participants' perceptions deductively, as well as to collect and analyze qualitative data, allowing for inductive interpretation. Using multiple types of data allows a researcher to construct a more complete understanding of the situation, since real world phenomena are typically complicated and interwoven. By integrating the quantitative and qualitative data, a researcher may understand the subjects' perceptions as well as the contexts in which they occur.

Researcher Reflexivity

The researcher is a STEM educator and adjunct instructor who teaches part-time at a public university. Her personal experiences as a woman persisting in STEM allow her to empathize with others in the target population but may bias her perspective. She is described as having an infectious enthusiasm for science, which aptly describes her deep affinity for STEM subjects, willingness to talk about STEM, and sense of relatedness to people in STEM fields. Although not a primary job requirement, she is sometimes involved in incidental recruiting and informal mentoring of students in STEM.

In a previous role, she worked at a nonprofit science museum, helping to create informal science educational activities for patrons of all ages in the museum, at schools, online, and for home use. She currently participates in personal science outreach by writing about science topics on her blog and creating social media science content. Through these many avenues, she has reached hundreds of students, museum patrons, and Internet viewers. She acknowledges her favorable bias toward persistence in STEM and her identity as a science educator. She also recognizes her unique intersectionality (Crenshaw, 2015), as a biracial woman, single mother of a transgender daughter, cisgender son, and nonbinary child, who has experienced personal and professional obstacles that affect her persistence in STEM. Being aware of how identity intersections may interact with systems differently helps her appreciate the experiences of other women in STEM.

The researcher acknowledges that her family and friends influence her views of STEM and persistence. Her parents are both science educators and their persistence has influenced her personal goals and choices to pursue a career in STEM. She also seeks and participates in social media communities focused on STEM education and women in science and engineering. These activities provide the researcher with opportunities to discuss scientific topics as well as develop relationships with others in STEM fields. To mitigate the effects of her biases, several reflexivity practices will be followed. For example, a research journal will be maintained, and software will be used to document the process.

Theoretical Framework: Self-Determination Theory and Persistence

Self-determination theory (SDT) was originated by Deci and Ryan and started as research into intrinsic motivation (E. L. Deci, 1972). It has evolved from a theory about motivation to a universal organismic theory that addresses three basic psychological needs: autonomy, competence, and relatedness. At its foundation, SDT assumes that humans naturally tend to seek growth, learning, and social integration (Ryan & Deci, 2020). Humans are inherently motivated toward these goals, rather than externally controlled, which sets SDT apart from behaviorist theories (Ryan & Deci, 2020). The central idea of SDT is that people thrive when their needs for autonomy, competence, and relatedness are satisfied. Conversely, when their basic needs are frustrated, people tend to experience less satisfaction and success (Deci & Ryan, 2000). SDT has been studied in a diverse range of fields, including education (Skinner et al., 2017), athletic persistence (Calvo et al., 2010), workplace and organizational behavior (Gagné & Deci, 2005; Manganelli et al., 2018), inclusion (M. Moore et al., 2020), and personal health habits (Halvari et al., 2010; Ng et al., 2012; Patrick & Williams, 2012; G. C. Williams et al., 1998). Studies using SDT have been conducted by diverse research teams and provide strong evidence for its tenets across nationalities, genders, age groups, and other study populations. The SDT framework will inform the gathering of data in order to answer the research questions and achieve the study purpose.

Definitions and Descriptions

Definitions are organized by those associated with SDT followed by a description of STEM and what persistence in STEM means.

Autonomy. Autonomy is the feeling that one has volitional control over her choices and actions (Niemiec & Ryan, 2009). Deci and Ryan (2000) point out that autonomy is not synonymous with selfishness, independence, or internal locus of control. Rather, it encompasses the need to direct one's behavior in accordance with the sense of self (Deci & Ryan, 2000).

Competence. Competence is the perception that a person feels able to successfully perform a task or master an activity (Skinner et al., 2017). It is related to the perception of self-efficacy, or belief in one's ability to do something.

Relatedness. Relatedness is the need for personal relationships, including with friends, romantic partners, and in social groups (Deci & Ryan, 2000). It encompasses the desire to form and maintain connections, feel a sense of belonging, and to give and receive care (K.-A. Allen et al., 2022; Baumeister & Leary, 1995).

STEM. The fields of science, technology, engineering, and mathematics are commonly combined and abbreviated as STEM. According to the National Center for Education Statistics (2020), the U.S. government does not have a unified definition of what constitutes STEM. For the purpose of this study, STEM will be defined by the disciplines included in the National Science Foundation's (NSF) seven research areas: biological sciences; computer and information science and engineering; engineering; geosciences; mathematical and physical sciences; social, behavioral and economic sciences; education and human resources (National Science Foundation, n.d.). To determine whether a particular job title falls within STEM for the purposes of this study, the U.S. Census list of STEM and STEM-related jobs for the American Community Survey will be used (U.S. Census Bureau, 2021). A detailed list of STEM occupations is included in Appendix A.

Persistence in STEM. Persistence will be defined as having graduated with a four-year undergraduate degree in a STEM subject and working in a STEM field for at least two years beyond college. Alternatively, a person will be considered to have persisted in STEM after earning an undergraduate degree and continuing for at least two years in a related graduate program, whether or not she has completed the advanced degree program at the time of the study.

Significance of the Study

The nature of science is social and collaborative, from the laboratory to the publication and peer review process (Osborne et al., 2022). As in nature, diversity contributes to robust ecosystems. Including women in STEM benefits not only those individuals involved, but results in more innovation, improved productivity (National Science Board, 2020), and better retention rates (Drury et al., 2011). When women persist in STEM, they not only improve outcomes for themselves, but for their peers and successors. To fully appreciate the benefits to women's persistence in STEM, it is also necessary to understand the negative effects related to their underrepresentation.

The consequences of homogeneity have been reported in fields such as medicine. As a result of women being historically excluded from science and medical research, models and devices were developed based on the needs and preferences of those who were involved in the research – mostly men (Graves et al., 2022). When drugs are developed based on men's characteristics, there may be hidden risks to women that are not discovered until the treatments are implemented and harmful effects are reported (Gibaldi, 1992; Holdcroft, 2007; McMurray, 1991). Decades of engineering dominated by men produced vehicles with features optimized for users with men's physical dimensions, based on crash test dummies modeled after men in the 1970s (Forman et al., 2019; Gupta, 2021; Linder & Svensson, 2019). Although airbags and seat belts generally improve survivability in car accidents, they may not offer as much protection for those with different-size bodies, including women and older people (Forman et al., 2019; Kahane, 2013). Without women's participation, there are real risks to health, safety, and economic success.

Women tend to be more represented in early-career STEM positions than in tenured faculty and leadership roles (Blackburn, 2017; Daldrup-Link, 2017). In some engineering and other male-dominated STEM subfields, women in full professorial roles are still rare (National Center for Science and Engineering Statistics, 2021), and some students may complete schooling without ever having a woman instructor (Corbett, 2015). This ongoing dearth of women in STEM academic and leadership roles perpetuates the cycle of underrepresentation. Without visible women in leadership positions and classrooms, students may perceive a lack of opportunity or feel that they do not belong in STEM. Understanding why some women persist in STEM may help schools and organizations support more women in those fields, resulting in better representation, productivity, and innovation. Investigating the experiences of persisters may also highlight points where attrition risk is higher, as well as identify strategies that help in the overcoming of those challenges.

Benefits of Women's Persistence

Having a broad range of perspectives and ideas leads to more possible approaches and more innovative solutions (Ferrari et al., 2018). Research shows that teams with greater gender and racial diversity are more creative and innovative (Bello-Pintado & Bianchi, 2021). There is a positive association between gender diversity and corporate performance (Rodríguez-Domínguez et al., 2012). Demographic diversity in for-profit organizations is associated with better sales revenue and market share (Herring, 2009, 2017). The presence of varied perspectives means a broader range of ideas and can encourage creativity in problem-solving and innovation. Having women involved in research and leadership helps ensure that products, services, and policies are developed with the needs of women in mind.

Underrepresentation can contribute to gaps in pay, since women in STEM jobs have the potential to earn more than women in non-STEM jobs (Beede et al., 2011). Even when women are represented, they tend to reach tenured and leadership positions at a lower rate than men in academia and government institutions (Broyles, 2009; Goris, 2020; Sterling et al., 2020; Walker, 2018). Women who do persist in STEM careers tend to be underemployed, concentrated in jobs at the lower end of the salary range available in their fields, making less than their male counterparts (Goris, 2020). As discussed earlier in this chapter, there is a skills gap for filling STEM-related jobs in the U.S. (Jang, 2016; National Academies, 2011; National Science Board, 2018, 2020), which could be addressed by encouraging more women to pursue STEM careers (Weeden et al., 2020). Since women hold nearly half of all the jobs in the U.S., but are only one-quarter of STEM workers (Martinez & Christnacht, 2021), there is an opportunity to fill more STEM openings with women (Beede et al., 2011). Women tend to leave STEM during developmental and career transition points such as during adolescence, in college, during the hiring process, and when approaching tenure (Dasgupta & Stout, 2014), highlighting opportunities for improved retention supports during those periods (Glass et al., 2013; Sassler et al., 2017). For instance, researchers have identified introductory calculus, a standard requirement for undergraduate STEM majors, as a common attrition point. Calculus is known to be a weed-out class, which is a selective gateway through which STEM majors must pass. There is a gendered effect among college students who fail calculus, which effectively removes women from STEM majors while having no significant effect on men (Ellis et al., 2016; Sanabria & Penner, 2017). Women who fail the class have only a seven percent chance of completing their intended STEM major, while men continue on their predicted degree paths. This example of a gender-specific attrition point highlights an opportunity for greater persistence support for women.

There is also a gap in role models for women in STEM, which may perpetuate the cycle of underrepresentation. Women who have peer and instructor role models tend to earn higher grades and experience lower withdrawal rates than those who lack role models (Dennehy & Dasgupta, 2017; Herrmann et al., 2016). Increasing the proportion of women in STEM can provide better community support and greater availability of role models for peers and younger students, encouraging them to persist in STEM education and careers. Even without direct interaction, some women perceive greater belonging in STEM by observing fictional role models, a phenomenon known as the Scully Effect (Geena Davis Institute, n.d.; Mwale, 2022). The Scully Effect is named after Dana Scully, a character from the television series *The X-Files*. In the early 1990s, Scully was the only prominent woman in STEM on prime time television, and she became a pop culture icon and role model for young women (Norman, 2015; Reich-Shackelford, 2017). Women who were fans of Scully entered STEM educational and career pathways after being inspired by the character (Nobel, 2020). After years of anecdotal speculation on the Scully Effect, a study led by the Geena Davis Institute on Gender in Media found that a media role model can produce statistically significant increases in women's attitudes toward and interest in STEM careers (Geena Davis Institute, n.d.). The results of the Scully Effect study added evidence to the women's representation motto, "if she can see it, then she can be it."

Representation of women in STEM seems to support persistence in college students. A recent study found a significant relationship between persistence and the proportion of women students in STEM departments. Koch et al. (2022) found a higher probability of persistence in STEM when women comprise higher proportions of students in STEM subjects. The existence of women in STEM environments can provide peer role models, which may mitigate some negative stereotype effects (Dennehy & Dasgupta, 2017; Van Camp et al., 2019). Among proposed causes of attrition from STEM education and career pursuits, Dasgupta (National Science Foundation, 2016) identified belonging as the most critical factor driving the decision to stay or leave the field. Dasgupta and Stout (2014) offered specific recommendations for supporting women with a sense of belonging in STEM fields, which included the intentional creation of opportunities for exposure to women in STEM professions, peer, academic, and professional mentoring, and adding support at times of developmental transition (i.e., moving from secondary school to college, from college to graduate school, changing jobs). In another study, belonging was identified as a key element necessary for success among women in STEM Ph.D. programs (A. J. Fisher et al., 2019). Walton and others have found that belongingness interventions can improve academic outcomes in minoritized student groups (M. C. Murphy et al., 2020; Walton & Cohen, 2011).

As more women are retained throughout their educational and career pathways in STEM, there will be more opportunities for real-world role modeling and collaboration. For an example of the benefits of role models, consider Dr. Carolyn Bertozzi, winner of the 2022 Nobel Prize in Chemistry. Dr. Bertozzi recently credited the diversity of women and underrepresented minorities in her early-career laboratory with enabling her current prize-winning work (Cosco, 2022). Besides pioneering the new field of bioorthogonal chemistry, she has been recognized for her mentorship and support of diversity in science. The American Association for the Advancement of Science awarded her the 2022 Lifetime Mentor Award (Collins & Kubota, 2022). In her post-Nobel remarks, Bertozzi emphasized how the impact of her own success is small, compared with the potential contributions her mentees will make in the world (Collins & Kubota, 2022; Jarvis, 2022).

Bertozzi's sentiment is an excellent encapsulation of the intent of this dissertation. Bertozzi highlights the importance of women in her own early career, which led to her globally recognized work in chemistry. She draws attention to the diversity of people in her own laboratory, how working with women as an early-career STEM professional, and then as a mentor to younger scientists, helped her achieve global recognition as a chemist and mentor. I wonder how many women have left STEM due to a lack of support and motivation and imagine what could be accomplished if more women had the support and experiences exemplified by Dr. Bertozzi. Role modeling is clearly a key factor in creating environments in which women can succeed in STEM and improving persistence can help close the representation gap.

Chapter Summary

The proportion of women earning degrees and pursuing careers in STEM has increased in recent decades, but the overall representation of women across STEM remains relatively low when compared to their share of the general population. The lack of women in STEM is associated with negative effects on other women's success, ideas and innovation, and the strength of the national economy. By investigating the experiences of women who persist in STEM, the researcher aims to contribute meaningful insight into what can be done to cultivate the motivational factors of autonomy, competence, and relatedness, to support current and future STEM professionals. The value of this study will be to determine how SDT may be applied to help other women succeed.

Chapter Two: Literature Review

This chapter provides a brief history of research on the gender gap and women's persistence in STEM careers, focusing on biological and sociocultural explanations. It also includes an in-depth discussion of the Self-Determination Theory (SDT) framework and its theoretical constructs. The researcher defines the concepts of motivation, autonomy, competence, and relatedness, in greater detail. Next, she discusses factors that have been found to contribute to attrition and persistence. Finally, she presents evidence from empirical studies that show how autonomy, competence, and relatedness support the persistence of women in STEM.

Biological and Sociocultural Explanations for Gender Disparities in STEM

Women have been historically underrepresented compared to men in STEM fields. Research reveals myriad possible reasons for this disparity, and after decades of work, explanations are complicated and controversial. Arguments about the causes of gender differences can be roughly grouped into nature- or nurture-based explanations. Inherited biological factors, such as physical traits and innate abilities, are considered nature, while learned characteristics, sociocultural influences, and environmental factors are grouped into nurture (Traynor & Singleton, 2010). Although the nature versus nurture dichotomy is overly simple for providing explanations of human behavior (Levitt, 2013), it guided early attempts to explain gender differences and will serve as a practical rhetorical framework for this review.

The gender gap in STEM has been studied from many biological, psychological, educational, feminist, and other perspectives, and no clear explanation has emerged. The reasons for women's underrepresentation in STEM range from differences in brain size to discriminatory exclusion and seemingly innumerable combinations of biological, political, and cultural factors. This review will focus on two of the most prominent areas of investigation, which are biological and sociocultural, both of which offer inconclusive and controversial explanations. To maintain the focus of this study, the discussion will be limited to factors that affect women's underrepresentation in STEM fields in particular. General differences in women's career pathways, such as motherhood and maternity-related interruptions, are important but too broad for the scope of this dissertation.

Biological Differences

Early hypotheses assumed that women had less natural intellectual aptitude than men (Jungert et al., 2019) and raised the possibility that anatomical sex differences made men more successful in math and science. Brain sizes of men tend to be larger than those of women (Davison Ankney, 1992; Lynn, 1994; Peters, 1991), which led to hypotheses that men would have inherent advantages in STEM fields due to biologically superior general intelligence (van der Linden et al., 2017). While some researchers assert that larger brain size correlates with higher intelligence (Andreasen et al., 1993), consensus on the degree and importance of the size difference has not been reached (Lynn, 1994). Some researchers maintain that any differences in brain mass are negligible when overall body dimensions are considered, and others claim that the difference in size is not necessarily important (Eliot et al., 2021; Peters, 1991, 1993; Sarseke, 2018). Leaving the debate over anatomical brain size and its effect on general intelligence (Pietschnig et al., 2022), the idea that women are less successful in STEM due to inferior natural intelligence has fallen out of favor. Research suggests that boys' advantages in mathematics and spatial reasoning are likely due to environmental influences rather than biological factors (Ceci et al., 2014). However, the lingering idea that boys are smarter than girls may contribute to enduring cultural biases that women are less suited for careers in science than men (Bourne & Özbilgin, 2008).

Despite anatomical differences, few people today would assert that women are underrepresented in STEM because girls' brains are inferior. However, there is evidence of differences in academic performance. On standardized tests, girls outscore boys on verbal tests, while boys perform better on math tasks (Fennema, 1974; Kramer et al., 1997; Machin & Pekkarinen, 2008; Skaalvik & Rankin, 1994; van Tetering et al., 2018). These differences are most likely due to intertwined inherited and environmental influences, ranging from prenatal hormones (Ceci & Williams, 2011; Kimura, 2002) to test anxiety (Bolger & Kellaghan, 1990; Niederle & Vesterlund, 2010). Since math is a major component of STEM, and boys tend to outperform girls on math tests, it follows that boys might be better suited to STEM studies. However, there is debate over the reliance on math test scores as predictors of STEM ability. Some studies show that the math performance gap can be explained by factors other than biological differences, countering the "boys are better at math" stereotype. For instance, parental influence at home may negatively affect girls' attitudes toward math, contributing to lower interest in STEM (Dossi et al., 2019; Tenenbaum & Leaper, 2003). Parental education level is another external factor affecting test scores, with children of more educated parents outscoring children of less educated parents (Sandqvist, 1995; van Tetering et al., 2018). In other studies, there is evidence that the math gap is narrowing (Marsh, 1989) or even reversed in favor of girls, as in countries with more gender-equal cultures (Machin & Pekkarinen, 2008). Studies such as these highlight the complicated work of sorting out biological and cultural factors in math and science attitudes and performance.

Hyde claims that the gender differences model overinflates sex differences and recommends a gender similarities approach instead. After conducting a meta-analysis of gender difference studies, Hyde (2005) concluded that while differences exist, their effects should not be taken out of context, which can exaggerate or erase perceived advantages for boys in math, depending on the circumstances. In an early study demonstrating stereotype threat (Spencer et al., 1999), men and women of similar mathematical abilities took an exam under two conditions. In one condition, they were told the exam had been judged to be gender fair. In the other condition, they were told the same exam had produced skewed results, with women achieving lower scores than men. Although the test was the same in both conditions, women scored more poorly when they had been told it resulted in lower scores for women, illustrating the effect of stereotype threat. This study illustrates how context can affect the outcome, possibly obscuring similarities and exaggerating gender differences. Given the body of conflicting explanations, the fact remains that girls and women still choose and persist in STEM at lower rates than boys and men. Assuming that women are biologically able to learn and perform science tasks well enough to pursue college degrees and science careers, the question remains as to why they choose to leave at much higher rates than men. Researchers examine the factors influencing women's choices to leave STEM through sociocultural studies.

Gender Stereotypes: "Science is for Boys"

Another obstacle to women's persistence in STEM is the tendency for girls and women to prefer fields that focus on people rather than things. The people versus things premise has been used to explain why many women who remain in science do so in biological and social sciences, while men dominate the physical sciences and engineering (P. H. Miller et al., 2006; Su & Rounds, 2015). Research has been done to determine whether women's preference for people over objects is innate or learned, with mixed results. Since research on infants is ethically difficult, little data exists to show whether baby boys and girls exhibit these preferences. As children develop, it is possible that gender stereotypes are so thoroughly incorporated into cultural practices that any inherited preferences are masked or confounded by environmental conditioning. Some of this occurs in the home before children attend school (BaramTsabari & Yarden, 2008). In the U.S., toys for girls and boys have been clearly gendered for decades. Girls' products include pink housewares, dolls, makeup, and other items that reflect stereotypically feminine gender roles. Even popular LEGO building sets are themed to promote stereotypical gender roles and activities (Reich et al., 2018). These early childhood experiences may influence girls' perceptions of their own career choices. By kindergarten, children express stereotypical attitudes about sex differences in math abilities and career suitability (Ceci et al., 2014). By the time girls enter high school, they tend to have lower levels of interest and self-confidence in science (Baker & Leary, 1995; Vincent-Ruz & Schunn, 2017) and poorer attitudes toward science than boys (Weinburgh, 1995). Their reasons include perceptions that science is not a good fit for girls or that the scientific career lifestyle is unfeminine, unattractive, or unappealing (Archer et al., 2013; Kahle & Lakes, 1983; Kerger et al., 2011; P. H. Miller et al., 2006). There is evidence that career stereotypes act as gatekeepers that constrain women's career aspirations such that they are pushed away from STEM (Cheryan et al., 2015). Ceci and Williams (2011) found that career choices constrained by motherhood and stereotype bias now contribute to women's underrepresentation in STEM more than blatant sex discrimination. The effects of stereotype bias can be somewhat mitigated by the presence of women as role models (Buck et al., 2007; Cheryan et al., 2015) or by presenting science concepts in contexts that fit with girls' identities (Archer et al., 2012, 2013; Kerger et al., 2011). Researchers hypothesize that girls' inclinations toward people-oriented activities contribute to their relatively strong preferences for biology and health sciences. To counteract career gender stereotypes, presenting scientific concepts in people-oriented contexts may strengthen girls' attitudes toward STEM. Providing role models and presenting science in varied contexts allows girls to imagine the STEM universe as a place where they belong. Having a sense of belonging is a critical piece of the persistence puzzle. This aligns with the relatedness construct of SDT.

Separate from math ability, social and emotional pressure also affect math performance. Students describe math anxiety as feeling nervous, unable to concentrate, and physically ill when confronted with a math assessment (Woodard, 2004). Math anxiety can affect any gender student and is considered a barrier to STEM achievement due to its negative effect on math performance (Ashcraft & Moore, 2009; Meece et al., 1990). High math anxiety is strongly correlated with lower math self-efficacy, especially among women and younger students (Ashcraft & Moore, 2009; Rozgonjuk et al., 2020; Woodard, 2004). In a longitudinal study of American students, Ahmed (2018) found that those with higher levels of math anxiety were less likely to choose STEM careers. Daker et al. (2021) added findings that math anxiety might predict poor STEM outcomes, including avoidance of STEM courses, independently of math ability. This means that women with acceptable math ability may earn lower grades than expected and avoid taking STEM courses due to anxiety about math. These studies suggest that high math anxiety and low math self-efficacy in women may contribute to their disproportionate attrition from STEM.

Further complicating math anxiety is the influence of teachers' math anxiety on their students. Elementary school teachers in the U.S. are overwhelmingly women, and teacher math anxiety is associated with lower achievement in students (Beilock et al., 2010; Novak & Tassell, 2017; Ramirez et al., 2018). In a longitudinal study of women teachers and their early elementary students, Beilock et al. (2010) found that higher teacher math anxiety correlated with lower math achievement in girl students. Also, the more anxious teachers were, the more likely girls were to endorse the stereotype that girls are not good at math at the end of the school year. Boys in the same classes did not exhibit the same results, indicating that math-anxious women teachers may contribute to their girl students' poor math achievement.

Self-efficacy is related to the SDT construct of competence, raising the possibility that better math self-efficacy could improve persistence in STEM. It is interesting to note that math self-efficacy and confidence are separate from math ability. Women tend to experience higher math anxiety and lower math confidence and self-efficacy than men (Ellis et al., 2016), while men express greater confidence about their math abilities (Orenstein & American Association of University Women, 1994). A boy who receives a C in math may judge his own performance as better than a girl who receives a B would rate her own performance. Where he finds confidence in passing the class with a C, she may perceive a lack of math ability for not scoring higher than a B. The confidence gap (Rittmayer & Beier, 2009) is supported by the cultural myth that male brains are better at math and science and perpetuated by stereotype-confirming experiences.

Parental education and attitudes about career suitability (Archer et al., 2013; Tenenbaum & Leaper, 2003; van Tetering et al., 2018), math anxiety (Ahmed, 2018; Daker et al., 2021; Meece et al., 1990; Rozgonjuk et al., 2020), teacher math anxiety (Beilock et al., 2010; Novak & Tassell, 2017; Ramirez et al., 2018), and gendered career stereotypes (Bourne & Özbilgin, 2008; Cvencek et al., 2011; Soylu Yalcinkaya & Adams, 2020; Steinke, 2017), are some environmental influences that contribute to the belief that girls are not good at science. The adoption of the "math is for boys" stereotype can occur during early childhood before sex differences in math achievement emerge (Cvencek et al., 2011; Kuhl et al., 2019). These factors can lead to a fixed mindset that women cannot succeed in STEM, driving them toward other career paths years before they would enter the STEM workforce.

Professional Pressures for STEM Women

Women who maintain their interest and participation throughout schooling and pursue STEM careers face barriers not encountered by male counterparts. Some are external pressures such as overt and implicit gender biases against women (S. Jackson et al., 2014; Moss-Racusin et al., 2012, 2018; Verdugo-Castro et al., 2022). Into the 1900s, women were prohibited from entering some scientific disciplines in the United States. After gaining admission into previously closed fields, they continued to face barriers to achievement and recognition (Rossi, 1965). In a landmark paper, Margaret Rossiter (1993) identified the Matilda Effect, which is the systematic obscuring and suppression of women’s contributions in the sciences. Rossiter cited numerous instances of women’s data being removed from studies, their contributions subsumed into work named for men, or women’s discoveries being attributed to men without credit. The Matilda Effect was illustrated in an experiment comparing identical scientific publications bearing the names of male or female authors. Reviewers rated papers written by male authors as better quality than papers written by women, and expressed higher levels of interest in collaborating with the male authors (Knobloch-Westerwick et al., 2013). This study shows how a gender bias may create barriers for women in STEM.

Some of the challenges faced by women in academic careers are shared by faculty across disciplines. In academia, typical faculty duties include teaching, researching, and performing campus service. Commonly, workloads are not distributed equitably among faculty, and women tend to take on significantly more campus service work, such as committee assignments, than men (Guarino & Borden, 2017; O’Meara et al., 2017; Winslow, 2010). Researchers have found that women spend more time on advising and service tasks that do not translate into professional advancement, placing them at a disadvantage compared to men, who spend more time on work that leads to promotions (O’Meara, 2016). Research publications are considered a key measure of academic accomplishment and carry a great deal of weight in career advancement (Misra et al., 2012). In a reflection of broader gender stereotypes about women's roles as caretakers, women may be expected to take care of faculty "family" responsibilities. Women faculty members are more likely than men to be asked to serve, to volunteer, and to accept requests to serve in roles that help the organization but do not translate into professional development (Guarino & Borden, 2017). These unbalanced workloads and expectations can hold women back from professional growth and salary improvements and may contribute to an adverse climate.

Chilly Climate in STEM

While overt discrimination may be diminishing for women in STEM, the environment in the field can still be unwelcoming, so it causes some to leave the field. Some obstacles are difficult to see directly but may be observed in the reactions of women to unwelcoming cultural and social conditions at school and work. *Chilly climate* is an umbrella term used to describe conditions that create a negative environment for participants (Biggs et al., 2018; Constantinople et al., 1988; Jensen & Deemer, 2019; Miner et al., 2019; Rincón & George-Jackson, 2016; Walton et al., 2015; Wilkins-Yel et al., 2022). Even in the absence of obvious hostility or mistreatment, a chilly climate may exist due to intentional or perceived inequities, including exclusion, devaluation, and marginalization (Maranto & Griffin, 2011). A chilly STEM climate can have a marginalizing effect on women and minority graduate students, resulting in depression and decreased persistence (Cabay et al., 2018; Wilkins-Yel et al., 2022). In a study of women in physics and astronomy, factors contributing to the chilly climate included a lack of women professors and poor "general social treatment" (Flam, 1991). Participants in the study described instances of poor treatment including sexual harassment, being underestimated, condescension, and other "micro-inequalities" (Flam, 1991). Some behaviors that are difficult to detect, but pervasive, may contribute to a chilly climate. Microaggressions have also been found to result in feelings of isolation, marginalization, racism, and gender discrimination among Black women undergraduates in STEM (Dortch & Patel, 2017). Studies such as these show that a chilly climate may be perceived in different ways by different people. When micro-inequalities are not noticed by those who are not directly affected, it can be difficult to convince others that a chilly climate exists.

Miner et al. (2019) studied ostracism and incivility as operational variables contributing to a chilly climate. Ostracism can result from feeling excluded from social gatherings and information-sharing opportunities, and incivility is characterized by rudeness and condescension (Miner et al., 2019). Both ostracism and incivility are experienced at a greater rate and to a more harmful degree among women early-career STEM faculty than men, and are associated with negative career and well-being outcomes (Miner et al., 2019). To improve a chilly climate, Miner et al. (2019) and Walton et al. (2015) recommended that organizations implement relationship-building interventions, which align with the SDT need for relatedness.

The chilly climate has been observed at special events such as academic conferences. Biggs et al. (2018) surveyed conference presenters and found that women who perceived negative conference climates were more likely to indicate intentions to leave academia than men. However, the greater the proportion of women in attendance, the less likely women were to perceive sexism. This suggests that better representation of women can improve the perceived climate and reduce intent to leave a field. A qualitative study of women engineers found that discrimination and difficult work environments were themes among groups of persisting and out-opting engineers (Buse et al., 2013). Among those who remained in engineering despite the chilly climate, Buse et al. (2013) found that several individual factors contributed to career persistence: self-efficacy, identity, adaptability, other orientation (working with others, collaboration), and work engagement. Those factors map onto the basic needs of autonomy (self-efficacy, identity), competence (adaptability, work engagement), and relatedness (other orientation), suggesting a connection between persistence and basic needs satisfaction.

Self-Determination Theory

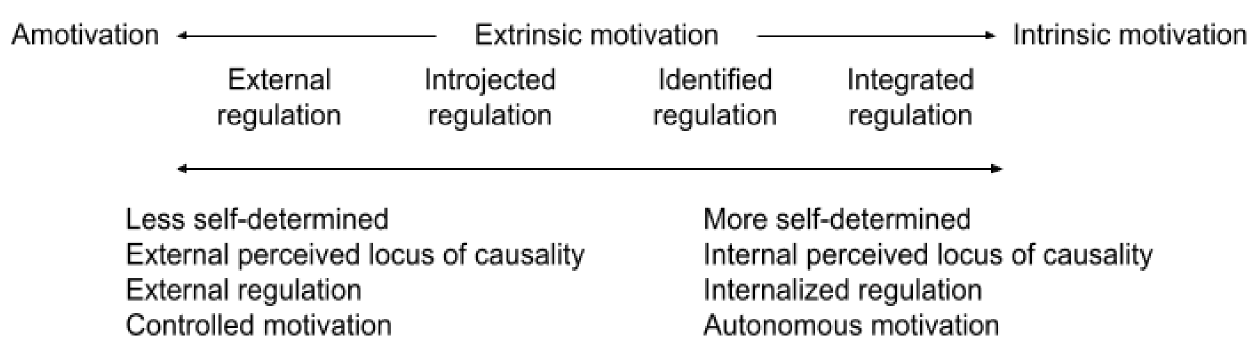
Deci and Ryan originated self-determination theory (SDT) circa 1985, and they continue to participate in the active testing and development of the theory. Since its introduction as a working theory (E. Deci & Ryan, 1985), SDT has been strengthened and affirmed by hundreds of empirical studies spanning diverse cultures, academic disciplines, industries, and practical domains (TEDx Talks, 2012). Unlike some theories that portray humans mechanistically, as being acted upon by physiological drives such as hunger and sex, SDT presents an organismic explanation for behaviors. It is an underlying assumption of SDT that humans are evolved organisms that actively seek growth, interesting experiences, and integration (Ruiz-Mirazo et al., 2000), rather than only being driven by physiological needs (E. Deci & Ryan, 1985). Deci and Ryan define autonomy, competence, and relatedness as “innate, psychological nutriments that are essential for ongoing psychological growth, integrity, and well-being” (2000, p. 229). Deci describes motivation as energy for action and suggests that asking what motivates people is less valuable than asking how to create conditions that will allow people to motivate themselves (TEDx Talks, 2012). By studying people through the SDT lens, researchers find that autonomy, competence, and relatedness are nearly universally linked with greater intrinsic motivation, which generally leads to better well-being and more positive outcomes (Schüler et al., 2013). Conversely, in contexts where these basic psychological needs are frustrated, people will not thrive, and may exhibit depression, ill-being, and negative behaviors (Deci & Ryan, 2000).

The Motivation Continuum

The earliest version of SDT grew out of studies of motivation. Motivation is the energy that moves one to act, and it may be generated from an external or internal perceived locus of causality (DeCharms, 1968; E. L. Deci, 1972; E. Deci & Ryan, 1985; Ryan & Connell, 1989; Vallerand, 2000). The types and levels of motivation can be visualized as a continuum from amotivation to external motivation to autonomous motivation (Howard et al., 2017; Ryan & Connell, 1989; Ryan & Deci, 2020). The motivation continuum coexists with a continuum of self-determination, which is tied to the perceived locus of causality for a behavior (DeCharms, 1968; Howard et al., 2017). The spectrum of motivation features several subtypes of extrinsic motivation, differentiated by the level of internalization experienced by the individual. In SDT, a person may change her perception of the locus of causality for an action if she internalizes its value and adopts it as part of her identity (Ryan, 1995). Put together, these elements comprise a spectrum of motivation (extrinsic - intrinsic) and self-determination (controlled - autonomous) (Howard et al., 2017; Ryan & Connell, 1989), as depicted in Figure 1.

Figure 1

Motivation Continuum in Self-Determination Theory



Amotivation and Extrinsic Motivation. At the left extreme of the continuum is amotivation, which is the absence of motivation. Amotivation is characterized by the lack of any interest or intent to engage in an activity (Markland & Tobin, 2004; M. Moore et al., 2020; Ng et al., 2012), which may occur when the needs for autonomy, competence, and relatedness, are not met (Deci & Ryan, 2000). The central area of the continuum is occupied by degrees of extrinsic motivation, from external regulation to internalized regulation (Howard et al., 2017; Ryan, 1995; Ryan & Deci, 2020). External regulation includes motivating people using rewards and punishments; for example, using prizes to entice students to complete homework. In this example, the perceived locus of causality is external (homework is assigned by instructor). Similarly, this behavior is considered externally motivated, or controlled, because the students are performing the homework due to the offer of rewards. If a student completes the homework instigated by the teacher (external locus of causality) just to earn external rewards (extrinsic motivation), that situation does not allow much autonomy. The lack of student volition in this situation may be recognized by a sense of having no choice, or of being forced to do something.

Introjected Regulation. Slightly closer to the intrinsic motivation end of the spectrum are activities performed due to a sense of duty or a fear of negative emotions (Patrick & Williams, 2012). These motivations, characterized by feelings that one should or must act a certain way, are considered extrinsically motivated because they depend on feelings based on external expectations. This category of behavior is referred to as introjected regulation, where an external cause is partially internalized (involving the ego) and leads to a somewhat self-determined action (Howard et al., 2017; Ryan & Deci, 2020). An example of introjected motivation is an athlete who engages in training to improve self-esteem, or to avoid feelings of guilt from missing a workout, or the shame of losing a game. While it may seem that emotional motivations are internal, they are related to social pressures tied to what one feels is expected by others. Therefore, ego and self-esteem motivations are considered to be external controls, rather than intrinsic motivations (Howard et al., 2017; Ryan & Deci, 2020).

Identified and Integrated Regulation. Some situations occur in which a person is motivated by external influences that are highly internalized. Identified and integrated regulation are nearer to intrinsic motivation because they describe conditions where an individual may be caused to perform an activity that is not necessarily enjoyable or interesting but holds some value or is important to her identity. To demonstrate this level of motivation, consider a situation where a person volunteers at a zoo because she believes it is important to care for animals. In this case, the volunteer may need to complete some unpleasant tasks, such as cleaning manure. Although the task originates from an external locus of causation, and is not inherently enjoyable, she believes it is meaningful, and considers herself an animal lover, so it is in line with her identity. Internalization is a process whereby an individual accepts the value of an activity that was originally externally motivated, thereby assimilating it into her autonomous behavior (E. Deci et al., 1994; Ryan & Connell, 1989). By doing this, it is still considered externally caused, but approaches intrinsic motivation. Well-internalized extrinsic motivation is also called autonomous extrinsic motivation (Ryan & Deci, 2020). Intrinsic motivation, integrated regulations, and identified regulations have been strongly linked with positive outcomes, including well-being and healthy behaviors (Ng et al., 2012).

Intrinsic Motivation. Intrinsic motivation is at the opposite end of the continuum from external control. To illustrate intrinsic motivation, consider a situation where a student engages in a behavior simply for the interest (internal locus of causality) and pleasure inherent (intrinsic motivation) in the activity. There is no external reward or penalty associated with the performance of the activity; therefore, it is intrinsically, autonomously motivated (E. Deci & Ryan, 1985; Howard et al., 2017). Intrinsic motivation is characterized by curiosity and self-initiated engagement in an activity. To determine whether an activity is intrinsically motivated, it can help to consider whether the addition of an external incentive would increase a person's enjoyment or likelihood to continue in the activity. An excellent example of intrinsic motivation is play, which does not need to be coaxed or incentivized. If a child is playing, she is doing so of her own volition and not to earn a reward. If offered a reward to continue the activity, while she may accept the reward, it would not increase her enjoyment or persistence. The individual plays because the activity itself is interesting and enjoyable. Autonomous behavior, indicative of intrinsic motivation, is exhibited in the performance of an activity that satisfies the basic psychological needs of autonomy, competence, and relatedness (E. L. Deci, 2017). An intrinsically motivated learner tends to position herself such that the level of challenge is neither too easy, which leads to boredom, nor too difficult, which leads to frustration.

Research on motivation shows that when an individual is performing an activity based on intrinsic motivation, the addition of external rewards does not improve outcomes and may undermine intrinsic motivation (Ryan & Deci, 2020). External rewards, such as money, recognition, or prizes, may be adequate short-term motivators but tend to lessen motivation over time (Benabou & Tirole, 2003; E. L. Deci, 1972; Ryan & Deci, 2020). The assertion that external rewards diminish intrinsic motivation is contradictory to economic and behaviorist theories, both of which rely on incentives to influence behavior (Ertmer & Newby, 2013; Lindenberg, 2001). It is worth noting that debate over the effects of external rewards on motivation led to a lively exchange of meta-analyses between behaviorist and SDT researchers in the 1990s (Cameron & Pierce, 1994; E. L. Deci et al., 1999; Kohn, 1996; Lepper et al., 1999). Despite the conflicting paradigms, there was general agreement that the experience of motivation is complex and multifaceted, and recognition of its importance in education. When people are conditioned to expect external rewards, the desired behavior tends to stop when the rewards are discontinued (E. L. Deci et al., 1999). In situations where intrinsically motivated learning is occurring, the introduction of external rewards can have the effect of turning "play" into "work," undermining intrinsic motivation (Lepper & Cordova, 1992). Internalized motivation is associated with better long-term outcomes, including in learning and mental health. Proponents of SDT maintain that by cultivating environments that support autonomy, competence, and relatedness, people are more likely to experience intrinsic motivation, resulting in better outcomes than in systems that rely on external incentives, controls, and penalties.

A meta-analysis encompassing more than 220,000 students found that intrinsic motivation was related to success and well-being and that internalized extrinsic motivation was highly related to persistence (Howard et al., 2021). Intrinsic motivation, which is associated with higher course persistence (Brubacher & Silinda, 2019; Vallerand & Blssonnette, 1992), is cultivated when the basic psychological needs of autonomy, competence, and relatedness are satisfied. To connect the framework of SDT to this dissertation, the researcher now presents examples of studies that show how autonomy, competence, and relatedness each support persistence. She also applies the SDT lens to previous studies to identify the antecedents and effects of autonomy, competence, and relatedness on women's persistence in STEM.

Autonomy and Persistence. While the three basic psychological needs of autonomy, competence, and relatedness are important to foster optimal outcomes, autonomy is considered the primary factor necessary for intrinsic motivation (Deci & Ryan, 2000). Autonomy is perceived when a person can act according to her own volition rather than feeling constrained or controlled. As a variable related to persistence, autonomy has been found to significantly improve motivation to maintain effort toward goals (E. L. Deci & Ryan, 1987; Koestner et al., 2015), including healthcare (Jacobs & Claes, 2008; Ng et al., 2012; G. C. Williams et al., 1996, 1998) and STEM education and careers (Mau, 2003; Perez-Felkner et al., 2014). Autonomous motivation and perceived autonomy support have also been found to negatively predict dropout intentions (Girelli et al., 2018; Hardre & Reeve, 2003; Jeno et al., 2018). In a study of college students over the course of a semester, researchers found that adopting autonomy-supportive practices significantly improved intrinsic motivation and self-efficacy across biology, English, and social science classes (Garcia & Pintrich, 1996). Instructors changed some practices to allow students to help make decisions about deadlines and readings to improve perceived student autonomy in the courses. At the end of the semester, data was collected to measure variables, including academic performance, test anxiety, self-efficacy, and intrinsic goal orientation. Researchers determined that the students' increased perceived autonomy had a significant positive effect on intrinsic motivation (Garcia & Pintrich, 1996).

While the educational environment created by teachers has been shown to be important for autonomy support, the student perspective is also valuable. Intrinsic motivation is exemplified by engagement in an activity for its inherent enjoyment and interest. As a component of autonomy, deep interest contributes to motivation to engage with a subject or activity. Studies have found that interest in STEM subjects in high school has a significant positive effect on the intent to select a STEM major in college (Jungert et al., 2019; Maltese & Tai, 2011; Moakler & Kim, 2014). Students identify pre-college experiences such as family activities (Talley & Martinez Ortiz, 2017) and extracurricular STEM activities (VanMeter-Adams et al., 2014) as influential in developing a deep interest in STEM (Buschor et al., 2014;

Jungert et al., 2019). Studies such as these provide evidence that interest-based autonomy affects intent to persist in STEM studies. At the professional level, higher perceived career autonomy contributes to women's persistence in STEM careers (Schmitt et al., 2021; VanAntwerp & Wilson, 2018).

Autonomy-supportive teaching does not require instructors to surrender to classroom anarchy to be effective, nor does it mean students are expected to learn without any guidance (Garcia & Pintrich, 1996; Wielenga-Meijer et al., 2011). Structure, not to be confused with control, contributes to positive motivational outcomes in autonomy-supportive environments (Jang et al., 2010). Many conditions may be considered autonomy-supportive if they facilitate feelings of volitional control over one's actions. Some autonomy-supportive practices have been identified as particularly effective. In the educational context, autonomy-supportive practices may be implemented by teachers, and their effects can be measured based on student performance. Autonomy supports in a classroom include allowing students to provide input, allowing opportunities for choices, providing rationales, using noncontrolling and inviting language, being open to student perspectives, accepting student resistance, and encouraging curiosity and interest (E. Deci et al., 1994; Garcia & Pintrich, 1996; Patall et al., 2017; Patall & Zambrano, 2019; Reeve & Jang, 2006). These elements of autonomy support are grouped and described in greater detail below.

Input and Choice. Soliciting and accepting student input facilitates autonomy by allowing students to feel that they are contributing to decisions about their educational activities. In classroom settings, teachers may adopt several practices to support students' sense of autonomy. For example, the instructor may ask students for input on course activities, deadlines, and pacing. Considering student input does not mean the teacher acquiesces to student demands but that the students are given opportunities to participate in making decisions. Choice opportunities are a critical element of autonomy support (Patall et al., 2010, 2017). In a context of trust, allowing people to provide input and make choices increases perceived fairness (Lawrence et al., 2014), motivation, and enjoyment (Mouratidis et al., 2011). A meta-analysis of studies on the effects of choice found that allowing participants to provide input and make choices improved their motivation, persistence, and performance (Patall et al., 2008). The study concluded that for both children and adults, choices affirm the sense of autonomy and enhance motivation. However, there are some contexts in which choice does not support motivation, such as when a person does not feel competent to make a choice, or when the choice is presented in a controlling manner (Katz & Assor, 2007; Patall et al., 2008). Therefore, choices should be presented in appropriate contexts of competence and trust (Mouratidis et al., 2011) in order to be supportive of autonomy.

Providing Rationales. Providing the rationale for assignments or uninteresting tasks can help with autonomous motivation (Jang, 2008; Reeve et al., 2002; Reeve & Jang, 2006). Rather than imposing a task without explaining its value, providing a reason for the activity allows the student to understand its importance. Understanding and appreciating the purpose of a task improves the internalization of its value, which is more autonomous than an extrinsically controlled activity. To produce autonomy-supportive results, explanations should be presented from the subject's perspective, highlighting specific connections to the student's goals, and building on prior knowledge (Steingut et al., 2017; Vansteenkiste et al., 2018). However, if rationales are provided only to reinforce teacher controls or external pressures, they may diminish perceived autonomy (Steingut et al., 2017; Vansteenkiste et al., 2004). Soliciting student input can improve the effect of rationale provision by informing the instructor of the student's perspective.

Using Inviting Language. The previous strategies of inviting input, providing choices, and presenting rationales, are all facilitated by using language that encourages conversations with students. Soliciting participation is effective when instructors approach conversations with words that demonstrate a willingness to listen to students without judgment (Patall & Zambrano, 2019). Using nonjudgmental, informational language, such as "explain, "consider," or "might," are examples of nonevaluative words that show a teacher is willing to listen. Conversely, a teacher's use of directly controlling language can decrease students' perceived autonomy and can even contribute to amotivation and feelings of anger (Assor et al., 2005). Using words such as "should," "must," or "stop" to give commands, suppress opinions, or change behavior, can be harmful to the sense of autonomy (Assor et al., 2005; Patall et al., 2018). In addition to inviting discussion with students, instructors support autonomy when they listen to negative feedback or opinions without trying to change them (Patall et al., 2018). Given the importance of student input in creating autonomy-supportive environments, the role of inviting conversation using culturally-inclusive language should be highlighted. Teachers who solicit and consider students' preferences and perspectives support the autonomy of students from diverse backgrounds (Aronson & Laughter, 2016).

Cultivate Curiosity and Genuine Interest. Since intrinsic motivation is more likely when a person feels a genuine interest in the subject, autonomy-supportive environments should allow for exploration and curiosity. STEM education typically includes hands-on activities, whether as part of formal coursework or in informal environments, such as museum visits or extracurricular activities. Hands-on activities cultivate STEM engagement and stimulate interest (Blakey &

McFadyen, 2015; Christensen et al., 2015). Open learning environments, such as science centers, allow visitors to choose which activities to participate in, which supports learner autonomy (Salmi & Thuneberg, 2019). Although boys and girls do not differ in the age of first taking an interest in STEM, the mechanisms of developing an initial interest do. A survey of almost 8,000 people showed that men reported self-generated childhood interest in STEM, resulting from independent activities such as building or tinkering. Women were more likely to report developing an initial interest in STEM while playing outdoors, and also due to family or teacher influences (Maltese & Cooper, 2017). The same study found that STEM interest was the primary factor in choosing a STEM major or career. However girls enter the STEM pathway, maintaining interest throughout the educational journey is essential. Once the spark of curiosity is lit, interest can be maintained through participation in activities like science projects, science clubs, and visits to maker spaces (García-Guerrero et al., 2019; Newton et al., 2020; Ryu et al., 2020).

In summary, students with deep interest and enjoyment associated with STEM activities tend to experience more autonomous motivation in STEM educational experiences. Interests are often initiated during family and informal educational experiences, including extracurricular activities. In school, perceived autonomy can be enhanced when instructors cultivate autonomy-supportive learning environments (Reeve & Cheon, 2021). As the primary component of intrinsic motivation, autonomy contributes to persistence, and is therefore a key construct of interest in this study of women's persistence in STEM.

Competence and Persistence. A sense of competence is derived from the perception that one can effectively perform a task based on the necessary skills (E. Deci & Ryan, 1985; Deci & Ryan, 2000). As an essential psychological need, competence satisfaction is believed to be a factor in successful persistence, according to SDT. Studies have found that competence and its antecedents contribute to positive outcomes, including persistence, for women in STEM contexts (Edzie et al., 2015; Sakellariou & Fang, 2021). Environments that support perceived competence provide opportunities for learning and the development of mastery (Skewes et al., 2018). Competence-supportive environments have clear guidelines that define mastery, whereas ambiguous rules or unclear measures of performance undermine perceived competence (Skewes et al., 2018). As mentioned earlier, there is a gender confidence gap in STEM. Since confidence in one's ability is a part of competence, it is necessary to understand factors that contribute to women's STEM confidence. Some factors that support the development of competence in STEM include science identity, self-efficacy, and having a growth mindset. These are described in greater detail below.

Science Identity. Science identity is the sense that science is a good fit for a person, and also that the person fits in the science field (Kim et al., 2018; Xie et al., 2015). The development of science identity begins in early childhood (S. M. Cohen et al., 2021; Dou et al., 2019) and contributes to a person's sense of competence in STEM learning and practice. Science identity and persistence are strongly related (Buschor et al., 2014; Graham et al., 2013; Kane, 2012; Stets et al., 2017), and therefore opportunities for girls to develop science identity may improve chances for persistence in STEM education and careers (Stets et al., 2017). Components of science identity include a sense of being able to perform competently and be recognized in a STEM role (Carlone & Johnson, 2007; M. M. Williams & George-Jackson, 2014). Access to material resources associated with scientific practices also supports girls' development of science identity. For example, participating in activities using authentic science tools and instruments can help girls imagine themselves as scientists (Perin et al., 2020). Taking part in authentic science activities has been shown to strengthen science identity in minoritized students and improve their perceptions about the diversity of scientists (Chapman & Feldman, 2017). Opportunities to participate in science activities, such as hands-on learning, playing with science-themed toys, watching science television programs, talking about science, and extracurricular experiences contribute to the development of one's science identity (S. M. Cohen et al., 2021; Dou et al., 2019; K. M. Jackson & Suizzo, 2015). While some identity work occurs in school and at home, out-of-school activities such as science camps also offer important opportunities for science identity development (R. M. Hughes et al., 2013; R. Hughes & Roberts, 2019; Rahm & Moore, 2016; Riedinger & Taylor, 2016), although those optional activities are not accessible to all students. In a recent study, researchers found that talking about science and consuming science and science fiction media during childhood were predictive of college STEM identity (Dou et al., 2019), which reinforces the importance of early informal experiences. Developing a strong science identity by adolescence is a critical factor in girls' choices to continue in science (Vincent-Ruz & Schunn, 2018).

Self-Efficacy. Self-efficacy is predictive of persistence (Zimmerman, 2000) in college and graduate science students (Chemers et al., 2011). Girls tend to have lower perceived competence in math (Green & Sanderson, 2018) and science than boys (Vincent-Ruz & Schunn, 2017). This gender gap in STEM self-efficacy highlights a need to provide support in this factor of competence. STEM self-efficacy has been found to result from mastery experiences, vicarious experiences, and social persuasion (Sithole et al., 2017; Zeldin & Pajares, 2000). Mastery experiences, such as classroom activities and assessments, give people opportunities to practice skills and demonstrate understanding. Vicarious experiences provide opportunities to observe others, such as role models or exemplary peer demonstrators (Bautista, 2011), successfully performing the desired tasks (Bandura, 1978; Britner & Pajares, 2006). A student who sees someone similar to her complete a task can experience improved self-efficacy as a result.

Social persuasion often takes the form of verbal and non-verbal encouragement from others, including peers, teachers, and parents. To result in better self-efficacy, the feedback needs to be affirming and encourage the person that the goal can be attained (Britner & Pajares, 2006). While boys and men derive competence mainly from task mastery, vicarious experiences and social persuasion are more important contributors to STEM confidence for girls and women (Rittmayer & Beier, 2009; Zeldin & Pajares, 2000). Researchers found that social recognition and encouragement improved interest in STEM careers among women with relatively low science identity (M. C. Jackson et al., 2019). Although girls rely on vicarious and social influences more than boys for science self-efficacy, mastery experiences still support girls' development of self-efficacy and competence. Opportunities to develop and demonstrate mastery, such as experiential programs during high school, contribute to persistence by building confidence and skills that increase the likelihood of girls majoring in STEM (Hunt et al., 2021). The combination of multiple support factors is important for girls to develop strong science self-efficacy.

Growth Mindset. The concept of brilliance or natural talent can undermine competence. Brilliance or giftedness implies that success in STEM derives from an innate propensity for science, rather than through the challenges and struggles that can accompany learning. Confusion, a common part of learning new concepts in math and science, tends to have a disproportionately negative effect on girls compared to boys (Dweck, 2007). If a student believes that her success in STEM depends on whether she was born with the ability, she may assume confusion is a sign that she was not born with the math or science "gift." She may attribute her struggle or failure to a lack of natural ability (S. Murphy et al., 2019; Saucerman & Vasquez, 2014). Conversely, a person with a growth mindset will view challenges as a normal part of learning and continue to pursue mastery. A survey of STEM-oriented adults showed that most had a growth mindset (Kricorian et al., 2020), suggesting that it is a common element in STEM persistence into adulthood.

Research shows that interventions designed to normalize challenge and show that learning is incremental can improve students' persistence by encouraging a growth mindset (Blackwell et al., 2007). Faculty attitudes can also affect women's goals by sending signals about whether they can succeed in STEM. Undergraduate women students who perceive that their professors endorse intellectual growth as opposed to fixed ability mindsets are more likely to maintain STEM interests (Fuesting et al., 2019; Muenks et al., 2020). In a study of current and former engineering majors, researchers found that women who persisted in engineering were more likely to attribute good performance to their own efforts, while those who left engineering were more likely to blame a lack of ability for their poor performance (Nauta et al., 1999). Preparing students to expect challenges can help them view confusion as part of learning, rather than a sign of incompetence. Interventions that portray struggle as normal have been shown to improve persistence rates in undergraduates and doctoral students (Posselt, 2018; R. Binning et al., 2019). To persist in a field where there are many documented obstacles to success, as there are for women in STEM, it appears beneficial to view challenges as opportunities for growth rather indicators of failure (R. Hughes & Roberts, 2019).

Relatedness and Persistence. Relatedness is supported in environments where women feel a sense of belonging and mutual care with others. There is evidence that a welcoming environment and the social support associated with it is predictive of persistence in STEM

(DuBow et al., 2017; Gloria & Ho, 2003). In some cases, simply not being numerically alone improves a woman's chance of persisting in STEM. For example, one study found that women in STEM Ph.D. programs are more likely to graduate within six years when there are other women in the cohort (Bostwick & Weinberg, 2022). Beyond a woman's immediate department, campus supports can assist her in finding a place to belong. Special programs or clubs for women in STEM, informal study groups, and contact with advisors may help women feel a sense of belonging.

Among women of color in STEM undergraduate majors, peer relationships and participation in STEM student organizations support persistence (Espinosa, 2011). In computer science, a STEM field with a pronounced underrepresentation of women, redundant supports, including a reinforced sense of community belonging, are critical in persistence (DuBow et al., 2017). Even adjusting environmental cues, such as increasing the proportion of women depicted in posters and in classroom objects, can improve the perceived sense of ambient belonging for women in computer science (Cheryan et al., 2009). Environmental cues and campus infrastructure can improve perceived belonging, as can interventions designed to make women feel welcome in STEM communities. In an online intervention, women STEM students were provided a short message about belonging and managing challenges, sent from a woman role model. The students who received the messages had better grades and persistence rates than those who did not (Herrmann et al., 2016). Normalizing concerns about belonging helps women overcome relatedness challenges to persistence.

Beyond the perception of relatedness that exists in a woman's immediate surroundings and personal relationships, a feeling of relatedness may also be gained by the perception that she is contributing to communal goals. If the assumption is that women prefer careers dealing with people rather than things, the presentation of STEM fields as promoting collaboration and altruistic goals can improve perceived goal congruity and support a feeling of relatedness (Diekman et al., 2015; Fuesting et al., 2017). There are two aspects of communal motivation, which are working with others and working to benefit others (Diekman & Steinberg, 2013). Both collaboration and helping can contribute to a sense of relatedness.

Altruistic ambitions have been shown to be related to women's persistence in STEM majors (Espinosa, 2011). Communal values can be perceived in projects where collaboration may benefit a small group of students, or while pursuing broader altruistic or socially beneficial long-term goals. Portraying STEM activities as communal opportunities has been shown to improve and repair a sense of belonging after a prior experience of exclusion (Belanger et al., 2020). The use of communal goals to heighten belonging in STEM offers opportunities to improve women's relatedness in the field.

Role Models and Mentors. Role models and mentors are believed to be valuable in supporting girls in STEM by helping them build science identity, shape their career intentions (A. Campbell & Skoog, 2004; Millar et al., 2022), and improve persistence (Canaan & Mouganie, 2021; Drury et al., 2011). In a group of studies on the effects of same-sex expert role models on the self-concept of women in STEM courses, researchers found an inoculation effect that improved attitudes, identification, and career intent (Dasgupta & Stout, 2014). The results suggested that even while holding negative stereotypes about women in STEM, building connections with same-sex experts in the field strengthened self-efficacy and commitment to pursue STEM careers. The benefits of role models are evident among peers as well as with advanced experts. Peer mentors for women in engineering have been shown to improve belonging, confidence, and retention (Dennehy & Dasgupta, 2017).

There is an argument for women's representation in STEM that assumes girls will be more successful if their mentors are also women. However, there are factors besides gender that affect the value of a mentor, including engagement and authenticity. In other words, it is not enough to be a woman scientist to successfully mentor a girl in STEM (Conner & Danielson, 2016). The relationship that is built between a student and mentor is more important than gender matching, although gender matching may be an important initial factor (Buck et al., 2007). The timing of role modeling also produces different results. While women role models are as effective as men in recruiting women STEM majors, women are more influential in retention efforts (Drury et al., 2011). This suggests that if women role models are in short supply, their influence for retaining women mid-major may be more useful than in recruiting new students.

Peer Climate. Peer support and contributions to confidence predict intent to persist in STEM-oriented women (Banchefsky et al., 2019; Robnett, 2013). Women who experience a welcoming environment are more likely to wear or display signs of STEM identity, reinforcing the influence of relatedness and belonging on overall motivation and self-determination (Ramsey et al., 2013). Social coping is a strategy that can help mitigate a perceived chilly climate, so opportunities to develop supportive peer relationships is an important element in belongingness (Leaper, 2015; Shapiro & Sax, 2011). Women rely on social coping more than men, which may contribute to better persistence when there are more women in the STEM environment (Rainey et al., 2018; Wuhib & Dotger, 2014). The support derived from women peers in STEM may be more meaningful than gender-matched faculty members or role models (Griffith, 2010; Price, 2010).

Marginalized students may not feel that they fit with the rest of the STEM-oriented students in school groups, adding another barrier to belonging for minoritized girls (Brickhouse

& Potter, 2001; Carlone & Johnson, 2007; K. M. Jackson & Suizzo, 2015; Rainey et al., 2018). Providing support for women via single-sex STEM programs can improve a sense of belonging, including for women of color in STEM majors (Rosenthal et al., 2011). Inclusive practices can help mitigate especially chilly climates experienced by women of color in STEM (Dortch & Patel, 2017). Interestingly, however, there may be a negative effect for some women in STEM if they perceive their peers to have much higher abilities. A study determined that lower-performing women who are enrolled with high-performing women are less likely to persist in STEM majors (Fischer, 2017).

Online Connections. With social media platforms offering ubiquitous opportunities to connect online, technology offers new ways to support relatedness. There is not much research on the effect of social media participation on a sense of belonging for women in STEM. However, studies in other domains show how social media participation creates communities and fosters relationships. For example, video game communities have been using social media platforms to develop content and culture for decades. Platforms such as Facebook and Twitter function as always-open meeting spaces, with one science communicator referring to social media as a "nonstop academic conference for all" (Foell, 2021, p. 812). The open nature of many social media groups allows women to look beyond their classes and campuses for associates and role models.

Recently, groups of educators have started hosting online discussions using Twitter hashtags to track conversations (Carpenter & Krutka, 2014; Cole et al., 2013). Social media has been thought of as a distraction for students, but some schools are incorporating it into pedagogy to support learning by leveraging its affordances (Danjou, 2020; Emerick et al., 2019). Formally established groups cultivate communities for sharing domain-specific information (Buffington, 2008), and other loosely-organized groups coalesce around topics, events, and interests (Beguerisse-Díaz et al., 2017; Carpenter & Krutka, 2014; K. Petersen & Gerken, 2021; Sugawara et al., 2012). In one of the few studies of using Twitter specifically to support relatedness in an academic community, researchers found that students had a significantly higher sense of belonging compared to previous class experiences without Twitter (Friess & Lam, 2018). There is also evidence that incorporating synchronous and asynchronous social media interactions support engagement and belongingness for STEM students, including underrepresented minority students (Thacker et al., 2022). The COVID-19 pandemic catalyzed the use of social media for purposes that need further investigation.

The factors of belonging in STEM are difficult to untangle, and there is no simple recipe for relatedness. Providing opportunities for social connections, peer and professional role models, welcoming environmental cues, and communal goals are some of the factors that can help support relatedness for women in STEM. Emerging evidence also suggests that social media communities may offer additional means to satisfy relatedness needs.

Chapter Summary

The underrepresentation of women in STEM results from a complex interplay of influences. While there is no consensus on the primary cause for the gender gap in representation, there is evidence of several key factors. The pressures experienced by girls and women throughout their educational and career pathways are different from those experienced by boys and men. While some improvements have been made to the systems that historically excluded women from scientific fields, barriers remain. As important as it is to continue working on inequities that deter women from pursuing STEM careers, it is just as important to investigate how persisting women succeed despite disproportionate obstacles.

Self-determination theory provides a framework for studying women's motivation and persistence in STEM, based on the constructs of autonomy, competence, and relatedness. Each of these three constructs is an essential psychological need that contributes to intrinsic motivation. Intrinsic motivation is associated with greater persistence, well-being, and success in life. The use of SDT in this study will provide greater understanding of the relationship between these motivational factors and persistence for women in STEM.

Chapter Three: Methods

While researchers have been studying the reasons for women's underrepresentation in STEM for decades, there is less knowledge about how successful women persist despite the obstacles. Intrinsic motivation is known to result in better persistence and performance in many domains, including academic and professional success (Deci & Ryan, 2000; Gagné & Deci, 2005). According to Self-determination theory (SDT), intrinsic motivation is bolstered when the psychological needs of autonomy, competence, and relatedness are satisfied (Deci & Ryan, 2000). To contribute to the development of strategies to support women in STEM education and careers, this goal of this study is to explore and evaluate how autonomy, competence, relatedness, and other factors affect persistence.

Research Purpose and Research Questions

The overall purpose of this study was to understand how women persist in STEM fields. This study explored career persistence among women in STEM occupations who have experienced at least six years in STEM education or work. This study included women who completed an undergraduate degree in STEM and continued in graduate education or a career in a STEM field. Four research questions guided this investigation.

Research Questions

- RQ1: What are the levels of autonomy, competence, and relatedness of women who have persisted in STEM?
- RQ2: What experiences and influences contribute to women's persistence in STEM?
- RQ3: How do women explain various sociocultural influences on their persistence in STEM?

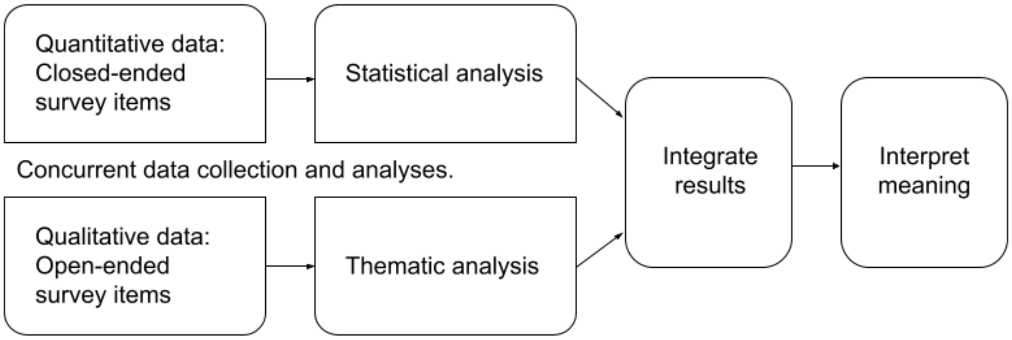
- RQ4: How do women's experiences align with their levels of autonomy, competence, and relatedness?

Research Design

Mixed methods studies use quantitative and qualitative data to investigate phenomena and questions (Creswell & Creswell, 2018). Combining quantitative and qualitative methods in a single study allowed the researcher to construct a flexible study to suit her research questions. A concurrent embedded mixed methods design (Creswell & Creswell, 2018) was used to collect quantitative and qualitative data in a single phase (Figure 2). This design was selected due to its flexibility and the researcher's pragmatic approach. Pragmatists tend to focus on finding solutions to problems, using a flexible approach to gathering data and understanding situations (Creswell & Creswell, 2018). Instead of collecting just one type of data, the researcher combined methods to gain the most complete understanding of the problem. In this study, the pragmatic inquiry approach (Morgan, 2014) allowed the researcher to use quantitative data to analyze participants' perceptions deductively and collect and analyze qualitative data, allowing for inductive interpretation. Using multiple types of data allowed the researcher to construct a more complete, contextualized understanding of the problem, since real-world phenomena are typically complicated with interwoven variables (Castro et al., 2010). Using multiple types of data in this research enabled a multidimensional understanding of women's experiences in STEM.

Figure 2

Diagram of Data Collection, Analysis, and Integration Process



The quantitative data were collected using the *Basic Psychological Need Satisfaction and Frustration Scale* (BPNSFS) to measure the three constructs of autonomy, competence, and relatedness (R. Campbell et al., 2015; Chen, Vansteenkiste et al., 2015; van der Kaap-Deeder et al., 2015; Van der Kaap-Deeder et al., 2020). Qualitative data were gathered using open-ended items asking participants about their lived experiences persisting in STEM fields. By constructing qualitative questions that addressed the variables measured by the quantitative items, the study methods were integrated by design, and further merged during the analysis and discussion phases (Creswell & Creswell, 2018; Fetters et al., 2013).

Role as Researcher

In qualitative studies, the researcher plays an integral role in the collection and analyses of data (Creswell & Creswell, 2018). However, researchers' personal experiences, assumptions, and biases can affect the analyses and conclusions. To mitigate the effects of her biases, several reflexivity practices were followed. Recording self-observations, concerns about the research process, and ideas about codes and themes help minimize bias in results (Creswell & Creswell, 2018). The researcher kept a research journal to maintain awareness of how her background could influence her interpretation of the data. She also used online tools to interact with participants anonymously instead of meeting personally with subjects. The survey was administered using Qualtrics, allowing data collection without the recording of personally identifiable information. Throughout the process, the researcher took care to apply horizontalization, considering every piece of data as equally valuable (Davidsen, 2013; Given, 2008). Additionally, statistical and thematic analysis software programs were used to provide transparent and robust analyses.

The researcher is a STEM educator and adjunct instructor who teaches part-time at a public university. Her personal experience with persistence in STEM includes a Bachelor's degree in biology, a Master's degree in environmental science, and professional roles in STEM education and science communication. She is familiar with many of the obstacles and barriers women face in STEM environments and is involved in teaching and mentoring others. Over the course of seven years as an adjunct instructor, she has taught biology, earth science, and environmental science laboratory courses. She also developed two new "Eco-Adventure" courses for the university, for which she connected with outside science experts to deliver presentations to small groups of students. The classes included field trips to integrate classroom learning with immersive, hands-on experiences. For example, a Yosemite Eco-Adventure course started with classroom discussions of the geology of Yosemite National Park, its indigenous inhabitants, history of conservation practices, and current ecological challenges. The course culminated in a multi-day camping trip to Yosemite National Park, where the class met with park scientists and performed volunteer work to help restore a meadow by manually removing invasive conifers. The combination of classroom and field instruction attracts STEM majors and others who may enjoy the outdoor experiences. She works to create a welcoming atmosphere of inquiry, safety, and belonging, and strives to set an example of intellectual humility. The researcher welcomes opportunities to connect everyone with positive science educational experiences and receives appreciative comments from students on course evaluations.

In a previous job, she worked at a nonprofit science museum, helping to create informal science educational activities for on-premises, school-based, and remote engagement. She has written science lessons for the online learning platform Study.com and engages in informal science outreach by creating multimedia science content for social media. She has reached hundreds of students, museum patrons, and Internet viewers through these many avenues. She acknowledges her enthusiasm for STEM subjects and identity as a science educator.

The researcher's parents are both science educators who set examples of persistence in STEM. Growing up in a science-oriented home, her parents influenced her perceptions of STEM as a suitable career choice. They incorporated science and inquiry into recreational activities, from outdoor exploration to a kitchen microscope for examining pond water samples. The researcher tagged along on science field trips with her parents' biology classes, making her first class trip in utero (Saigo & Saigo, 1973). The researcher attended extracurricular science activities and spent a week at Space Camp during middle school. These experiences helped deepen her science interest, identity, and competence. Her parents both earned doctorates, taught at the university level, wrote science textbooks, and encouraged her to explore a similar path. Her mother took a career break for childrearing and then returned to complete a Ph.D. in science education later in life. Her mother's experience showed the researcher that career interruptions are not insurmountable obstacles to persistence.

The researcher participates in social media groups that focus on science, engineering, and women in STEM. As a member of such online communities, the researcher engages in conversations with people beyond her locality. She uses social media to meet other women in STEM and discuss professional practices and personal experiences. Developing relationships with online peers helps the researcher feel engaged with STEM content and the community around STEM. This study included questions about social media, opening the door to exploring a little-researched area of technology as it relates to STEM persistence-supportive influences for women.

Target Population

In 2019, the National Science Board reported that seven million women in the STEM workforce had a bachelor's degree or higher (Burke et al., 2022). The target population for this study was women who have persisted in STEM beyond college for at least two years. To answer the research questions, the researcher needed to gather data from women who have remained in the STEM pathway for long enough to provide information on their experiences as persisters. For this study, persistence was defined as having earned a Bachelor's-level degree in a STEM subject, plus at least two additional years of graduate education toward an advanced STEM degree, or at least two additional years of STEM work experience. The experience did not need to be continuous, allowing women with career interruptions to participate in the study.

Sampling Method. The participant recruitment strategy was a combination of network and snowball sampling. Since the data were gathered using an online survey, the researcher distributed invitations containing a link to the survey via email and social media messages. She targeted her personal contacts in STEM as well as members of social media groups that attract women in science and engineering. She asked potential participants to share the survey invitation with their own networks to increase the pool of possible respondents.

Data Collection Strategies and Procedures

A single data collection strategy was used to capture both quantitative and qualitative data. The survey was constructed and distributed using Qualtrics, an online survey administration platform that is used to host surveys, collect and store responses, and analyze data. The Basic

Psychological Need Satisfaction and Frustration Scale (BPNSFS), created by the Center for Self-Determination Theory (Appendix B), was used to collect quantitative data (Van der Kaap-Deeder et al., 2020). The BPNSFS survey was developed to measure perceived satisfaction and frustration of autonomy, competence, and relatedness. To collect qualitative data, open-ended questions were used to prompt participants to share their experiences with STEM persistence. The demographic items of age, race, household size, geographic region, and area type were included. Additionally, items related to participants' STEM backgrounds, including years in STEM, highest STEM degree, current and previous occupations, and social media use, were also included.

The researcher constructed the survey and set up a sharing link for electronic distribution. The link led potential participants to a survey information page where they were informed of the study purpose and possible risks. Participants were required to give consent to participate in the survey and have their responses recorded before viewing the survey items. The survey was open to participants for three weeks during the early summer of 2023. The network and snowball recruitment of participants yielded a sample of 641 respondents.

Survey Instrument. The BPNSFS, developed by the Center for Self-Determination Theory, allows participants to rate their perceived satisfaction and frustration levels of autonomy, competence, and relatedness. The corresponding author of the instrument, M. Vansteenkiste (personal communication, February 17, 2023), was consulted regarding the appropriate use of the instrument, and The Center for Self-Determination Theory granted permission to use this copyrighted survey for academic purposes (Van der Kaap-Deeder et al., 2020).

The instrument consists of 24 items, each rated on a 5-point Likert-style scale from strongly disagree to strongly agree. The BPNSFS measures three subscales (autonomy, competence, relatedness), with four items to measure the satisfaction of a construct and four items to measure the frustration of a construct (Table 1).

Table 1

Basic Psychological Needs Satisfaction and Frustration Scale Items, Grouped by Subconstruct

Construct	Item
Autonomy satisfaction	I feel a sense of choice and freedom in the things I undertake.
	I feel that my decisions reflect what I really want.
	I feel my choices express who I really am.
	I feel I have been doing what really interests me.
Autonomy frustration	Most of the things I do I feel like “I have to.”
	I feel forced to do many things I wouldn’t choose to do.
	I feel pressured to do too many things.
	My daily activities feel like a chain of obligations.
Competence satisfaction	I feel confident that I can do things well.
	I feel capable at what I do.
	I feel competent to achieve my goals.
	I feel I can successfully complete difficult tasks.
Competence frustration	I have serious doubts about whether I can do things well.
	I feel disappointed with many of my performances.
	I feel insecure about my abilities.
	I feel like a failure because of the mistakes I make.
Relatedness satisfaction	I feel that the people I care about also care about me.
	I feel connected with people who care for me, and for whom I care.
	I feel close and connected with other people who are important to me.
	I experience a warm feeling with the people I spend time with.
Relatedness frustration	I feel excluded from the group I want to belong to.
	I feel that people who are important to me are cold and distant towards me.
	I have the impression that people I spend time with dislike me.
	I feel the relationships I have are just superficial.

In validation tests, the survey items produced results that correlated with established measures of associated outcomes. Satisfaction of the basic psychological needs correlated with measures of well-being (life satisfaction and vitality), while the frustration of basic psychological needs correlated with ill-being (depressive symptoms), whether or not participants desired to have those needs met (Chen, Vansteenkiste et al., 2015). These validation studies confirmed that needs satisfaction and needs frustration are separate factors, rather than degrees of the same construct, and that the survey items effectively discriminated between them. Vansteenkiste’s group and subsequent researchers further validated the BPNSFS in numerous studies across multiple countries, populations, age groups, and subject matter domains (Chen, Van Assche, et al., 2015; Chen, Vansteenkiste et al., 2015). In a four-country study with 1051 participants conducted in 2015, the instrument produced acceptable levels of internal consistency, with alpha values between .73 and .89, meaning that the survey items measured their constructs consistently across cultures. According to George and Mallery (2018), reliability is considered excellent when $\alpha > .9$, good when $\alpha > .8$, acceptable when $\alpha > .7$, questionable when $\alpha > .6$, poor when $\alpha > .5$, and unacceptable when $\alpha \leq .5$. For the current sample of women persisting in STEM, reliability for each subscale was evaluated as either good or excellent, based on Cronbach's alpha coefficients ranging from .84 to .92 (Table 2).

Table 2

Reliability Coefficients for BPNSFS Survey Items by Subconstruct

Subconstruct	α	Reliability
Autonomy satisfaction	.88	Good
Autonomy frustration	.84	Good
Competence satisfaction	.90	Good
Competence frustration	.86	Good
Relatedness satisfaction	.92	Excellent
Relatedness frustration	.86	Good

Note. Each subconstruct was measured by four survey items as shown in Table 1.

In addition to the 24 BPNSFS items, several open-ended items were included to gather narrative explanations and context for the quantitative ratings. The open-ended items asked participants to explain their experiences while persisting in the STEM environment in their own words. The BPNSFS survey, combined with demographic and qualitative items, is provided in Appendix C. To ensure content validity of the entire instrument, two content experts and a survey construction expert reviewed it offering suggestions for strengthening prior to creation of the electronic version in Qualtrics. A pilot test of the electronic survey administration process necessitated minor adjustments to the survey instructions and flow in Qualtrics before it was opened to participants.

Human Subjects Considerations

The anonymous survey posed minimal risk to the participants. The questions asked were about the individuals' professional experiences and posed no more risk than usually encountered in professional activities. No personal identifying information was captured, so there was no threat to an individual's personal or professional status. The recruitment message included information about the study's purpose and contained contact information for the researcher. Prospective participants were invited to contact the researcher with questions or concerns before visiting the survey link. After clicking on the survey link, participants landed on a welcome page with an informed consent statement. The message informed them that their responses would be anonymous and that they should not include any personally identifiable information. The statement included the required elements for informed consent and that participants could opt out of the survey at any time. Clicking to begin the survey signified consent to participate.

The study met the requirements for Category 2 exemption under the federal regulations in 45 C.F.R. Part 46 that govern human subject protections. Approval was received from the university's Graduate and Professional School's IRB (Appendix D) prior to initiating the recruitment process.

Data Analysis

All data were collected and stored in the Qualtrics system within the researcher's password-protected Pepperdine account. No personally identifiable information was submitted in the open-ended responses. The data were downloaded and stored on a password-protected laptop, with backups to a password-protected Pepperdine OneDrive cloud storage account. After cleaning, the data were loaded into Intellectus (Intellectus Statistics, 2023) for statistical analyses and MAXQDA (MAXQDA, n.d.) for thematic analyses. After analyses were completed, the Qualtrics data file was deleted from the Qualtrics platform. The findings are reported in aggregate, with selected deidentified direct quotes from respondents.

The BPNSFS scale items were used to generate quantitative results. The three theoretical constructs — autonomy, competence, and relatedness — each had eight items that provided subscale scores. A combined score of need satisfaction and each of the subscale scores were calculated. Scoring of the overall scale and subscales occurred directly within Qualtrics based on each participant's ratings. Descriptive statistics including range, variability, and central tendencies of participants' scale ratings were calculated using Intellectus software. To assess the relationships between the extent of persistence (*Years in STEM*) and the constructs, analysis of variance (ANOVA) tests were conducted. Additional statistical analyses, including *t*-tests and Spearman correlations, were used as necessary.

Responses to the open-ended survey questions were evaluated using an iterative thematic analysis process, as outlined by Kuckartz (2014). Responses were downloaded from Qualtrics as comma-separated values, and then imported into MAXQDA for qualitative analysis (MAXQDA, n.d.). Keeping in mind the research questions and theoretical constructs, an initial code book was developed. The a priori codes were based on the theoretical definitions of autonomy, competence, and relatedness, their antecedents, and associated elements, as identified during the literature review. During the first phase of analysis, passages within the responses were highlighted and linked to the initial set of codes. In subsequent iterations, emergent codes were added, and other codes combined. Annotations were made to the codebook to create detailed definitions of codes. In the next phase of analysis, codes were grouped into closely-related themes (Kuckartz, 2014). Following several iterative coding sessions with the data, a peer reviewer was engaged to ensure a reliable interpretation process. The peer reviewer confirmed that the researcher's qualitative analyses were reliable.

After the data were collected and analyzed, results from both strands were woven together to examine the relationships between quantitative results and themes revealed in narrative responses (Fetters et al., 2013). The narrative integration of results reflects the agreement of the data, using qualitative results to expand understanding of the quantitative results.

Means to Ensure Study Validity

The BPNSFS scale is a valid and reliable tool for measuring perceived levels of autonomy, competence, and relatedness of people in a variety of situations. The addition of open-ended items provides further explanations of the participants' experiences. There was a substantial target population, and the network and snowball recruitment of participants yielded a sample size of 641 respondents to the anonymous survey.

Using merged methods to collect and analyze data allowed the researcher to triangulate meaning from quantitative and qualitative strands, using rigorous processes. Software was used for a transparent and documented process and experts were consulted to ensure consistent statistical and thematic analyses. The quantitative and qualitative findings are presented separately and in an integrated format. Integrated results are presented in a joint display of quantitative and qualitative results to show statistical results and narrative examples of the theoretical constructs.

Chapter Four: Findings

The targeted population of the study was women in STEM, and participants were recruited through use of network and snowball sampling. The data were gathered using an online survey administered with Qualtrics. The resultant sample was comprised of 641 women who responded to the request for participation. Since participants were allowed to skip any survey items of their choice, the number of respondents varied by item. Findings are organized by first providing a demographic description of the sample. Next, the results of the BPNSFS and qualitative questions will be presented. The BPNSFS survey tool included 24 Likert-type items to measure respondents' levels of autonomy, competence, and relatedness. There were eight items per construct: four items to measure construct satisfaction and four items to measure construct frustration. Participants were presented five open-ended items (four common items and one of two conditional items) to explain responses in their own words. The number of responses to the open-ended questions varied from 174 to 502. The responses to the open-ended questions were analyzed thematically. The quantitative results of the BPNSFS and construct-associated qualitative themes are presented together, including direct quotes to illustrate the findings. Next, findings of relationships between *Years in STEM* and other variables are presented. Finally, additional qualitative findings are presented.

Description of Sample Demographics

Table 3 displays the response distributions for each of the demographic variables. The number of responses to these items ranged from 611 to 632. For the variables associated with participants' STEM experiences, Table 4 provides the distribution of responses.

Table 3

Frequencies and Percentages of Demographic Variable Responses

Variable	Responses n	%	Frequency Distribution
Age	632		
27-42 years	392	62.03%	
18-26 years	123	19.46%	
43-60 years	96	15.19%	
Over 60 years old	21	3.32%	
Race	613		
Caucasian	470	76.67%	
Asian	72	11.75%	
Mixed race	34	5.55%	
Latina	17	2.77%	
Other	11	1.79%	
Black or African American	6	0.98%	
American Indian or Alaska Native	3	0.49%	
Household size	614		
2-3	393	64.01%	
Only me	132	21.50%	
4-5	80	13.03%	
6+	9	1.47%	
Geographic region	612		
Outside the US	185	30.23%	
US West	152	24.84%	
US South	107	17.48%	
US Northeast	101	16.50%	
US Midwest	67	10.95%	
Area type	611		
Urban	299	48.94%	
Suburban	245	40.10%	
Rural	67	10.97%	

Note. Due to rounding errors, percentage totals may not equal 100%.

There were 632 responses to the *Age* item on the survey. Respondents were asked to indicate their ages by category. The most frequently observed category of age was 27-42 years (n = 392, 62.03%) and the least frequently observed age group was over 60 years (n = 21, 3.32%), as shown in Table 3. More than 80% of the respondents were concentrated in the younger age categories, between 18-42 years old.

Race was indicated by 613 of the respondents. For the purposes of analysis, responses written into the *Other* category were recoded into matching categories when possible. In addition, it was noticed after the survey was deployed that no category was offered for Hispanic or Latina, but those were frequently written into the *Other* category. To provide a more accurate representation of responses, the *White* category was renamed to *Caucasian*, and any *Other* responses that were understood as Hispanic were recoded as *Caucasian*. Similarly, any *Other* responses that were understood to be Latin American were recoded into a new category called *Latina*. Finally, any responses that included multiple categories except for *White + Other (Hispanic)* were recoded as *Mixed race*. The most frequently observed category of *Race* was *Caucasian* (*n* = 470, 76.67%), with all other categories totaling less than 25% of responses. Frequencies and percentages for all categories are presented in Table 3.

The *Household Size* item was completed by 614 participants. The most frequently observed category of *Household Size* was *2-3* (*n* = 393, 64.01%), followed by *Only me* (*n* = 132, 21.50%), indicating less than 15% of respondents live with larger families or household groups. Frequencies and percentages are presented in Table 1.

Geographic Region was reported by 612 participants, with the largest proportion of respondents living *Outside the U.S.* (*n* = 185, 30.23%). Among participants within the U.S., the most frequently indicated region was the *U.S. West* (*n* = 152, 24.84%), followed by approximately 17% from both the *U.S. South* and *U.S. Northeast,* and about 11% from the *U.S. Midwest*. Frequencies and percentages are presented in Table 3.

The *Area Type* item asked participants to indicate whether the area where they live is considered urban, suburban, or rural (Table 3). The item was completed by 611 respondents. Most of the respondents chose either *Urban* (*n* = 299, 48.94%) or *Suburban* (*n* = 245, 40.10%).

Description of Sample STEM Background

Table 4 shows the number of respondents reporting on their STEM experiences.

Table 4

STEM Background Variables

Variable	Responses n	%	Frequency Distribution
Years in STEM	632		
9-15 years	246	38.92%	
6-8 years	174	27.53%	
16-29 years	161	25.48%	
30-45 years	39	6.17%	
45+ years	12	1.90%	
Highest STEM degree	641		
Doctorate level	265	41.34%	
Bachelor's level	205	31.98%	
Master's level	171	26.68%	
STEM occupation (current)	620		
Life scientist	189	30.48%	
Computer scientist	166	26.77%	
Physical scientist	57	13.55%	
Engineer	61	9.84%	
Other	45	7.26%	
Mathematical scientist	33	5.32%	
Social scientist	29	4.68%	
STEM educator	13	2.10%	
STEM occupation (previous)	609		
I haven't' had a previous STEM occupation	292	47.95%	
Life scientist	115	18.88%	
Computer scientist	64	10.51%	
Physical scientist	51	8.37%	
Engineer	27	4.43%	
Social scientist	22	3.61%	
Mathematical scientist	19	3.12%	
Other	16	2.63%	
STEM educator	3	0.49%	

Note. Due to rounding errors, percentage totals may not equal 100%.

As a measure of persistence in STEM, respondents were asked to indicate their total number of *Years in STEM*. Most respondents had between *9-15 years* in STEM (*n* = 246, 38.92%), followed by those with the least experience of *6-8 years* (*n* = 174, 27.53%), suggesting that most participants were in their early- to mid-career stages. Approximately one-quarter of respondents had *16-29 years* of experience (*n* = 161, 25.48%), and relatively few had more than 30 years of experience in STEM (*n* = 51, 8.07%).

There were 641 responses to the item reflecting a participant's *Highest STEM Degree* (Table 4). The most frequently observed category of *Highest STEM Degree* was *Doctorate level* (*n* = 265, 41.34%), followed by *Bachelor's level* (*n* = 205, 31.98%) and *Master's level* (*n* = 171, 26.68%). The data indicate that most respondents (*n* = 436, 68.02%) hold graduate degrees in STEM.

Two items were presented to determine respondents' *Current STEM Occupation* and *Previous STEM Occupation* (Table 4). There were 620 and 609 responses to these questions, respectively. The largest category of *Current Occupation* was *Life Scientist* (*n* = 189, 30.48%). The most frequently observed category of *Previous Occupation* was *I haven't had a previous STEM occupation* (*n* = 292, 47.95%), suggesting that a respondent had not changed occupations or was currently in her first STEM job, followed by *Life Scientist* (*n* = 115, 18.88%). For the purposes of analysis, occupations written into the *Other* category were manually recoded into matching categories where possible. Additionally, a new category called *STEM Educator* was created, since it appeared several times in responses under *Other*.

STEM-specific Social Media Use

Participants were asked whether they participate in STEM-specific social media. There were 611 responses to this question. Most of the respondents reported that they did participate in STEM-specific social media (*n* = 405, 66.28%). The rest of the respondents answered *No* (*n* = 206, 33.72%).

Scoring of Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS). The BPNSFS scale (Van der Kaap-Deeder et al., 2020) included 24 items to quantify participants' perceived satisfaction and frustration levels for the theoretical constructs of autonomy, competence, and relatedness. Each item on the BPNSFS is a statement that is rated on a 5-point Likert-type scale from strongly disagree (1 point) to strongly agree (5 points). The autonomy section included eight items: four measuring autonomy satisfaction and four measuring autonomy frustration. Competence and relatedness also each had four items measuring satisfaction and four measuring frustration. The BPNSFS items were scored according to Combined Satisfaction (12 items) and Combined Frustration (12 items) and then subscored by construct. Since satisfaction and frustration are separate factors, they are measured and scored separately, rather than as the inverse of one another; each results in a separate score. Combined Satisfaction scores are the sum of autonomy, competence, and relatedness satisfaction scores. Combined Frustration scores are the sum of autonomy, competence, and relatedness frustration scores. The participants were permitted to skip any survey items, which resulted in different numbers of responses for each item.

Combined Satisfaction of Autonomy, Competence, and Relatedness

There were 477 cases used to calculate scores for *Combined Satisfaction* across the constructs of autonomy, competence, and relatedness. For the sample, the maximum observed score was 60.00, which was the highest score possible if a respondent chose *strongly agree* (5) for all 12 satisfaction items. The minimum observed score was 7.00. The mode was 54.00, with a mean of 48.40, and a standard deviation of 9.65. The most frequently observed scores occurred toward the maximum, suggesting the respondents generally perceived high overall levels of psychological need satisfaction. The summary statistics are described in Figure 3 and the frequency distribution of *Combined Satisfaction* scores is shown in Table 5.

Figure 3

Frequency Distribution of Combined Satisfaction Scores

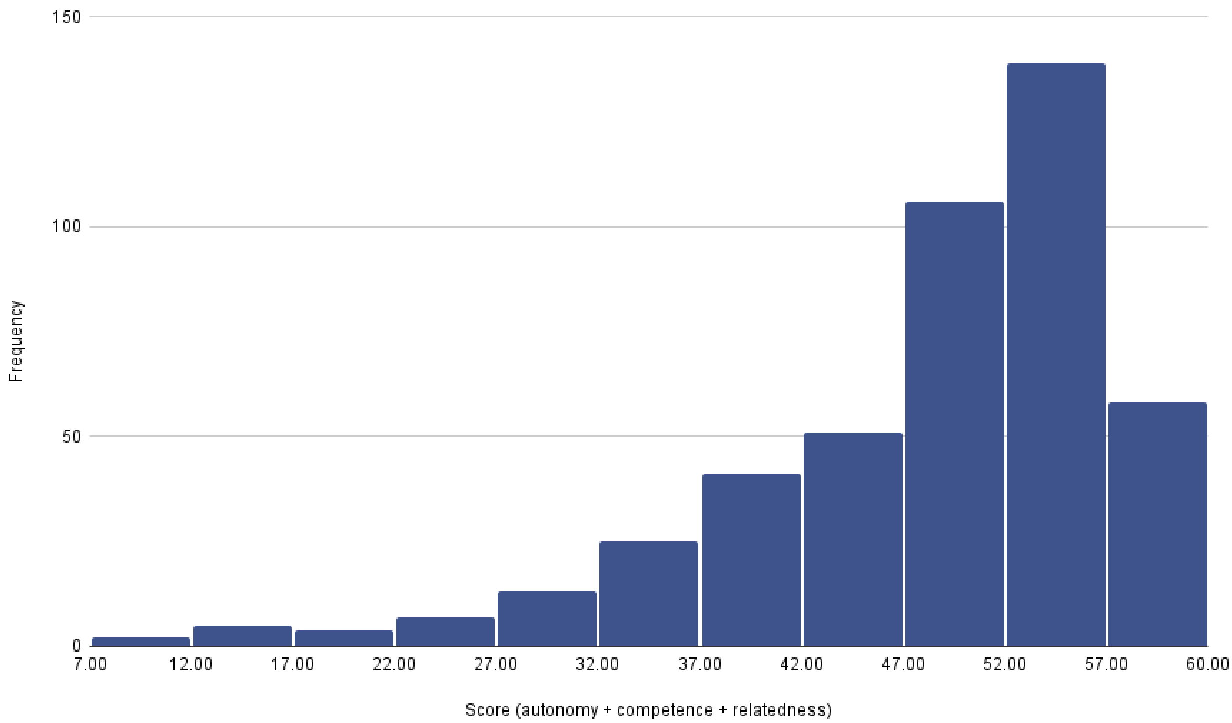


Table 5

Summary Statistics for Combined and Individual Construct Satisfaction Scores

Variable	Mean	Std Dev	*n*	Min	Max	Mode
Combined satisfaction	48.40	9.65	477	7.00	60.00	54.00
Autonomy satisfaction	15.75	3.84	477	3.00	20.00	20.00
Competence satisfaction	16.70	3.43	469	4.00	20.00	20.00
Relatedness satisfaction	16.69	3.65	464	4.00	20.00	20.00

The satisfaction results are divided and discussed by individual construct below.

Quantitative Findings on Autonomy Satisfaction

The four items measuring autonomy satisfaction were completed by 466 to 476 respondents. The autonomy satisfaction subscores ranged from 3.00 to 20.00 with a mean value of 15.75 (*SD* = 3.84; Table 5). The four survey items to measure autonomy satisfaction are presented with their results summaries in Table 6. The high measures of central tendency suggest that the participants generally experienced high levels of perceived autonomy. Overall, when calculating all four autonomy satisfaction items together, 77% of respondents indicated that they either somewhat or strongly agreed with the statements and less than 13% of respondents either somewhat or strongly disagreed with the same items.

Table 6

Autonomy Satisfaction Survey Items and Responses

	Responses		
Scale Item	n	%	Frequency Distribution
I feel a sense of choice and freedom in the things I undertake.	476		
Strongly agree	167	35.1%	
Somewhat agree	208	43.7%	
Neither agree nor disagree	32	6.7%	
Somewhat disagree	49	10.3%	
Strongly disagree	20	4.2%	
I feel that my decisions reflect what I really want.	475		
Strongly agree	149	31.4%	
Somewhat agree	221	46.5%	
Neither agree nor disagree	48	10.1%	
Somewhat disagree	41	8.6%	
Strongly disagree	16	3.4%	
I feel my choices express who I really am.	466		
Strongly agree	165	35.4%	
Somewhat agree	179	38.4%	
Neither agree nor disagree	65	14.0%	
Somewhat disagree	40	8.6%	
Strongly disagree	17	3.6%	
I feel I have been doing what really interests me.	474		
Strongly agree	204	43.0%	
Somewhat agree	175	36.9%	
Neither agree nor disagree	39	8.2%	
Somewhat disagree	33	7.0%	
Strongly disagree	23	4.9%	

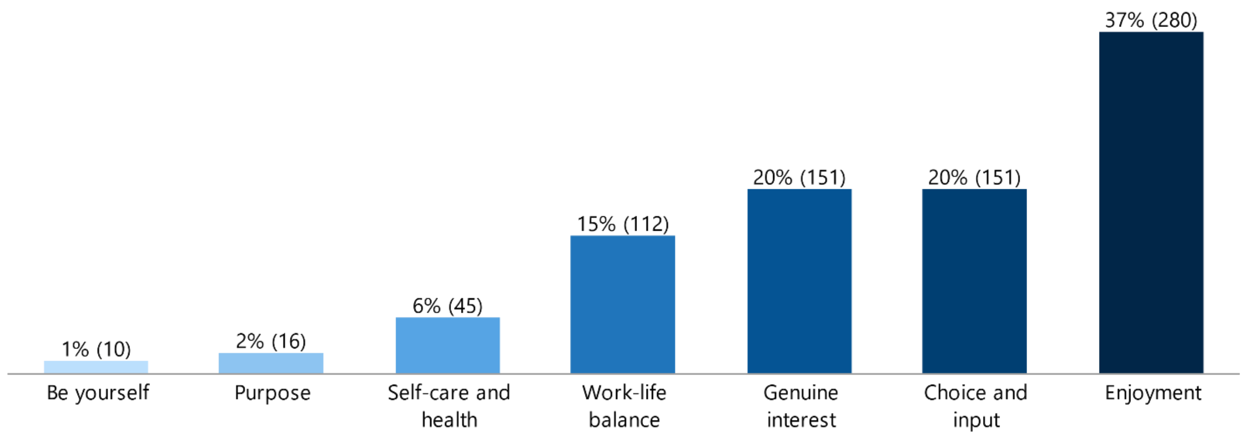
Note. Due to rounding errors, percentage totals may not equal 100%.

Qualitative Findings on Autonomy Satisfaction

Narrative responses reflected most subjects expressed autonomy satisfaction. Within the qualitative data, 765 segments were coded for autonomy and seven themes were identified: *Be Yourself*, *Purpose*, *Self-care and Health*, *Work-life Balance*, *Genuine Interest*, *Choice and Input*, and *Enjoyment*. The most frequently coded autonomy theme was *Enjoyment*, which was identified in 280 segments of participant responses. The frequencies of autonomy-related themes are shown in Figure 4 and each theme is discussed in greater detail below.

Figure 4

Autonomy Satisfaction Themes and Coding Frequencies



Be Yourself. This theme was assigned to passages reflecting a desire or ability to be authentic, not needing to behave or look like others, being comfortable being the only woman in a group, or being feminine even if it seemed more acceptable to be masculine. Answering the question about what she wished she had known earlier about persisting in STEM, one respondent commented, “Even though most of my colleagues are men, you don’t need to be masculine or eschew your feminine qualities to fit in and be successful.” Another offered, “You don’t need to represent all women, you don’t need to prove yourself to everyone, just find the right place to be yourself.”

Purpose. Sixteen passages reflected the theme of *Purpose* and included references to a personal sense of purpose, remembering why STEM is important, or having reasons for doing activities. One respondent shared how participating in STEM-specific social media supports her persistence, saying it “Solidifies my sense of purpose and motivation to stay in STEM.” Another woman said one of her strategies for overcoming obstacles to persistence is to “Stay positive and remind myself of why I am doing this.” Similarly, one participant stated simply, “I have to remember my why.”

Self-care and Health. There were 45 passages coded for the theme of *Self-care and Health*. These segments referred to maintaining one’s physical or mental health, going to therapy, exercising, taking breaks, getting rest, and other related ideas. Several respondents shared advice about *Self-care and Health* as strategies for overcoming obstacles to persistence. Going to therapy was commonly mentioned, “I see a therapist regularly to maintain my mental health,” and “Recommend therapy for life to all women in STEM.” Tending to one’s physical health was also noted: “Take care of your body, don’t forget about it as you worship your brain,” and “workout at gym a lot.” Others expressed the importance of hobbies, such as “Keep my hobbies to stay mentally ok,” and “Focus on distracting hobbies when co-workers or bosses are condescending, rude, or sexist.”

Work-life Balance. In addition to mentioning *Work-life Balance* explicitly, this theme includes passages that mention not working crazy hours, leaving work on time, not working on weekends, taking vacation, and keeping work separate from pleasure. There were 112 passages coded for *Work-life Balance*. Several respondents cited the desire for work-life balance as their reason for not participating in STEM-specific social media. For example, "I prefer to keep work at work and try to limit all technical discussion outside of my 9-5," and "I get enough STEM exposure through my work, so I prefer my social media to be separate." The ability to balance work and other activities was an important part of why some participants stay in STEM: "Supervisor is incredibly flexible and understanding about my wanting to have both a career and a family," and "Amazing autonomy and flexibility which works well for my work life balance." Others shared advice about maintaining work-life balance as a strategy for persistence, as in "Draw strong boundaries for maintaining a healthy work-life balance," and "Assert work life balance – literally block time on the calendar to be uncontactable."

Genuine Interest. Responses that mention having interest in a topic, curiosity, being fascinated, or not being bored, were coded under the theme *Genuine Interest*. There were 151 passages coded for this theme. Many respondents described their interest in STEM as something that developed early in life: "Always been interested in STEM since I was a kid doing science fairs," and "I learned programming in high school and I've never wanted to do anything else." Another frequent subtheme related to persistence was the potential to keep learning about a subject, such as, "Science is endlessly interesting, and I don't get tired of learning more about it," and "Curiosity, I can always be looking for something new to learn."

Choice and Input. There were 151 responses coded for the theme of *Choice and Input*, which referred to having volitional control over actions, being able to make choices, having flexibility to choose, prioritizing, giving input or speaking up for oneself. Being able to make choices was a frequent sentiment in respondents' reasons for staying in STEM. Many participants mentioned freedom or flexibility. For example, "I do love the freedom academia gives me to work on exactly what I want to, in whatever way I want to (10 hour lab days one week, 2 hour sofa days the next week).” Being able to choose jobs and work situations was also mentioned by several respondents, as in, “Selecting positions that interest me even if they pay less,” “Choosing fields that are historically less cut-throat and which have more women,” and “Granting myself more agency over my path has helped me keep the door open and not feel trapped.”

Giving input and expressing oneself were also mentioned frequently as factors in persistence. Many participants talked about speaking up and being heard. In response to a question about what she wished she had known earlier about persisting, one woman offered, “Speak up speak up SPEAK UP. No one is listening out for you. No one is coming to look for you. You must make your voice heard.” Others echoed the need for self-advocacy: “It is necessary to be loud to be heard,” “Don’t be afraid to speak up,” and “Don’t take shit, be assertive without trying to act like an aggressive male.”

Enjoyment. The theme of *Enjoyment* was indicated in 280 passages. These segments referred to loving or having passion for a subject or activity, having fun, finding the work itself rewarding, or work that feels like a hobby. *Enjoyment* was the most frequently mentioned theme in the autonomy category. Some participants said they found *Enjoyment* in STEM-specific social media groups: “Reminds me of the joy of the areas I study and research in,” and “Science-based humor is also a great way to remember to have fun and share the joy of science.” Many respondents expressed their love and enjoyment of science as reasons for persisting in STEM. For example, “I love chemistry! I love thinking about it, learning more about it, talking about it, and making others think, learn, and talk about chemistry.” Others expressed similar sentiments, such as, “I enjoy my work immensely,” “I stay in STEM because I enjoy solving problems, finding answers,” “I love the way it makes my brain light up,” and “I absolutely love my job.”

Quantitative Findings on Competence Satisfaction

The four scale items to measure competence satisfaction were completed by 465 to 469 respondents. The statistical summary of the competence satisfaction scores is shown in Table 5 and the individual survey statements and results are displayed in Table 7. The competence satisfaction subscore mean was 16.70 (*SD* = 3.43), with a mode of 20.00 and an observed maximum of 20.00. The measures of central tendency for competence satisfaction were high, indicating that the respondents experienced high overall competence satisfaction. Calculating across the four items pertaining to competence satisfaction, nearly 84% of respondents indicated that they either somewhat or strongly agreed with the statements. Conversely, less than 10% of respondents said they either somewhat or strongly disagreed with the competence satisfaction statements.

Table 7

Competence Satisfaction Survey Items and Responses

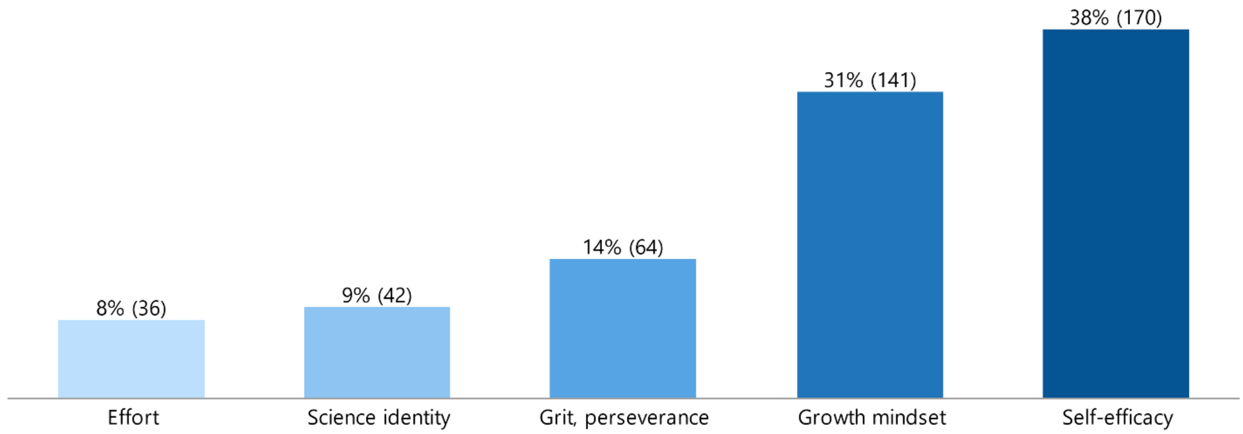
Scale Item	Responses n	%	Frequency Distribution
I feel confident that I can do things well.	467		
Strongly agree	214	45.8%	
Somewhat agree	177	37.9%	
Neither agree nor disagree	29	6.2%	
Somewhat disagree	40	8.6%	
Strongly disagree	7	1.5%	
I feel capable at what I do.	468		
Strongly agree	216	46.2%	
Somewhat agree	182	38.9%	
Neither agree nor disagree	27	5.8%	
Somewhat disagree	35	7.5%	
Strongly disagree	8	1.7%	
I feel competent to achieve my goals.	465		
Strongly agree	189	40.7%	
Somewhat agree	179	38.5%	
Neither agree nor disagree	45	9.7%	
Somewhat disagree	41	8.8%	
Strongly disagree	11	2.4%	
I feel I can successfully complete difficult tasks.	469		
Strongly agree	238	50.8%	
Somewhat agree	173	36.9%	
Neither agree nor disagree	29	6.2%	
Somewhat disagree	24	5.1%	
Strongly disagree	5	1.1%	

Qualitative Findings on Competence Satisfaction

The qualitative data provide additional evidence of competence satisfaction in the sample. From 453 passages coded for competence, five themes were identified: *Effort*, *Science Identity*, *Grit and Perseverance*, *Growth Mindset*, and *Self-efficacy*. The frequency distribution of those five themes are shown in Figure 5 and the themes are discussed in greater detail below.

Figure 5

Competence Satisfaction Themes and Coding Frequencies



Effort. Passages coded as *Effort* referred to working toward a degree or career, investing time or money, using or earning degrees, making progress, having worked too hard to change now, being qualified for this job, etc. The 36 comments coded for *Effort* may have a positive or negative tone. For example, some respondents shared, "I get to utilize all my education (I have 4 degrees) within the scope of my career," and "My educational and work background has set me on a path to stay in STEM." Some participants mentioned that they felt unqualified to do anything else, saying, "It doesn't seem right to me to change my area of interest and waste the years of training," and "It's all I know, started it since I was 21 and it'll be really hard to switch."

Science Identity. The 42 passages coded for *Science Identity* referred to feeling a good fit in one's field, being born to be a scientist, feeling this is what one is meant to do, or feeling that one's career defines her identity. One respondent credited her father with helping her develop her science identity, saying "My father identified me as a scientist when I was very young and I have never not seen myself as a scientist." Another cited her science identity as a reason for her persistence, saying "I stay in STEM because I identify as a scientist and with the scientific method." Other participants said they felt they were born with science identities, as in "…I was born an engineer," and "Frankly, I feel like I was born to be a surgeon."

Grit and Perseverance. There were 64 passages coded for the theme *Grit and Perseverance*. This theme includes references to hard work, work ethic, sheer will, grit, stubbornness, perseverance, resilience, not quitting, refusing to give up, having a thick skin, ignoring the haters, or sticking with it. Messages about *Grit and Perseverance* varied in tone, from encouraging to defiant. Some respondents credited “Obstinate persistence,” “Spite and stubbornness,” or “Just persevering no matter what” for overcoming obstacles and helping them stay in STEM. Others shared the importance of work, including a perceived need to work harder than others to be considered successful, such as “I had to work harder for people to take me seriously,” and “Women will have to work twice as much but that doesn’t mean they’re any less good than men.” Another subtheme was the need to stay in STEM to help create change, as in “Sometimes it feels like being a woman in STEM is a rebellious act,” “We have to grit our teeth and keep going to make change from within,” and “Being in STEM will mean a life of struggle, resistance and fight for what is right.”

Growth Mindset. There were 141 passages coded for the *Growth Mindset* theme. These segments referred to accepting challenges and failures as learning opportunities, making progress, career growth, keeping up with the field, learning new things, not needing to be perfect, improvement, and related ideas. Many respondents included thoughts about a *Growth Mindset* when explaining their motivations to stay in STEM. Some said that social media allows them to see other women’s struggles, which normalizes difficult experiences and support persistence. For example, “Understanding that hardships/struggles are common and don’t mean I am a failure,” or “Discourse that does not vilify failure and allows me to remain motivated/not discouraged.” Another repeated idea was the need to continue learning, as in “You can’t do STEM without learning something new every day,” “Being adaptable and a lifelong learner helped me navigate big career changes," and "Be willing to learn new things, that's often the direction of new opportunity." Finally, several women offered inspirational advice they wish they had known earlier. For example, "It's okay to be bad at it at first. In fact, it is normal," "If something is hard, that doesn't mean you can't do it," and "Be humble, and when you don't know something, look it up and learn it!"

Self-efficacy. The most frequently mentioned Competence theme was *Self-efficacy*. There were 170 passages coded for *Self-efficacy*, which referred to ideas such as confidence in one's ability to do something, demonstrating mastery, being good at a job, being an expert, being able to tackle challenges, overcoming imposter syndrome, or believing in oneself. Many women expressed strong *Self-efficacy* when explaining why they persist in STEM, such as "I stay in STEM because I'm good at it," or "I stay in it because I'm the expert in my field now." Another subtheme was a recognition of the need to demonstrate one's skills to prove mastery to others — frequently men — as in, "Make sure you are damn good, so no one can question your belonging," and "Act competent. Demand respect not with words but with being good at what you do." And finally, several respondents said they fight feelings of "imposter syndrome" by reminding themselves of their competence. For example, "I remind myself of what I have accomplished in the past which helps me work towards the future," "Be more confident and resist imposter syndrome," and "Recognize and celebrate your achievements, take credit for your contributions, and trust in your abilities."

Quantitative Findings on Relatedness Satisfaction

The four survey items to measure relatedness satisfaction were completed by 455 to 464 participants. The statistical description of the relatedness satisfaction subscale is presented in Table 5. The relatedness satisfaction mean was 16.69 (*SD* = 3.65), with a median of 18.00, a mode of 20.00, and an observed maximum of 20.00. The four survey items to measure relatedness satisfaction are presented with their results summaries in Table 8. The overall score for relatedness satisfaction was relatively high. Calculated across all four items, 82% of respondents indicated that they somewhat or strongly agreed with the relatedness satisfaction statements on the scale. Less than 8% of the participants indicated that they somewhat or strongly disagreed with the same statements.

Table 8

Relatedness Satisfaction Survey Items and Responses

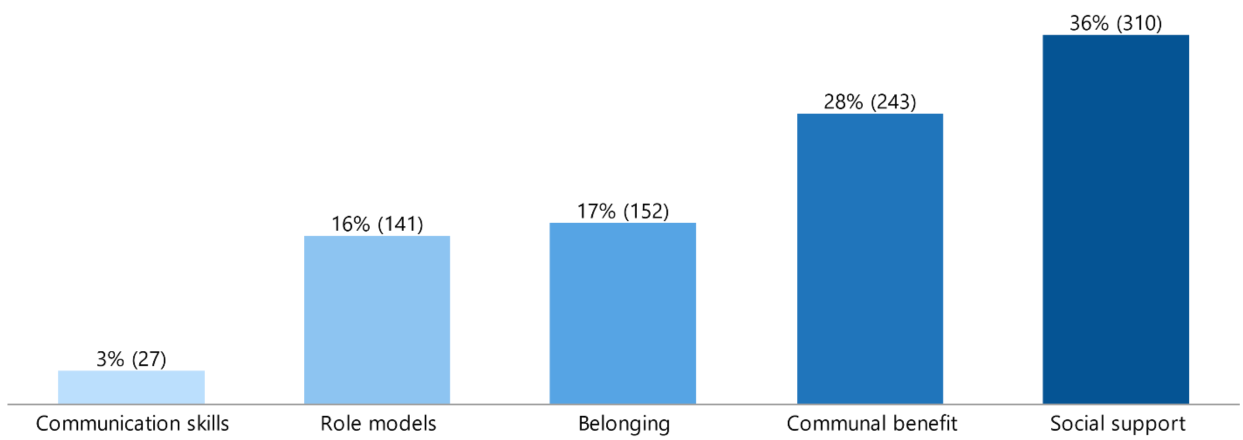
	Responses		
Scale Item	n	%	Frequency Distribution
I feel that the people I care about also care about me.	464		
Strongly agree	222	47.8%	
Somewhat agree	170	36.6%	
Neither agree nor disagree	32	6.9%	
Somewhat disagree	27	5.8%	
Strongly disagree	13	2.8%	
I feel connected with people who care for me, and for whom I care.	464		
Strongly agree	240	51.7%	
Somewhat agree	150	32.3%	
Neither agree nor disagree	38	8.2%	
Somewhat disagree	27	5.8%	
Strongly disagree	9	1.9%	
I feel close and connected with other people who are important to me.	455		
Strongly agree	228	50.1%	
Somewhat agree	145	31.9%	
Neither agree nor disagree	44	9.7%	
Somewhat disagree	27	5.9%	
Strongly disagree	11	2.4%	
I experience a warm feeling with the people I spend time with.	462		
Strongly agree	201	43.5%	
Somewhat agree	157	34.0%	
Neither agree nor disagree	71	15.4%	
Somewhat disagree	19	4.1%	
Strongly disagree	14	3.0%	

Qualitative Findings on Relatedness Satisfaction

There were 873 passages coded for relatedness-related ideas, which fit into five themes for relatedness satisfaction. Those themes were *Communication Skills*, *Role Models*, *Belonging*, *Communal Benefit*, and *Social Support*. The themes and the frequency of their codes are shown in Figure 6. Each theme is defined and described in detail below.

Figure 6

Relatedness Satisfaction Themes and Coding Frequencies



Communication Skills. The theme of *Communication Skills* was identified in 27 passages, which referred to communicating effectively, having open channels of communication, knowing how to negotiate, having social skills, speaking and writing, and other related ideas. The need to be comfortable asking questions was highlighted by respondents, as in "Asking questions when you aren't familiar opens more doors than pretending and trying to catch up later," and "Ask questions to anyone you believe might have the answer." Being able to negotiate and handle challenges was also mentioned, including the ability to maintain professional decorum and navigate difficult situations. Several women wished they had known these things earlier saying, "I did have to learn strategies to deal with questioning older, more experienced men," "I wish I learned to negotiate earlier and diplomatically navigate tough situations," and "Be able to communicate and understand issues." Finally, several respondents shared that documenting and promoting their accomplishments helped with persistence. One woman said, “I meticulously document everything I do and always communicate transparently,” and another recommended “Strong communication and self-promotion skills.”

Role Models. There were 141 passages coded for the theme of *Role Models*. These segments referred to experiencing positive real-life or fictional role models, having a good mentor, advisor, or boss, peer exemplars, seeing positive representation, and other related ideas. This theme includes references to having role models, but not being a role model. Those passages are coded for the *Communal Benefit* theme. Many stated the importance of having supportive and exemplary family members, as in “Both my parents are physicians and mother is also a researcher,” and “My parents are STEM educators and they encouraged me,” and “My mother worked with data and databases and is a strong role model.” Others noted the influence of media representation in their lives, such as “As I grew up, more women were visible as scientists in media, on TV, in scientific articles, books, news stories… movies… ‘Dinosaurs eat man, woman inherits the earth’ Sign me up.” Another noted, “I was non-trivially influenced by Star Trek. Probably as much because of the inclusive message as because of a woman on the bridge of the Enterprise.” Several respondents reported finding examples of positive representation and role models on social media. One commented, “Seeing and interacting with others who have faced and overcome similar obstacles, I feel inspired and encouraged to persevere in my STEM journey.” Another recommended, “Join online communities to gain insight and advice from more experienced people.” Many participants said the presence of women as mentors and advisors was crucial to their STEM persistence, mentioning “Guidance and mentorship early in my career from other women in STEM,” “Powerful women mentors who helped and motivated me,” and “Mentorship from other women is key.” A small number of respondents noted that they had positive experiences with men as mentors and advisors too, as in "I've nearly always been the only woman in the room, I was trained early by a male mentor to not let it bother me," and "Male mentors and colleagues who understand the importance of advocating for women in STEM have used their influence to open professional doorways for me."

Belonging. There were 152 passages coded for *Belonging*, which referenced being part of a community, not feeling alone, having shared experiences, being accepted, feeling connected, and so on. Many participants found social media helpful for finding community: "STEM specific social media helps me feel involved in a community and that positively impacts my motivation to stay in STEM," "Since I have few people to connect with as females in STEM in person, it helps give a sense of community," and "Social media groups help keep me motivated and help me feel a little less isolated." Another common thread was the importance of shared experiences and feeling less alone, as in "I don't feel alone when I hear other women's stories and perspectives," "Very motivating to feel seen and to see others like me with similar issues and journeys," and "Makes me feel less alone and helps motivate me so I don't give up." Some participants said belonging in a community supports their persistence in STEM: "I also really enjoy the scientific community, which also makes me want to stay in STEM," and "Being part of diverse and inclusive communities within STEM has played a significant role in sustaining my commitment."

Communal Benefit. This theme was coded in 243 passages that referred to working with others or for the benefit of others, serving as a mentor, being a role model, social justice or advocacy, networking or mutual assistance, working for the good of society, setting an example, and other related ideas. Many women noted their desire to serve as role models or mentors to other women in STEM. For example, several respondents said social media provided opportunities to "provide mentorship to future professionals," "inspire the next generation of scientists," and "support other women so they'll stay in STEM." Wanting to help other women was commonly listed as a reason for persisting in STEM, with participants saying "I stay because I'm helping the next generation of women in STEM," and "I stay in STEM because I want to mentor other women in STEM so they don't have as horrible an experience as I did." Others expressed the importance of improving society or making the world a better place, such as "I remain here because I feel like I am moving humanity and the Earth forward," and "My work helps people." Some respondents mentioned the career benefits of working together and networking. Examples of these include: "Online communities have been key to me growing in my STEM career," and "I don't think I realized how much I could help myself and my career by inspiring girls to pursue tech and helping other women stay in tech." Finally, several respondents emphasized the importance of having a mutually supportive group of colleagues and friends, saying "we can carry each other through the more difficult times," "find ways to connect and encourage other women in my STEM field," and "it's about finding a community that tries to help each other and build everyone up."

Social Support. There were 310 passages coded for *Social Support,* which referred to having supportive relationships, people to talk to, hearing other people's perspectives, commiserating, and other social coping ideas. *Social Support* from family members was mentioned by respondents, as in "My parents celebrated my enjoyment of science and encouraged it," and another said "A strong family foundation" was crucial to her persistence in STEM. Many participants noted the influence of supportive friends and colleagues on their motivation, such as "Support from friends… has been the single most important thing that has pulled me through tough spots," and "Creating a community of women in your field… helps fight isolation and provides a group for advice," and "Find female friends in the field, it makes every difference." Some participants recommended having friends outside their field, such as "My family and friends outside of STEM keep me motivated," and "I have persisted in STEM by connecting with people outside this field." Several women said having a group of people to "vent" with was a strategy they use to persist. For example, one woman said social media "offers a place to vent and commiserate with others about the challenges faced by being a woman in this field." Finally, some participants pointed out the support they received from men. For example, "It is also vital to have support from men as well, as the unfortunate reality is often that their opinion will hold more weight," and "Find men with daughters. These men have been my biggest supporters."

Combined Frustration of Autonomy, Competence, and Relatedness

The frustration scores were calculated in the same manner as satisfaction scores. For the *Combined Frustration* score, the responses for all 12 frustration items (four items per construct) were added together. The scores were assigned to survey options from 1 (*strongly disagree*) to 5 (*strongly agree*). There were 471 responses included in the calculation of *Combined Frustration* scores. Since participants were permitted to skip any survey item, the number of responses varied by item, from 457 to 471. The observed responses ranged from 7.00 to 60.00 with a mean of 30.64 (SD = 10.28), shown in Figure 7. The frustration scores for autonomy, competence, and relatedness are shown in Table 7 and discussed in greater detail below. Results from participants' qualitative responses are discussed to provide additional context for the quantitative scores.

Figure 7

Frequency Distribution of Combined Frustration Scores

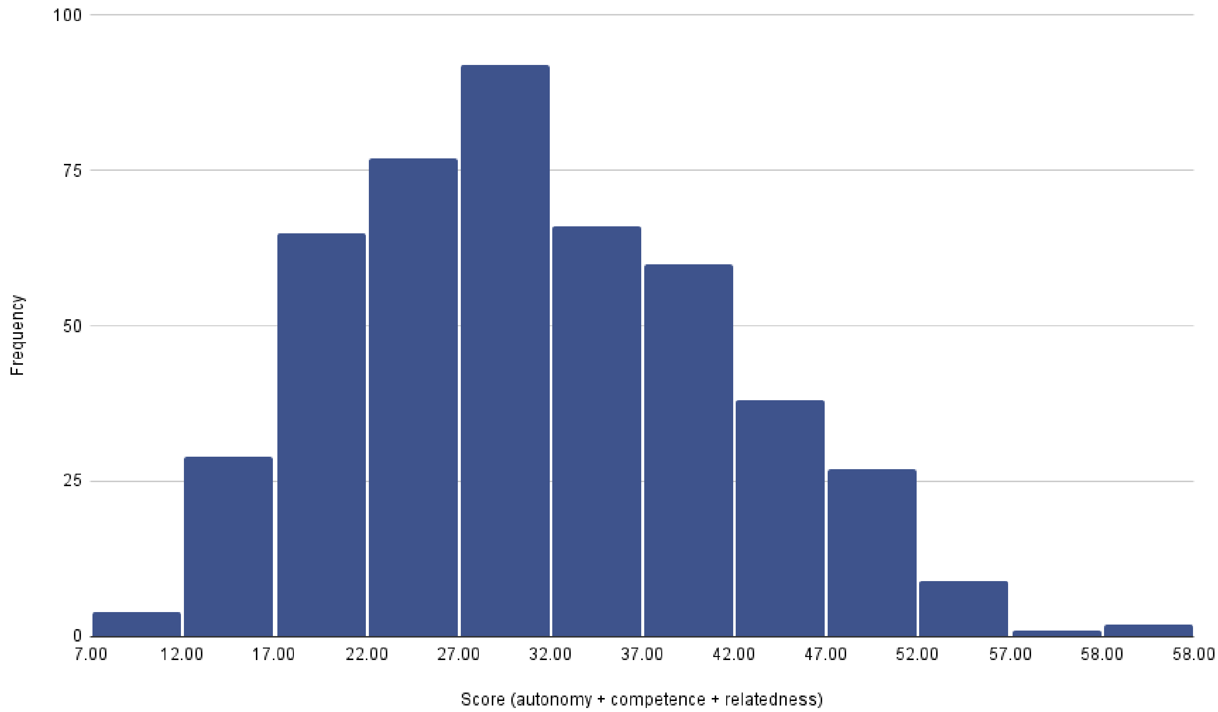


Table 9

Summary Statistics for Combined and Individual Construct Frustration Scores

Variable	Mean	Std Dev	*n*	Min	Max	Mode
Combined frustration	30.64	10.28	471	7.00	60.00	28.00
Autonomy frustration	12.07	4.20	470	3.00	20.00	11.00
Competence frustration	10.17	4.52	465	3.00	20.00	4.00
Relatedness frustration	8.82	4.11	457	2.00	20.00	4.00

Quantitative Findings on Autonomy Frustration

The score for autonomy frustration was calculated using data from 470 respondents. Scores ranged from 3.00 to 20.00 and the mean was 12.07 (Table 9). Compared to frustration levels for competence and relatedness, autonomy frustration had the highest mean and mode values. Calculated across all four items for autonomy frustration, about 43% of respondents either somewhat or strongly agreed with statements, while about 39% either somewhat or strongly disagreed. Results for individual survey items are displayed in Table 10.

Table 10

Autonomy Frustration Survey Items and Responses

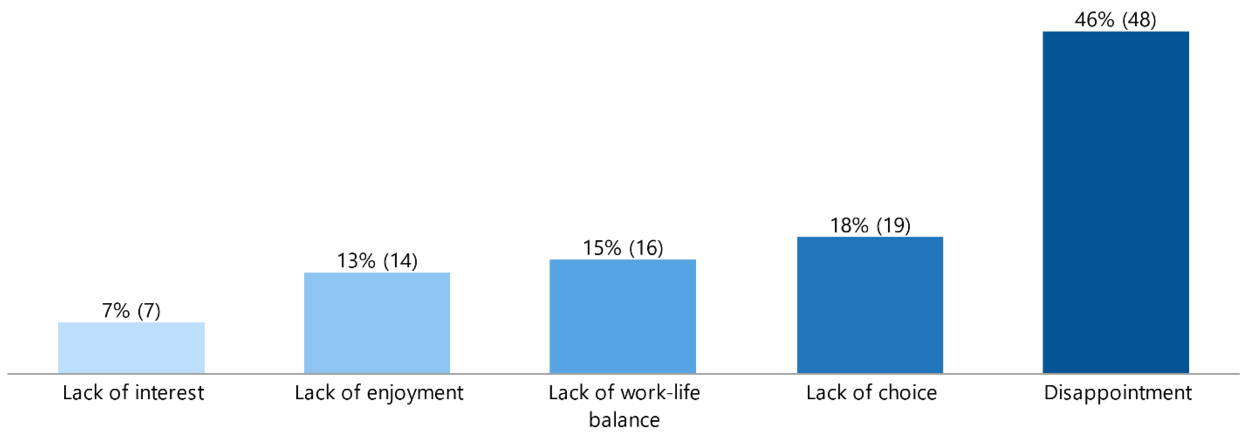
Scale Item	Responses n	%	Frequency Distribution
Most of the things I do I feel like "I have to."	467		
Strongly agree	51	10.9%	
Somewhat agree	159	34.0%	
Neither agree nor disagree	102	21.8%	
Somewhat disagree	119	25.5%	
Strongly disagree	36	7.7%	
I feel forced to do many things I wouldn't choose to do.	468		
Strongly agree	39	8.3%	
Somewhat agree	96	20.5%	
Neither agree nor disagree	66	14.1%	
Somewhat disagree	156	33.3%	
Strongly disagree	111	23.7%	
I feel pressured to do too many things.	464		
Strongly agree	106	22.8%	
Somewhat agree	158	34.1%	
Neither agree nor disagree	68	14.7%	
Somewhat disagree	74	15.9%	
Strongly disagree	58	12.5%	
My daily activities feel like a chain of obligations.	467		
Strongly agree	63	13.5%	
Somewhat agree	131	28.1%	
Neither agree nor disagree	103	22.1%	
Somewhat disagree	113	24.2%	
Strongly disagree	57	12.2%	

Qualitative Findings on Autonomy Frustration

There were five themes identified from 104 codes for autonomy frustration, which were *Lack of Interest*, *Lack of Enjoyment*, *Lack of Work-life Balance*, *Lack of Choice*, and *Disappointment*. These themes (Figure 8) are defined and described in detail below, illustrated with direct quotes from participant responses.

Figure 8

Autonomy Frustration Themes and Coding Frequencies



Lack of Interest. There were seven passages coded for *Lack of Interest* among participants, which were all offered as reasons for not participating in STEM-specific social media. These responses indicated that some women either are not interested in social media in general, or they do not know what STEM-specific social media might be interesting to them. For example, "I'm not that interested in social media," and "Not sure what interesting stuff is out there."

Lack of Enjoyment. This theme refers to not liking or enjoying something, finding it unpleasant or boring, hate doing it, or not being into something. There were 14 passages coded for *Lack of Enjoyment*. Most of these passages were related to not using STEM-specific social media, such as "Social media is a curse on humanity," or "I do not like social media." Some respondents mentioned a *Lack of Enjoyment* related to their STEM careers. For example, one woman said "Most jobs are just jobs, and kill passion. You don't get to do the fun science you dreamt of." Another said she wish she had known earlier "How mind-numbingly boring a lot of the work would be. Not everything is a fun challenge or an interesting puzzle."

Lack of Work-life Balance. There were 16 passages that mentioned feeling unable to maintain a work-life balance, working unreasonable hours, giving up other activities for work, and being unable to set one's own schedule. Several women mentioned long hours, saying "The hours are insane," and "The time commitment is tremendous and the work-life balance is awful." Other respondents shared frustrations about what they gave up in exchange for work, such as "Very difficult to have any form of personal life, no holidays," and "Ignoring life in general and focusing on work." Finally, one woman shared *Lack of Work-life Balance* as her strategy for overcoming obstacles to persistence: "Give up other things that are important to me, to the detriment of my soul."

Lack of Choice. There were 19 segments that expressed feeling forced to persist, being trapped in a job or degree program, pressure to perform, pressure to be perfect in male-dominated fields, not being able to choose, or not having one's input heard. Several women expressed *Lack of Choice* due to family expectations, saying "Invisible pressure from my parents," or "Family expectations" were reasons for staying in STEM. Other respondents reported feeling trapped due to financial circumstances, such as "STEM pays better than any other thing. I would flee if I could," and "With the rising cost of living it feels like a trap that I couldn't leave even if I wanted to." Finally, one woman mentioned the stress of stereotype bias, saying "I can't be seen making a mistake, without confirming others' biases that women can't do math."

Disappointment. The most frequently coded theme in this category was *Disappointment*. There were 48 passages that referred to the persistent frustration of being a woman in STEM, including feelings of disappointment with the way things are, resignation, hopelessness, or the sense that things will never change. Several respondents indicated a sense of resignation over the limitations associated with being a woman in STEM. For example, one participant said she had accepted "… that there are limitations on how far I can progress in my career because I am not willing to play the toxic political games and suck up to the men at the top." Others mentioned the sense of having to play the "game," as in "I hate game playing but the world has made it necessary," and "Playing the politics game and bowing to the male superiority complex would have gotten me further." Some participants noted the lack of improvement over time, saying "The lack of progress and misogyny is frustrating and depressing," "Women still have to work twice as hard to get noticed half as much," and "24 years on, the percentage of women in STEM is still the same."

Quantitative Findings on Competence Frustration

Of 465 responses to the four competence frustration survey items (Table 11), the scores ranged from 3.00 to 20.00, with a mean of 10.17 (*SD* = 4.52). Calculated from all responses to the competence frustration items, about 31% of participants somewhat or strongly agreed, while about 57% of participants either somewhat or strongly disagreed with the frustration statements. Similar to the levels of autonomy and relatedness frustration, competence frustration was relatively low among respondents.

Table 11

Competence Frustration Survey Items and Responses

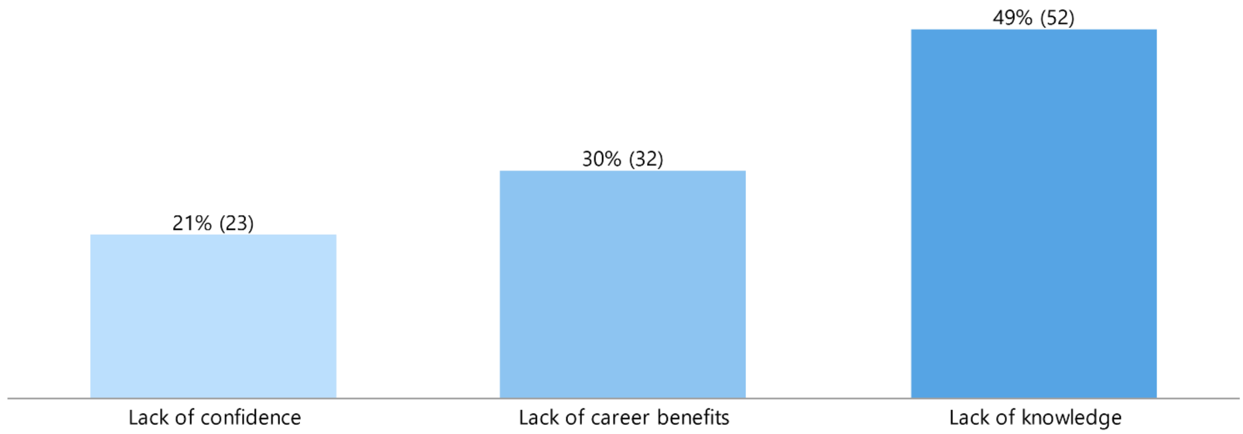
Scale Item	Responses		Frequency Distribution
	n	%	
I have serious doubts about whether I can do things well.	465		
Strongly agree	35	7.5%	
Somewhat agree	104	22.4%	
Neither agree nor disagree	46	9.9%	
Somewhat disagree	142	30.5%	
Strongly disagree	138	29.7%	
I feel disappointed with many of my performances.	465		
Strongly agree	32	6.9%	
Somewhat agree	73	15.7%	
Neither agree nor disagree	74	15.9%	
Somewhat disagree	139	29.9%	
Strongly disagree	147	31.6%	
I feel insecure about my abilities.	463		
Strongly agree	69	14.9%	
Somewhat agree	133	28.7%	
Neither agree nor disagree	56	12.1%	
Somewhat disagree	108	23.3%	
Strongly disagree	97	21.0%	
I feel like a failure because of the mistakes I make.	464		
Strongly agree	48	10.3%	
Somewhat agree	85	18.3%	
Neither agree nor disagree	50	10.8%	
Somewhat disagree	110	23.7%	
Strongly disagree	171	36.9%	

Qualitative Findings on Competence Frustration

The results of thematic analysis support and provide context for the quantitative findings on competence frustration. There were 107 passages coded for competence frustration, resulting in the identification of three themes. These were *Lack of Confidence*, *Lack of Career Benefits*, and *Lack of Knowledge* (Figure 9).

Figure 9

Competence Frustration Themes and Coding Frequencies



Lack of Confidence. The segments coded for *Lack of Confidence* referred to experiencing a lack of confidence, feelings of imposter syndrome, low self-efficacy, worrying about failure, or self-doubt. Some respondents said they felt "Inadequate" or "Like I haven't accomplished nearly enough" when they compared themselves to others' social media posts. One shared that "Academic Twitter can be encouraging but often gives me deeper sense of imposter syndrome." There were several participants who said imposter syndrome and self-doubt were difficult obstacles to persistence. For example, "My biggest obstacle has probably been self doubt and lack of confidence," and "The imposter syndrome is HUGE and though I LOVE my field I am anxious every day." Some women attributed *Lack of Confidence* to the influence of others, such as colleagues and students. One said she was "Not confident, afraid of being judged by academic peers." Another said it "can be really difficult to maintain confidence in yourself when there are guys that won't take you seriously." Finally, participants suggested that imposter syndrome seems to affect everyone, including men: "We all have imposter syndrome," and "I've never met a woman who doesn't have imposter's syndrome. I guess we just all live with it????????" and "Many cis white men also feel deeply insecure about their abilities; women aren't the only ones with imposter syndrome."

Lack of Career Benefits. There were 32 passages coded for *Lack of Career Benefits*. These segments referred to having trouble finding desirable jobs, insufficient pay or benefits, lack of opportunities for advancement, or low professional status. Several women said they thought STEM would provide better pay, but were disappointed to find "Stagnant wages," "The pay is terrible," and "It's not necessarily the golden goose of financial stability it has always been presented to me to be." Others shared frustration with STEM careers in academia. One woman said it was "So hard to find positions with just a BS in chem/math." Another noted difficulty with "The limited number of postdoc positions." Several respondents mentioned a lack of faculty positions, such as "Finding a professor job is already a nightmare," and how "Few tenure-track jobs there are, how difficult they are to obtain." Some reported feeling underemployed or underpaid, as in "How low women are paid in this field compared to a male," and "I have been disappointed by continued underemployment, and I feel 'discarded' despite useful skills and experience."

Lack of Knowledge. The most frequently observed theme of competence frustration was *Lack of Knowledge*. The 52 passages coded for *Lack of Knowledge* referred to not knowing about options, not being exposed to opportunities, not having information about career paths, or not knowing how to access opportunities or resources. Many respondents said they wished they had learned earlier about the range of STEM careers available. For example, "I wish I had been told about the positions available and in need in STEM while in college," "I wish I had more opportunities to experience STEM careers first hand," and "I wish I'd known more about the alternative careers you can have in STEM." Some participants said they lacked knowledge of specific skills or processes. For example, "I wish I'd known more about the process of applying to graduate school," "I wish computer coding and literacy was more available to me," and "Grant writing!"

Quantitative Findings on Relatedness Frustration

Relatedness frustration scores were calculated from 457 responses, which ranged from 2.00 to 20.00 (Table 9). The mean was 8.82 (*SD* = 4.11) and the mode was 4.00. Compared to the mean autonomy and competence frustration scores, the mean relatedness frustration score was the lowest. Using the responses from all four relatedness frustration survey items, approximately 20% of respondents either somewhat or strongly agreed, while about 66% somewhat or strongly disagreed. Results for the individual survey items are shown in Table 12.

Table 12

Relatedness Frustration Survey Items and Responses

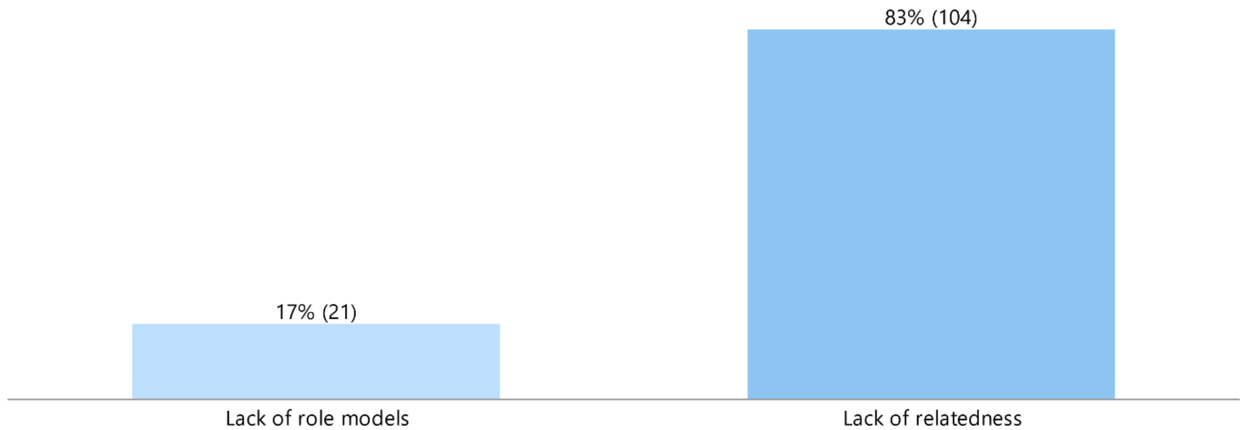
Scale Item	Responses n	%	Frequency Distribution
I feel excluded from the group I want to belong to.	455		
Strongly agree	41	9.0%	
Somewhat agree	89	19.6%	
Neither agree nor disagree	72	15.8%	
Somewhat disagree	132	29.0%	
Strongly disagree	121	26.6%	
I feel that people who are important to me are cold and distant towards me.	454		
Strongly agree	8	1.8%	
Somewhat agree	40	8.8%	
Neither agree nor disagree	61	13.4%	
Somewhat disagree	122	26.9%	
Strongly disagree	223	49.1%	
I have the impression that people I spend time with dislike me.	453		
Strongly agree	16	3.5%	
Somewhat agree	50	11.0%	
Neither agree nor disagree	70	15.5%	
Somewhat disagree	117	25.8%	
Strongly disagree	200	44.2%	
I feel the relationships I have are just superficial.	456		
Strongly agree	30	6.6%	
Somewhat agree	93	20.4%	
Neither agree nor disagree	57	12.5%	
Somewhat disagree	124	27.2%	
Strongly disagree	152	33.3%	

Qualitative Findings on Relatedness Frustration

The narrative responses from participants provide supporting data to the quantitative findings. Reflecting the relatively low mean relatedness frustration score, participants shared experiences about relatedness frustration in 104 passages. The themes indicated were *Lack of Role Models* and *Lack of Relatedness* (Figure 10).

Figure 10

Relatedness Frustration Themes and Coding Frequencies



Lack of Role Models. There were 21 passages coded for *Lack of Role Models*, which referred to not having mentors or role models, not having guidance, having negative experiences with advisors, not being represented, etc. Several women noted the rarity of women role models in STEM, as in "I wish I had more role models," "I have never had a female STEM professor," and "I wish I'd had a mentor." Some respondents said the lack of exposure to successful women in STEM made it difficult for them to navigate their career pathways. For example, "I wish I was exposed to other women in STEM who had made difficult career decisions," "I wish my parents had also been in STEM because they could have helped guide me better," and "More guidance throughout my journey would have been nice." Others mentioned a need for role models who combine STEM careers with motherhood, as in "I wish I had known that there are actually quite a lot of women who are successful surgeons and mothers," and "I had no examples of mothers who were also scientists until very recently." Some participants said they had discouraging experiences with advisors, and wished they had better mentorship. One woman said her advisor "was a terrible mentor who gave slow and fairly useless feedback to me, was generally unavailable to meet with me, and often made me feel like I was dumb and talentless."

Lack of Relatedness. The 104 passages coded for *Lack of Relatedness* referred to a lack of social support, lack of community, unbelonging, not liking coworkers, an unsupportive workplace or family, experiencing harassment, toxic environment, and so on. Many STEM fields are dominated by men, which can leave women feeling excluded or isolated. Some respondents reported feeling *a Lack of Relatedness* in social media spaces, saying “negative comments or experiences can demotivate individuals and create an unwelcoming atmosphere,” “I lurk, but don’t feel comfortable enough to actively participate,” and “I do not want to be visible online to men; STEM-specific social media groups are inundated by men.” Several respondents mentioned personal or acquaintances’ experiences of harassment. For example, “I’ve encountered a sexual harassment case at every place I’ve worked,” “I am bitter about the sexual harassment and men in STEM who didn’t believe in me,” and “Every woman in STEM I talked to has experienced harassment.” Feeling a sense of unbelonging was a common experience among participants. One explained, “I am the only woman in my department of ~50 people, so I interact with exactly ZERO other women on a day-to-day basis.” Others highlighted the negative effects of being underrepresented, such as “being excluded from men’s study groups,” having to “special-order your own PPE because the organization doesn’t make women’s sizes,” or feeling “lonely,” “solitary,” or having to “stand alone.” Several women mentioned feeling unwelcome due to STEM being “hypercompetitive,” and “super competitive and not always as collaborative as it feels like when you start.” One woman noted, “Competitiveness is rampant and that makes forming meaningful, trustworthy relationships hard.” Finally, some women experience a *Lack of Relatedness* due to factors such as race and disability. One respondent said she had experienced “rampant sexism, transphobia, homophobia,” another said she “was bullied and looked down on by professors at my institution for my disability,” and one mentioned “discrimination around race, weight, etc.”

Findings of Relationships Between Theoretical Constructs and STEM Persistence

Statistical tests were conducted to assess and measure relationships among variables. The variable of *Years in STEM* was collapsed from five categories into four categories for these tests. This was due to the small number of respondents in the categories of *30-45 years* (*n* = 39, 6.17%) and *45+ years* (*n* = 12, 1.90%) of STEM experience. These two groups were combined into a single category of *30+ years* in STEM (*n* = 51, 8.07%). The consolidated categories of STEM experience levels are shown in Table 13.

Table 13

Frequency Table of Years in STEM, Consolidated into Four Ordinal Groups

Years in STEM	*n*	%
9-15 years	246	38.92
6-8 years	174	27.53
16-29 years	161	25.48
30+ years	51	8.07

Note. Due to rounding errors, percentages may not equal 100%.

Using analysis of variance (ANOVA), significant relationships were observed between *Years in STEM* and *Combined Satisfaction* ($F(3, 473) = 3.19$, $p = .023$), *Combined Frustration* ($F(3, 467) = 3.69$, $p = .012$), *Competence Satisfaction* ($F(3, 465) = 11.90$, $p < .001$), and *Competence Frustration* ($F(3, 461) = 14.98$, $p < .001$). No other significant relationships were found between *Years in STEM* and the theoretical constructs (Table 14). The findings of significance are discussed in greater detail below.

Table 14

Results of ANOVA Examination of Theoretical Constructs and Years in STEM

Variable 1	Variable 2	*SS*	*df*	*F*	*p*	η_p^2
Combined Satisfaction	Years in STEM	879.35	3	3.19*	.023	.02
Combined Frustration	Years in STEM	1149.60	3	3.69*	.012	.02
Autonomy Satisfaction	Years in STEM	100.11	3	2.28	0.78	.01
Autonomy Frustration	Years in STEM	20.34	3	.38	.766	.00
Competence Satisfaction	Years in STEM	392.31	3	11.90*	< .001	.07

Competence Frustration	Years in STEM	840.99	3	14.98*	< .001	.09
Relatedness Satisfaction	Years in STEM	28.43	3	.71	.546	.00
Relatedness Frustration	Years in STEM	63.65	3	1.26	.288	.01

Note. * ANOVA examined based on alpha value of .05.

For further information about the associations found via ANOVA, additional analyses were performed. Although the relationship was statistically significant, the eta squared was .02, meaning that only 2% of the variance in *Combined Satisfaction* can be attributed to *Years in STEM*. For the relationship between *Combined Satisfaction* and *Years in STEM*, a post-hoc *t*-test showed that the mean for *6-8 years* of STEM experience (M = 46.41, SD = 10.34) was significantly smaller than the mean for *30+ years* in STEM (M = 51.05, SD = 9.73, p = .046). This suggests that the difference between the least experienced and most experienced groups of respondents accounted for most of this relationship.

There was a significant association found between *Combined Frustration* and *Years in STEM* (Table 14). ANOVA determined that *Combined Frustration* was lower for women with higher levels of persistence, with approximately 2% of the variance attributable to *Years in STEM*. A post-hoc *t*-test found that the means of *Combined Frustration* for women with *6-8 years* (M = 32.04, SD = 11.12, p = .012) and *9-15 years* (M = 31.21, SD = 10.02, p = .031) of experience were significantly larger than for those with *30+ years* (M = 26.11, SD = 8.75) in STEM. These results indicate that respondents with fewer years in STEM reported greater *Combined Frustration* than those who have persisted the longest.

ANOVA revealed significant relationships between *Years in STEM*, *Competence Satisfaction*, and *Competence Frustration* (Table 14). These results show that approximately 7% of the variance in *Competence Satisfaction* can be explained by *Years in STEM*. Post-hoc *t*-tests showed that women with higher levels of persistence also reported greater *Competence Satisfaction* than those with fewer *Years in STEM*. The mean *Competence Satisfaction* level for women with *6-8 years* (*M* = 15.47, *SD* = 3.78) in STEM was significantly lower than for those with *9-15 years* (*M* = 16.60, *SD* = 3.57, $p = .019$) and *16-29 years* (*M* = 17.51, *SD* = 2.71, $p < .001$) and *30+ years* (*M* = 18.58, *SD* = 1.65, $p < .001$). Also, the mean *Competence Satisfaction* for those with *9-15 years* in STEM was significantly smaller than for those with *30+ years* in STEM ($p = .006$).

Conversely, *Competence Frustration* was lower at higher levels of persistence, with about 9% of the variance attributable to *Years in STEM*. Post-hoc *t*-tests showed that the means of *Competence Frustration* for less experienced respondents were significantly larger than for those with more experience in STEM. The mean of *Competence Frustration* for women with *6-8 years* (*M* = 11.49, *SD* = 4.63) of experience was significantly larger than for those with *16-29 years* (*M* = 9.18, *SD* = 4.11, $p < .001$), and significantly larger than for women with *30+ years* (*M* = 6.56, *SD* 3.13, $p < .001$) in STEM. In addition, the mean of *Competence Frustration* for respondents with *9-15 years* (*M* = 10.66, *SD* = 4.45, $p = .018$) in STEM was significantly greater than for those with *16-29 years* (*M* = 9.18, *SD* = 4.11, $p = .018$) and *30+ years* (*M* = 6.56, *SD* = 3.13, $p < .001$) of experience. Finally, the mean of *Competence Frustration* for *16-29 years* was significantly larger than for *30+ years* ($p = .008$). These results suggest that the higher levels of competence frustration reported by the less experienced respondents account for this difference. While these associations were statistically significant, the strength of each was small, indicating that other variables were involved.

Findings of Sociocultural Influences on Persistence

In addition to the satisfaction and frustration of autonomy, competence, and relatedness, other variables are likely involved in persistence. To examine some of those possible influences, the researcher compared persistence between several groups of participants. Comparing *Years in*

STEM between various demographic groupings provides insight into how some social and cultural factors may be associated with women's persistence in STEM.

Quantitative Findings on Sociocultural Influences

Using a Spearman correlation analysis, a strong relationship was found between participant age and persistence. Cohen's standard shows the strength of a relationship, where coefficients between .10 and .29 indicate a small effect size, coefficients between .30 and .49 indicate a moderate effect size, and coefficients greater than .50 represent a large effect size (J. Cohen, 2013). Based on an alpha of .05, *Age* and *Years in STEM* were significantly and positively correlated ($r = .70$, $p < .001$), indicating that as one increases, so does the other. *Household Size* was also significantly correlated with *Years in STEM*, but the effect size was very small ($r = .11$, $p = .006$).

A significant relationship was found between *Years in STEM* and *Area type*. A Kruskal-Wallis test with an alpha value of .05, followed by post-hoc pairwise comparisons between *Urban*, *Suburban*, and *Rural* groups, showed a significant difference ($p < .05$) in persistence between *Urban* and *Rural* respondents (Table 15). This means that participants who lived in rural areas had significantly higher levels of *Years in STEM* compared to those in urban areas. No significant differences in persistence were found for *Suburban* residents compared to those in either *Rural* or *Urban* areas.

Table 15

Pairwise Comparisons for Mean Ranks of Years in STEM by Area Type

Comparison	Observed Difference	Critical Difference
Urban-Suburban	32.83	36.42
Urban-Rural	72.79*	57.12
Suburban-Rural	39.96	58.26

Note. * Observed Differences > Critical Differences indicate significance at the $p < .05$ level.

A Kruskal-Wallis rank sum test was conducted to assess differences in *Years in STEM* by *Race*. Acknowledging that the participants were not equally distributed among groups for *Race*, this test showed a significant difference in persistence based on an alpha value of .05 between *Caucasian* and *Asian* groups, and between *Other* and *Asian* groups (Table 16). In these pairwise tests, *Caucasian* and *Other* both had higher mean ranks than *Asian*. No other significant differences in *Years in STEM* were found between pairs of *Race* groups.

Table 16

Pairwise Comparisons for Mean Ranks of Years in STEM by Race

Comparison	Observed Difference	Critical Difference
Caucasian-Asian	98.17*	68.09
Other-Asian	212.12*	174.18

Note. * Observed Differences > Critical Differences indicate significance at the $p < .05$ level.

A Kruskal-Wallis test was conducted on *Years in STEM* and *Current Occupation*, using an alpha value of .05. A significant difference was found in persistence between *Current Occupation* groups. Further pairwise analyses showed a difference in persistence between *Computer Scientist* and *STEM Educator* groups, with the mean rank for *STEM Educator* significantly higher than that for *Computer Scientist* (Table 17). No other significant differences in persistence were found for *Current Occupation* groups.

Table 17

Pairwise Comparisons for Mean Ranks of Years in STEM by Current Occupation

Comparison	Observed Difference	Critical Difference
Computer Scientist-STEM Educator	170.30*	161.15

Note. * Observed Differences > Critical Differences indicate significance at the $p < .05$ level.

A significant difference in persistence was found between levels of *Highest STEM Degree*, using a Kruskal-Wallis test based on an alpha value of .05. Pairwise tests showed that respondents with *Doctorate Level* STEM education had significantly higher levels of *Years in STEM*, compared to those who only completed *Master's Level* or *Bachelor's Level* STEM education (Table 18). No significant difference in persistence was found between those whose highest STEM education were *Master's Level* and *Bachelor's Level* degrees.

Table 18

Pairwise Comparisons for Mean Ranks of Years in STEM by Highest STEM Degree

Comparison	Observed Difference	Critical Difference
Doctorate Level-Master's Level	141.35*	42.97
Doctorate Level-Bachelor's Level	174.56*	41.10
Master's Level-Bachelor's Level	33.21	45.58

Note. * Observed Differences > Critical Differences indicate significance at the $p < .05$ level.

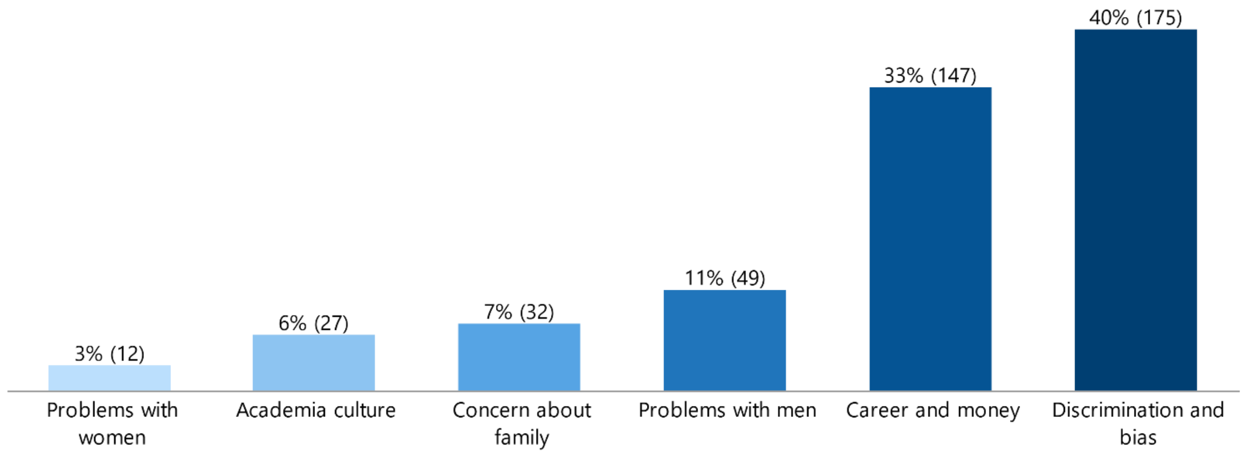
No significant association was found between persistence and the use of STEM-specific social media or between persistence and geographic region.

Qualitative Findings on Sociocultural Influences

There were 442 passages coded for themes related to sociocultural influences on women in STEM. These themes were outside of the theoretical constructs, which focused on psychological needs. Sociocultural influences include factors such as stereotypes, bias, discrimination, and social pressures. For this analysis, economic issues were included within the category of sociocultural influences. Six themes (Figure 11) emerged within this category: *Problems with Women*, *Academia Culture*, *Concern About Family*, *Problems with Men*, *Career and Money*, and *Discrimination and Bias*.

Figure 11

Sociocultural Themes and Coding Frequencies



Problems with Women. There were 12 passages coded for *Problems with Women*, which referred to having trouble with other women in STEM, women being detractors or unsupportive, exhibiting toxic behavior, or bullying. Some respondents mentioned that women in STEM can be as difficult or more toxic than men. One participant said, "Women are often the hardest on other women," and another said, "Female managers/senior are literally the worst in my profession; more likely to bully and harass staff." Another shared her experience with her advisor, saying "I picked a female advisor in a male-dominated field with an 83% female lab and she's still sexist." Finally, a participant noted the role of intersectionality in her experience, saying "Even in companies/organizations with good track records of supporting women in STEM, there can be pockets of intolerance. The hardest is when it's from other women. Intersectionality plays into this; white cis-women cannot shut the door behind them."

Problems with Men. Respondents mentioned *Problems with Men* 49 times, referring to harassment, being belittled, feeling unsafe, undervalued, outnumbered, and related experiences. Many women reported feeling unsafe in male-dominated STEM spaces. Respondents shared, "There is a dangerous amount of harassment," "I feel very uncomfortable with a male boss; I especially hate being alone with them," and having "dealt with porn in the lab and lab meetings at Hooters." Several mentioned pervasive misogyny, saying men are "casually sexist," or "condescending, overbearing and arrogant, and show blatant favoritism towards male coworkers." Some respondents thought that older men behave worse than younger men, saying "Women in STEM are not taken seriously, particularly by older men," "Men at VP and above… are 90% awful misogynists," and "There will always be men who will treat you as a 'little lady'." Several women offered advice for dealing with men. Some recommended listening to other women saying, "You need to listen to your gut feeling and trust the older women in STEM," and "There's a strong 'whisper network' of women warning others about bad men." While many respondents mentioned needing to "call men out" for bad behavior, they acknowledged the difficulties of handling uncomfortable situations. For example, "It's extremely difficult to be taken seriously," and "Being on alert… and knowing who to stay away from is exhausting."

Academia Culture. Respondents provided 27 segments that mentioned difficulties with university culture, having trouble finding funding, being treated unfairly, being outnumbered, or lacking stability. *Academia Culture* was often described as "toxic" and "exploitative," with researchers being undervalued and mistreated. One respondent said, "Academia is a never ending, often soul crushing grind," and another called it "mean girls on steroids." Several respondents complained about the overwhelming workload and low pay, especially for students and early-career academics. One woman said, "The salary to stay in academia, which was my original goal, just cannot support a single person. I also no longer want to participate in a system that is so exploitative (non-paid volunteers, underpaid grad students, etc.)." Another said, "Encouraging people to persist in an environment that exploits and manipulates them isn't a good idea." Others said academia is not welcoming to minoritized people, saying "Things are not changing very fast in the U.S. in terms of academia being women/minority/family friendly," and

"The academic world can be especially difficult for women." Finally, one woman stated that the difficulty of "getting and taking maternity leave without entirely messing up the tenure clock… is why many women have problems staying in academia and STEM."

Concern About Family. There were 49 passages coded for *Concern About Family* that referred to a lack of support for mothers, needing to care for dependents, how STEM is harder for mothers, being asked invasive questions, motherhood as a career obstacle, or unfair perceptions of mothers. Respondents said they worry about losing opportunities if they take time to have children, as in "I'm terrified of losing my place if my husband and I decide to start a family," and "Having kids would make it way more difficult to be competitive in education an career choices." Others mentioned having trouble balancing motherhood with career demands, such as "Huge barrier has been finding a way to be a primary care giver and scientist. Supports are minimal and most men take advantage whenever women take any time off for caregiving." This participant noted that there is even less support for women who need to care for other family members, saying "There's effectively no support for women caring for elderly relatives." One woman shared her strategy for avoiding some motherhood-related challenges: "I have to try and hide some parts of my identity (e.g., having a kid) so that people will know I'm serious about my career." Finally, some respondents said women should not try to have both children and a career: "You can't be simultaneously a good parent and a productive researcher. Women cannot have it all."

Career and Money. There were 147 passages coded for *Career and Money*. This theme refers to financial and career benefits, career stability, supporting oneself, supporting a family, staying for the money, etc. Many women said *Career and Money* were factors in their STEM persistence. Answering a question as to why they stay in STEM, respondents said, "I stay in

STEM because I have a stable job that pays my bills," "STEM is a particularly lucrative and secure job path," and "I'm in STEM mostly because it pays a living wage." Some mentioned benefits besides pay, such as "there is a sustainable career to be had," and "the benefits, including retirement as well as stability are why I stay." Finally, some women pointed out that good pay provides greater control, saying "Having the money I have now has set me free from bad relationships," and "I am motivated to help other women have sustainable stream of income so that they are in control of their lives."

Discrimination and Bias. The most frequently observed sociocultural theme was *Discrimination and Bias*, which was coded in 175 passages. This theme refers to male-dominated STEM fields, feeling disrespected or unheard, misogyny, sexism, a lack of diversity, experiencing racism, being excluded from activities or decision-making. Multiple respondents shared experiences where they felt discriminated against, such as "It is discouraging to know that our experiences in regards to gender discrimination and other forms of discrimination remain the biggest barriers for us," and "Women are at an inherent disadvantage in the STEM field compared to men." Other participants highlighted different types of discrimination and bias, including "ageism," "classism, racism, homophobia," "ablism," "nepotism in Ivy League schools is rampant and really keeps women and people of color at a disadvantage," and "anti-science machismo emboldened by the rise of Trumpism/fascism." Numerous comments expressed frustration with perceived extra work required from women in male-dominated fields. For example, "There is always a double standard for women," "Women (especially women of color) are marginalized in STEM content; We constantly have to prove our worth compared to men," and "I have to work twice as hard to be taken seriously or heard relative to my male counterparts." Some participants were affected by assumptions about their roles in the workplace, “People assume I’m a secretary,” “As a woman, it’s assumed that I’ll take and send the meeting minutes,” or “Teams often hire women looking for ‘mommies’ to keep them organized while the technical work gets done.” This respondent captured the sentiment of many others, saying:

> Women walk a much harder tightrope of how to interact with other scientists (women and men) and how to present themselves. Women can’t be the smartest in the room, or too soft, or too friendly, or too cold. It is an impossible situation and requires us to take on a much greater emotional burden just to be listened to and respected.

Integration of Findings to Answer Research Questions

The demographic description, quantitative findings from the BPNSFS, and thematic results of open-ended responses from the diverse sample of 641 women provided a rich depiction of their experiences with persistence in STEM. The results from the quantitative and qualitative data sets were aligned and integrated. Key quantitative and qualitative findings from the study are presented together in Table 19 and are applied to answer the research questions below.

Table 19

Integrated Display of Key Quantitative and Qualitative Findings

Variable	BPNSFS Score	*F, p*	Themes	Illustrative quote
Autonomy satisfaction	M = 15.75 SD = 3.84	2.28, .078	Enjoyment, Choice and Input, Genuine Interest, Work-life Balance, Self-care and Health, Purpose, Be Yourself	"I really enjoy math and I find it fulfilling."
Autonomy frustration	M = 12.07 SD = 4.20	.38, .766	Disappointment, Lack of Choice, Lack of Work-life Balance, Lack of Enjoyment, Lack of Interest	"It really sucks, honestly... would not choose again."
Competence satisfaction	M = 16.70 SD = 3.43	11.90*, .001	Self-efficacy, Growth Mindset, Grit and Perseverance, Science Identity, Effort	"There is nothing that will stop me. It's a mindset. Failure is not an option."
Competence frustration	M = 10.17 SD = 4.52	14.98*, .001	Lack of Knowledge, Lack of Career Benefits, Lack of Confidence	"I would've simply liked to know how it all works, without a roadmap it's so hard."

Relatedness satisfaction	*M* = 16.69 *SD* = 3.65	.71, .546	Social Support, Communal Benefit, Belonging, Role Models, Communication Skills	"I like contributing to society's scientific knowledge, mentoring and supporting younger researchers..."
Relatedness frustration	*M* = 8.82 *SD* = 4.11	1.26, .288	Lack of Relatedness, Lack of Role Models	"It is filled to the brim with males who hate me for being a woman."
Combined satisfaction	*M* = 48.40 *SD* = 9.65	3.19*, .023		
Combined frustration	*M* = 30.64 *SD* = 10.28	3.69*, .012		

Note. * ANOVA (*F*) examined based on alpha value of .05 when calculated for *Years in STEM* and variables. Detailed results shown in Table 14.

RQ1: What Are the Levels of Autonomy, Competence, and Relatedness of Women Who Have Persisted in STEM?

The respondents, all of whom are STEM persisters, generally displayed high levels of satisfaction and low levels of frustration across the constructs of autonomy, competence, and relatedness. Persistence, measured as *Years in STEM*, was found to be associated with combined psychological need satisfaction (F = 3.19, p = .023) and inversely associated with combined psychological need frustration (F = 3.69, p = .012). A significant association was found between the individual construct of competence and persistence, suggesting that competence satisfaction (F = 11.90, $p < .001$) and competence frustration (F = 14.98, $p < .001$) were important to the participants' persistence. The statistically significant associations between *Years in STEM*, need satisfaction, and need frustration, were small, suggesting that other variables also affected persistence.

RQ2: What Experiences and Influences Contribute to Women's Persistence in STEM?

The respondents shared many influences on their motivations to persist, including supports and obstacles. The most frequently mentioned supportive influences included satisfaction of autonomy, competence, and relatedness. Autonomy satisfaction was supported by feelings of *Enjoyment*, *Choice and Input*, having *Genuine Interest* in STEM, maintaining *Work-life Balance*, having a sense of *Purpose*, prioritizing *Self-care and Health*, and feeling able to *Be Yourself*. Competence satisfaction was supported by experiencing strong *Self-efficacy*, having a *Growth Mindset*, demonstrating *Grit and Perseverance*, a sense of *Science Identity*, and making *Effort*. Relatedness satisfaction was experienced with *Social Support*, working for *Communal Benefit*, having a sense of *Belonging*, the presence of *Role Models*, and good *Communication Skills*. In addition to the satisfaction of psychological needs, women were also motivated to persist in STEM by factors related to *Career and Money*.

RQ3: How Do Women Explain Various Sociocultural Influences on Their Persistence in STEM?

Respondents reported numerous sociocultural influences on their persistence in STEM. Several sociocultural demographic factors, in addition to theoretical constructs, were found to be significantly associated with persistence. Quantitative results indicated significant associations between persistence and *Age*, *Race*, *Area Type*, *Highest STEM Degree*, *Current Occupation*, and *Household Size*. Within those variables, certain subgroups were identified as being significantly different in terms of persistence. For example, *Age* (large effect) and *Household Size* (small effect) were positively correlated with *Years in STEM*, meaning that participants with higher levels of persistence tended to be older and live in larger household groups. Within the *Race* variable, members of *Caucasian* and *Other* groups had higher persistence than *Asian* respondents. Respondents living in *Rural* areas demonstrated higher levels of persistence than those in *Urban* areas. Respondents with *Doctoral Level* degrees demonstrated significantly greater persistence than those with *Master's Level* and *Bachelor's Level* degrees. Finally, those whose *Current Occupation* was *STEM Educator* had significantly higher persistence than *Computer Scientists*, suggesting that one's occupation may affect her persistence.

From the narrative data, the most frequently mentioned sociocultural influences involved *Discrimination and Bias*. There were multiple types of *Discrimination and Bias* experienced, including gender discrimination, sexual harassment, and racism. Women who are members of multiple minoritized groups are perceived by others to experience greater levels of *Discrimination and Bias* than those in majority populations. Other sociocultural influences included considerations of *Career and Money*, interpersonal *Problems with Men* and *Problems with Women*, feeling *Concern about Family* and navigating *Academia Culture*. Most respondents described their experiences as complicated and challenging, but said they were still motivated to persist.

RQ4: How Do Women's Experiences Align with Their Levels of Autonomy, Competence, and Relatedness?

There was strong alignment between quantitative levels of autonomy, competence, and relatedness and women's experiences persisting in STEM. The quantitative results showed strong satisfaction and lower frustration of autonomy, competence, and relatedness. Study participants shared thousands of personal examples, describing how they experience satisfaction and frustration of their basic psychological needs. The narrative evidence provided rich context and real-world examples of women's experiences of autonomy, competence, and relatedness. Table 19 highlights results from both the quantitative and qualitative analyses side-by-side to show this alignment.

Summary of Findings

Women who persist in STEM tended to display high satisfaction of their basic psychological needs. Significant associations were found between *Years in STEM*, *Combined Satisfaction* (autonomy, competence, and relatedness) and *Competence Satisfaction*. Women also tended to perceive low levels of autonomy, competence, and relatedness frustration. Significant associations were found between *Years in STEM*, *Combined Frustration*, and *Competence Frustration*. While significant associations were found between some variables and persistence, the effect sizes were small, indicating the presence of other influences. Sociocultural factors were described as contributing both positive and negative influences on women's motivations to persist in STEM.

Chapter Five: Conclusions, Implications, and Recommendations

Research into women's persistence in Science, Technology, Engineering, and Mathematics (STEM) fields is important due to its effects on the collective advancement of society as well as individual empowerment. Despite the progress society has made towards gender equality, a significant gender gap still exists in STEM fields (Kang & Kaplan, 2019; National Science Board, 2020). Women, who comprise roughly half of the U.S. workforce, hold only 25% of jobs in STEM fields (Noonan, 2017; A. M. Petersen, 2014). The disparity is even more pronounced among underrepresented minority women, who occupy only 4% of STEM jobs (Guy & Boards, 2019). The relative lack of women in STEM affects individual career achievement, since women in STEM jobs tend to earn higher wages than women in non-STEM jobs (Beede et al., 2011; Goris, 2020; Noonan, 2017). Encouraging more women to pursue STEM careers could lead to higher earning potential compared to non-STEM jobs, thereby helping close the gender pay gap and enhance women's economic opportunities.

The underrepresentation of women in STEM indicates a lack of diversity, which has broad implications beyond individual opportunities (Graves et al., 2022). A diverse workforce fosters a wider range of ideas, perspectives, and approaches, which can improve creativity and productivity (National Science Board, 2020). Studies have found that teams with greater gender diversity are more creative and innovative (Bello-Pintado & Bianchi, 2021), may experience better corporate performance (Rodríguez-Domínguez et al., 2012), revenue, and market share (Herring, 2009). Excluding women from the STEM workforce means potentially missing out on their perspectives and contributions. In addition to economic effects, the underrepresentation of women in STEM research has potentially harmful effects on health and safety. Despite recent changes to research guidelines, women were excluded from STEM subjects for decades. As a result of research being performed by men on male subjects, some products and practices caused unintended or harmful effects when applied to women, children, and others whose characteristics differ from those of the average male. For example, medical treatments developed for men may not produce the same results in women and could possibly cause harm (Holdcroft, 2007). Similarly, automobile safety features tested on crash test dummies modeled after men might not protect women equally (Forman et al., 2019; Gupta, 2021; Kahane, 2013; Linder & Svensson, 2019).

There are signs of improving gender parity in some STEM fields, but women are still underrepresented in math-intensive fields, including engineering and physics (Buse et al., 2013; Glass et al., 2013; Kahveci et al., 2006; Smith, 2011; Zeng & Duncan, 2007). Even in fields with a larger proportion of women earning college degrees, the gender gap grows at higher levels of academic attainment and industry leadership (McCullough, 2020; National Coalition for Women and Girls in Education, 2022; Ong et al., 2011). Researchers looking for the origination of the gender gap found that it may begin in childhood. Young boys and girls show similar levels of STEM interest and ability initially, but express differences in attitudes by kindergarten (Ceci et al., 2014). The gap grows throughout schooling, and is attributed to many influences, including exposure to toys and media portraying stereotypical gender roles and careers (Cheryan et al., 2015; Reich et al., 2018), math anxiety (Ahmed, 2018; Ashcraft & Moore, 2009; Woodard, 2004), low self-efficacy (Ellis et al., 2016; Rittmayer & Beier, 2009), and the idea that boys are naturally better suited for STEM (Cvencek et al., 2011; Kuhl et al., 2019). In post-secondary and graduate school environments, additional factors influence women's attrition from STEM, including an unwelcoming chilly climate (Miner et al., 2019; Walton et al., 2015), a lack of self-efficacy (Green & Sanderson, 2018; Vincent-Ruz & Schunn, 2018), and experiences with discrimination and bias (Barthelemy et al., 2016; Flam, 1991). These and other variables may contribute to women leaving STEM at a disproportionately high rate, resulting in the dearth of women at high levels in STEM.

Understanding and promoting women's persistence in STEM is key to improving representation and diversity across the STEM landscape now and in the future. By retaining more women in STEM now, they can become teachers, decision-makers, research leaders, role models and mentors for future generations. Seeing women represented in a wide variety of STEM roles can inspire and encourage girls by supporting the development of STEM identity (Millar et al., 2022; Steinke, 2017), improving a sense of belonging (Xu & Lastrapes, 2021), and help them think beyond gendered career stereotypes (Schmader, 2023). By understanding the factors that contribute to women's persistence in STEM and developing strategies to support their success, the future of STEM can be more equitable than its past.

The purpose of this study was to explore the motivations and experiences of women who have persisted in STEM. Through an investigation of the factors involved in their persistence, the findings of this study contribute to the understanding of how women persist in STEM. The following research questions guided the study.

- RQ1: What are the levels of autonomy, competence, and relatedness of women who have persisted in STEM?
- RQ2: What experiences and influences contribute to women's persistence in STEM?
- RQ3: How do women explain various sociocultural influences on their persistence in STEM?

- RQ4: How do women's experiences align with their levels of autonomy, competence, and relatedness?

Self-Determination Theory

Self-determination theory (SDT) is a framework that recognizes the necessity of autonomy, competence, and relatedness in fostering intrinsic motivation. Each of these constructs plays a critical role in shaping individuals' decisions and behaviors, including whether to persist in challenging fields like STEM. Self-determination theory has been tested by researchers around the world and is supported by evidence from diverse fields and populations. The body of evidence for self-determination theory shows that people tend to experience better outcomes, including better performance, improved persistence, and general well-being, when their basic psychological needs are satisfied (Deci & Ryan, 2000; Ryan & Deci, 2020). Conversely, the frustration of basic psychological needs is associated with suboptimal outcomes, negative feelings, and general ill-being (Chen, Vansteenkiste et al., 2015). Therefore, it is thought that environments that foster intrinsic motivation by supporting a person's autonomy, competence, and relatedness will increase her overall satisfaction and therefore improve outcomes such as persistence (E. L. Deci, 2017; Howard et al., 2021; Ryan & Deci, 2020).

Autonomy refers to the feeling of being in control of one's own choices and actions. It is not synonymous with independence or self-interest but is about having a sense of volitional control in making decisions (Ryan & Deci, 2000, 2020). In the context of STEM persistence, autonomy can be seen as the ability to choose one's path, exert control over one's learning and career trajectory, and make decisions in harmony with one's sense of self. Autonomy-supportive practices have been found to improve intrinsic motivation and self-efficacy (Garcia & Pintrich, 1996), reduce dropout intentions (Girelli et al., 2018; Jeno et al., 2018; Reeve et al., 2002), and significantly improve goal persistence (E. L. Deci & Ryan, 1987; Koestner et al., 2015). People experience greater autonomy satisfaction when invited to give input (Assor et al., 2005; Patall et al., 2018; Patall & Zambrano, 2019), make choices (Patall et al., 2008, 2010), understand rationale for tasks (Jang, 2008; Reeve et al., 2002; Steingut et al., 2017), and are genuinely interested in a subject (Blakey & McFadyen, 2015; Christensen et al., 2015; Maltese & Cooper, 2017; Salmi & Thuneberg, 2019).

Competence is the perception of being able to successfully perform tasks. It is related to feeling capable and effective in one's ability to learn and master skills (Skinner et al., 2017), and has been found to contribute to persistence for women in STEM (Edzie et al., 2015; Sakellariou & Fang, 2021). Competence-supportive environments can be cultivated by promoting science identity (Kim et al., 2018; Vincent-Ruz & Schunn, 2018; Xie et al., 2015), strengthening self-efficacy (Chemers et al., 2011; Hunt et al., 2021; Sithole et al., 2017; Zimmerman, 2000), and promoting a growth mindset (Blackwell et al., 2007; R. Hughes & Roberts, 2019; Kricorian et al., 2020).

Relatedness involves feeling connected to others, being cared for, and having meaningful relationships with family, friends, colleagues, and others (K.-A. Allen et al., 2022; Baumeister & Leary, 1995; Deci & Ryan, 2000). Relatedness includes having a sense of belonging and mutual care, and is predictive of persistence in STEM (DuBow et al., 2017; Gloria & Ho, 2003). To support relatedness satisfaction, environments may provide special groups or programs for women to lessen isolation (Bostwick & Weinberg, 2022; DuBow et al., 2017; Espinosa, 2011), improve environmental cues such as posters featuring women (Cheryan et al., 2009), promote communal goals (Belanger et al., 2020; Diekman et al., 2015; Espinosa, 2011; Fuesting et al., 2017), provide role models and mentors (A. Campbell & Skoog, 2004; Canaan & Mouganie, 2021; Dennehy & Dasgupta, 2017; Drury et al., 2011; Millar et al., 2022), foster peer connections (Banchefsky et al., 2019; Robnett, 2013) and social coping (Leaper, 2015; Shapiro & Sax, 2011). Particular attention should be given to cultivate relatedness for members of marginalized groups (Brickhouse & Potter, 2001; Carlone & Johnson, 2007; K. M. Jackson & Suizzo, 2015; Rainey et al., 2018) by using inclusive practices to mitigate chilly climates (Dortch & Patel, 2017).

According to SDT, these three psychological needs — autonomy, competence, and relatedness — are fundamental to human motivation and well-being. When these needs are satisfied, individuals are more likely to engage in activities out of inherent interest and enjoyment, leading to increased persistence and better outcomes. Conversely, the frustration of basic psychological needs can result in a lack of motivation, resulting in poorer persistence. SDT provides a robust framework for understanding motivation and persistence. Investigating persistence while focusing on autonomy, competence, and relatedness, this study offers insights into the factors that contribute to women's persistence in STEM.

Methodology and Methods

This study of women's persistence in STEM employed robust methods for data collection and analysis. A mixed methods approach was appropriate for this study because it facilitated a pragmatic investigation of women's experiences of persistence in STEM. The researcher used a concurrent embedded mixed methods design (Creswell & Creswell, 2018), which enabled her to gather both quantitative and qualitative data simultaneously. Participants for the study were women with at least an undergraduate degree in STEM, plus two or more years of STEM graduate education or STEM work experience, for a minimum of six total years of experience. The years of STEM experience did not need to be continuous, which allowed women with career interruptions to participate. Potential participants were recruited through network and snowball sampling, using email and social media posts to distribute the survey information. After the initial invitations were sent, recipients were encouraged to share the survey information with other potential participants in their networks.

The data were gathered using the online Qualtrics (Qualtrics, 2023) platform to administer an electronic survey comprised of both quantitative and qualitative items. The quantitative portion used the *Basic Psychological Need Satisfaction and Frustration Scale* (BPNSFS), a 24-item tool designed to measure participants' levels of autonomy, competence, and relatedness (Van der Kaap-Deeder et al., 2020). This scale provided data for a statistical representation of the psychological needs satisfaction and frustration levels among the participants. The qualitative data were gathered using several open-ended questions that allowed participants to narrate their lived experiences as persisters in STEM. Their responses were analyzed to glean deeper, more personal insights into how they perceived and experienced autonomy, competence, relatedness, and other influences on persistence. The open-ended questions were written to complement the scale items, thereby integrating both quantitative and qualitative methods throughout the study. The integration of quantitative and qualitative data was a critical aspect of this mixed methods study. The demographic description of the sample, combined with statistical results and narrative themes, allowed the researcher to develop a more complete understanding of the participants' experiences than would have been possible with only one type of data.

Key Findings

After the data were collected and cleaned, the sample size was 641 women. The respondents were demographically diverse (Table 3), with most reporting *Age* between 27-42 years (62.03%), *Caucasian* race (76.67%), residing O*utside the U.S.* (30.23%) or in the *U.S. West* (24.84%). The most common living situation was *Urban* (48.94%) with a household size of 2-3 people (64.01%). Most respondents reported having *9-15 Years in STEM* (38.92%), a *Doctorate Level* STEM degree (41.34%), and a current occupation of *Life Scientist* (30.48%) or *Computer Scientist* (26.77%).

This study resulted in several key findings that underscore the importance of autonomy, competence, and relatedness as fundamental factors influencing the persistence of women in STEM. The sample demonstrated high scores (Table 5) for *Autonomy Satisfaction* (*M* = 15.75, *SD* = 3.84), *Competence Satisfaction* (*M* = 16.70, *SD* = 4.20), and *Relatedness Satisfaction* (*M* = 16.69, *SD* = 3.65). The group produced lower scores (Table 9) for *Autonomy Frustration* (*M* = 12.07, *SD* = 4.20), *Competence Frustration* (*M* = 10.17, *SD* = 4.52), *Relatedness Frustration* (*M* = 8.82, *SD* = 4.11). ANOVA tests (Table 14) showed relationships between autonomy, competence, relatedness, and persistence. The *Combined Satisfaction* of autonomy, competence, and relatedness was significantly different between levels of *Years in STEM* ($F(3, 473) = 3.19$, $p = .023$), with the mean for *6-8 years* (*M* = 46.41, *SD* = 10.34) significantly smaller than for *30+ years* (*M* = 51.05, *SD* = 9.73, $p = .046$). Also, *Competence Satisfaction* ($F(3, 465) = 11.90$, $p < .001$) was significantly different between levels of *Years in STEM*. The mean scores for *Competence Satisfaction* were significantly lower for women in less-experienced groups than for those with the most *Years in STEM*.

ANOVA tests (based on an alpha value of .05) also showed significant differences in *Combined Frustration* ($F(3, 467) = 3.69$, $p = .012$) of autonomy, competence, and relatedness between levels of persistence (Table 14). Further analyses revealed significantly higher ($p = .031$) *Combined Frustration* for women with *6-8 Years* (*M* = 32.04, *SD* = 11.12) and *9-15 Years*

(*M* = 31.21, *SD* = 10.02) than for those with *30+ Years* (*M* = 26.11, *SD* = 8.75). Furthermore, *Competence Frustration* ($F(3, 461) = 14.98$, $p < .001$) was significantly different between levels of *Years in STEM*. The mean scores for *Competence Frustration* for women with *6-8 Years* (*M* = 11.49, *SD* = 4.63, $p < .001$), *9-15 Years* (*M* = 10.66, *SD* = 4.45, $p < .001$), and *16-29 Years* (*M* = 9.18, *SD* = 4.11, $p = .008$) were all significantly greater than for those with *30+ Years* (*M* = 6.56, *SD* = 3.13) in STEM. *Competence Frustration* for the group with *6-8 years* in STEM was significantly higher than for those with *16-29 years* (p < .001). Additionally, *Competence Frustration* for those with *9-15 years* in STEM was significantly higher than for those with *16-29 years* ($p = .018$) and those with *30+ years* ($p < .001$). The effect sizes (eta squared) of the associations were small, indicating that other variables were involved. These findings provide statistical evidence supporting the relevance of SDT in understanding and improving women's persistence in STEM.

The qualitative data complemented and enriched the quantitative findings by providing an in-depth look into the lived experiences of women in STEM. The open-ended questions garnered nearly 2300 narrative responses. The respondents described their experiences with persistence in seven *Autonomy satisfaction* themes (*Enjoyment*, *Choice and Input*, *Genuine Interest*, *Work-life Balance*, *Self-care and Health*, *Purpose*, and *Be Yourself*; Figure 4), five *Competence satisfaction* themes (*Self-efficacy*, *Growth Mindset*, *Grit and Perseverance*, *Science Identity*, and *Effort*; Figure 5), five *Relatedness satisfaction* themes (*Social Support*, *Communal Benefit*, *Belonging*, *Role Models*, and *Communication Skills*; Figure 6), and six sociocultural themes (*Discrimination and Bias, Career and Money, Problems with Men, Concern About Family*, *Academia Culture*, and *Problems with Women*; Figure 11). The narratives shared by participants provided valuable insights into how they navigate challenges and find support within their fields.

The thematic results enhanced the quantitative results, affirming the influence of autonomy, competence, and relatedness on persistence, but also highlighting the widely varied experiences of women in STEM. The integration of quantitative and qualitative results allowed for strong conclusions to be developed. The quantitative data provided statistical evidence of the positive relationship between need satisfaction and persistence in STEM, although the effect sizes of the theoretical constructs and sociocultural variables on persistence were small. This indicates that other influences must account for most of the observed associations. Given the diversity within the sample, which included participants from around the world, members of more than seven racial groups, spanning more than four decades in age and experience, representing more than eight STEM disciplines, at various stages of family life and identity intersections, it is not surprising that the results indicate additional variables at play. However, the totality of the findings emphasizes the need for policies and practices that foster the satisfaction of autonomy, competence, and relatedness to promote the persistence of women in STEM.

Study Conclusions

After comprehensive analyses of the data, the researcher drew four conclusions from the study. These conclusions are supported by the findings of either the quantitative or qualitative analyses or both. The conclusions are discussed below, along with explanations of how they fit with previous research.

Conclusion 1: Women Who Persist in STEM Are Highly Satisfied Overall

Women who persist in STEM reported high levels of satisfaction in autonomy, competence, and relatedness. These three factors contribute to a sense of motivation for women in STEM, thereby encouraging persistence. Considering the constructs separately, competence may be particularly essential to women's persistence in STEM, as this factor was individually and significantly associated with persistence for women in this study.

Implications for Scholarship. This study affirms previous findings that persistence is associated with the satisfaction of autonomy, competence, and relatedness. Women in this study, who have demonstrated persistence in STEM, exhibit high quantitative scores for construct satisfaction. These findings confirm previous research showing that autonomy (Mlambo & Mabokela, 2017; Schmitt et al., 2021; Simon et al., 2015; VanAntwerp & Wilson, 2018), competence (Buse et al., 2013; Nauta et al., 1998; Schaefers et al., 1997), and relatedness (Bostwick & Weinberg, 2022; Canaan & Mouganie, 2021; Dennehy & Dasgupta, 2017; Espinosa, 2011; Herrmann et al., 2016) positively affect persistence.

In addition to the significant positive association between overall satisfaction and persistence, there was a significant positive association between *Competence satisfaction* and persistence. This invites further investigation into the relationship between competence and persistence, and contrasts somewhat with previous research. Work by Dasgupta was essential in the conception of this dissertation, including her finding of the primacy of belonging as the critical factor in the retention of women in STEM (Dasgupta & Stout, 2014; National Science Foundation, 2016). The findings of this dissertation do not refute those of Dasgupta, since the current study also shows that persisters experience high relatedness satisfaction. However, the findings do provide evidence of the importance of competence in women's decisions to persist in STEM.

Conclusion 2: Women in STEM Persist Despite Their Negative Experiences with Discrimination and Bias

Despite facing *Discrimination and Bias*, women who persist in STEM were able to navigate and overcome these challenges. Women in the study perceived experiences with *Discrimination and Bias* as unavoidable. Respondents described encounters with criminal sexual harassment, racism, age discrimination, and ablism, with instances of overt mistreatment creating peaks above the baseline of unbelonging and frequent microaggressions. However, some shared that negative experiences inspired them to develop greater *Grit and Perseverance* to remain in STEM. Some women were motivated to persist in STEM so they could help change the system for future generations, as described in the theme of *Communal Benefit.* Others said they were willing to endure difficult situations due to their love and *Enjoyment* of science. Many respondents credited their own *Social Support* networks and *Role Models* with helping them navigate obstacles. Finally, a group of respondents said they were determined to stay in STEM for *Career and Money*. These and other themes show that women employ numerous strategies to persist in STEM careers despite widespread *Discrimination and Bias*.

Implications for Scholarship. This conclusion supports previous research findings that women who persist in STEM need strategies to handle discrimination (Casad et al., 2021; C. R. Fisher et al., 2020; Schmader, 2023). Women in this study persisted through harassment and discrimination by adapting their behavior (Buse et al., 2013), relying on other women for advice and support (Espinosa, 2011; Shapiro & Sax, 2011), focusing on deep subject interest (Verdín, 2021), expertise (Cech et al., 2011), sense of identity (Millar et al., 2022), and working toward change (Casad et al., 2021; Kong et al., 2020).

Conclusion 3: To Ensure Women Persist in STEM, Organizations Must Consider and Adopt Policies and Practices for Supporting Individual Autonomy, Competence, Relatedness, and Financial Equity with Their Male Colleagues

The third conclusion emphasizes the need to implement policies and practices that support women's autonomy, competence, relatedness, and workplace equity to maintain and improve persistence. This study provides statistical and qualitative evidence of multiple variables involved in women's persistence in STEM. Women in this study are highly satisfied with their autonomy, competence, and relatedness, which correlate with their persistence. The women who participated in this study described specific experiences that contribute to the satisfaction of those needs, which resulted in 765 passages coded for autonomy, 453 passages coded for competence, and 873 for relatedness. These persistence-supportive factors have been discussed in detail in previous sections. In addition, women provided 357 passages describing situations that made them feel controlled, undervalued, unwelcome, and in some cases mistreated and harmed. Taken together, these findings can inform the cultivation of environments and programs that support women's persistence and minimize obstacles.

Implications for Scholarship. The top three autonomy themes were *Enjoyment*, *Choice and Input*, and *Genuine Interest*, indicating that women desire opportunities to explore their interests, choose activities that they enjoy, and decide how to spend their time. Previous research found that these autonomy practices support persistence (Brubacher & Silinda, 2019; Maltese & Cooper, 2017; Patall et al., 2010, 2017; Talley & Martinez Ortiz, 2017). Respondents described their needs for competence satisfaction, including *Self-efficacy*, *Growth Mindset*, and *Science Identity*, which confirms previous research on the importance of self-efficacy (Charleston & Leon, 2016; Rittmayer & Beier, 2009; Zeldin & Pajares, 2000), science identity (Millar et al., 2022; Stout et al., 2011), and growth opportunities (Fuesting et al., 2019; Posselt, 2018; R. Binning et al., 2019). This study confirms previous research findings on the need for relatedness to support persistence, by providing social support and belonging (DuBow et al., 2017), role models (Herrmann et al., 2016), mentors (A. M. Petersen, 2014), and communal goals (J. Allen et al., 2021; Belanger et al., 2020; Henderson et al., 2022; Peacock et al., 2020). In addition to receiving the support of others, women who persist in STEM also value opportunities to serve others (J. Allen et al., 2021).

Environments that support women's persistence extend to their perceptions of equitable treatment on campus and at work. Financial equity for women in STEM goes beyond the numbers on a paycheck. The importance of *Career and Money* highlights the role of external factors in motivation, and supports previous findings that income positively affects women's motivation (Schmitt et al., 2021). This finding has a place within the SDT framework, which recognizes a continuum of motivation, ranging from amotivation to intrinsic motivation (Howard et al., 2017; Ryan & Connell, 1989). External rewards are accounted for in various degrees of extrinsic motivation and lessen as motivation becomes more intrinsically regulated (Figure 1). Some of the respondents said their need for financial security also factored into their willingness to endure unpleasant workplaces. Previous research found that a need for financial safety can affect motivation along with psychological needs (Chen, Van Assche et al., 2015). Respondents in this study shared their desires for flexible job options, maternity leave, and access to dependent care. These practices span multiple motivational variables and therefore are likely to require multi-pronged solutions, such as interventions to improve recruitment, mentoring, and climate (Casad et al., 2021) and practices designed to address psychological needs (Slemp et al., 2021). Organizations and educational institutions with environments that support these needs can help women persist in STEM.

Conclusion 4: There are Career Trajectory Points Where Risk of Attrition is More Likely to Occur

The findings of this study demonstrated that there are significant associations between satisfaction, frustration, and persistence. Statistical analyses showed that women with the greatest number of years in STEM had significantly higher levels of combined satisfaction and significantly lower levels of combined frustration than those with the least experience. Similarly, women in lower age groups and with less educational attainment had fewer average years in STEM than older women and those with doctoral degrees. These findings suggest that women in earlier career stages (in younger age groups, with less educational attainment, having fewer years in STEM) may be at greater risk for attrition than women with greater satisfaction and persistence levels. Therefore, early career environments that contribute to low satisfaction and/or high frustration may expose “leaks” in the STEM pipeline, perpetuating the gender gap problem. Knowing that persisters encounter higher frustration in their earlier careers can help them anticipate and prepare for obstacles.

Implications for Scholarship. Previous research has found many possible contributing factors to attrition from STEM, beginning in childhood and increasing throughout women’s educational and career pathways. This study confirms previous findings that women in STEM experience attrition-contributing factors including biases favoring men (Amon, 2017; Andrus et al., 2018; Moss-Racusin et al., 2012, 2018), low self-efficacy (Orenstein & American Association of University Women, 1994), lack of mentors and role models (Amon, 2017), and a lack of belonging (Dasgupta & Stout, 2014; Good et al., 2012; Goris, 2020; M. Z. Moore, 2020; Xu & Lastrapes, 2021).

Implications for Practice

This study provides additional evidence of the need for autonomy, competence, and relatedness, for women to persist in STEM. While research-backed practices for supporting each construct have been discussed in Chapter Two, there is a potential strategy that might address all three. These needs could be addressed by bringing together girls and women to engage in STEM activities before students make decisions about college majors and career fields. Since students begin to develop attitudes about gender-appropriate career roles by kindergarten (Ceci et al., 2014), interventions to support their exploration of STEM must begin early.

For example, science class visits from women in STEM, robotics clubs with women as coaches and leaders, and science-related social groups for girls and women in STEM, would expose girls to peer and adult role models, allow space for curiosity and hands-on exploration, and give STEM professionals additional opportunities for networking and community development. Some existing programs such as career days, classroom visits from STEM professionals, and STEM field trips, might be good starting places for such interactions. To be most effective, the activities should be planned inclusively, to represent the broad diversity of people and careers in STEM. Particular attention should be given to including members of historically excluded groups, since they tend to experience greater difficulty accessing such opportunities. For women in STEM jobs, organizations must assess and address weaknesses in their policies and practices to develop more supportive work environments.

In addition to childhood support for STEM education and exploration, science educators and employers need to be aware of potentially weak areas in the pipeline. During transitions between schools, after common weed-out courses, and during early career stages, there may be higher risk of attrition for women in STEM. Providing additional support for autonomy, competence, relatedness, and financial equity around these points may help retain women in STEM educational and career pathways. Interventions that reinforce women's volitional control, self-efficacy, growth mindset, and social support may contribute to retention.

Study Limitations

After it was launched, the researcher discovered that the survey offered an incomplete range of choices for the *Race* category, with no option listed for Latina or Hispanic respondents. Although respondents were able to write in an unlisted option, this omission may have caused some potential participants to feel excluded or to exit the survey. Also, the use of an anonymous online survey made it impossible to follow-up with respondents to probe for additional information. Another limitation was noted by a potential participant in a Reddit group, who pointed out that software engineers and other information technology (IT) professionals often focus on developing skills through experience and certificates, rather than obtaining traditional undergraduate and graduate degrees. By requiring an undergraduate degree to participate in this study, some women in IT were excluded, despite having persisted in STEM for more than six years. Finally, the sample size was not large enough to draw generalizable inferences about the relationships between variables, although this was not a goal of the study.

Internal Study Validity

Throughout the study, the researcher implemented reflexive practices to ensure study validity. She used a research journal to record observations, concerns, and ideas to help minimize the influence of her biases (Creswell & Creswell, 2018). The BPNSFS tool had been previously validated, and it was used with permission and scored according to the instructions provided by its originators (Van der Kaap-Deeder et al., 2020). Subject matter experts were consulted to ensure that the open-ended questions were appropriate for the study. A survey construction expert was consulted to assist with the design and flow of the instrument. The study was approved by the IRB prior to engaging participants, and no confidentiality or anonymity concerns were reported. Before launching the survey, a pilot test was conducted and minor adjustments were made. The researcher used software to collect and analyze data, which allowed for a transparent, documented process. A peer reviewer checked the researcher's statistical analyses and qualitative coding to make sure they were done reliably.

Recommendations for Scholarship and Further Research

The quantitative and qualitative results of this study reinforce the tenets of SDT, providing further evidence that basic needs satisfaction is associated with persistence, including for this sample of women in STEM. Many themes revealed in the narrative responses also fit rather neatly within the construct "buckets." Although the focus of this study was on factors that support persistence, it also found a significant negative association between frustration and persistence, which invites additional research. In addition to the scholarship implications noted after each conclusion above, this study provides additional support for the application of SDT and the BPNSFS. This is the first known study of women's persistence in STEM that combines the BPNSFS instrument with qualitative evidence to triangulate results using mixed methods. The Cronbach alpha values calculated in this study provide additional evidence of the reliability of the BPNSFS as a research tool.

In future studies, the researcher recommends segmenting the data from this sample into narrower groupings, such as by career stage, to determine whether autonomy, competence, and relatedness scores and narrative themes vary by persistence level. This might provide additional insight into what women experience at early, mid, and later career stages, and what types of support are most valuable to women at throughout their careers in STEM. She would also like to conduct a study to interview persisters and non-persisters to gain additional insights into their experiences in STEM. Another research thread would be to design and implement a program that brings together girls and professional women in STEM, to investigate how the experience affects their perceptions of autonomy, competence, and relatedness and persistence. Ideally, this would be a longitudinal study, to determine whether and how it affects STEM persistence over time.

Researcher Reflections and Closing Comments

The experiences of women who persist in STEM are as diverse as those who live them. The combined quantitative and qualitative results in this study provide strong support for the provision of educational and work environments that promote women's autonomy, competence, and relatedness. This study also highlights the influence of sociocultural and external factors on women's careers.

Some of the stories shared by respondents were heartbreaking, and others were inspiring. The researcher was moved by the willingness of so many others to give their time and share their experiences. In addition to contributing data for the study, many engaged in open conversations with each other on social media. Women were generally eager to talk about their lives, sharing stories about their troubles and triumphs. The interactions between women were overwhelmingly positive and supportive, with commenters adding notes to let others know they were not alone. Seeing the organic expression of camaraderie and concern sparked by a simple survey invitation reinforced the researcher's commitment to her work.

The findings from this study shined a spotlight on women's strategies for staying in STEM, but also illuminated conditions that threaten their persistence. The combined quantitative and qualitative results demonstrated the strength of many women's commitment to STEM careers. There were only a few respondents who said they experienced no obstacles to their persistence. The overwhelming majority of persisters had strong satisfaction but also reported frustrations. These results provide valuable insight into what supports persistence and point to areas where additional support is required. By listening to their experiences and advice, organizations can improve policies and practices that will help lessen the risk of attrition of women from STEM. Such improvements can help mitigate the attrition points by preparing young women for the challenges they are likely to face and thereby support their persistence.

The conclusion of this study merits a brief trip back to Chapter One and the story of Nobel Prize winner Dr. Carolyn Bertozzi. On her STEM pathway, Dr. Bertozzi pioneered a new field of chemistry and became an exemplary persister when viewed through the SDT lens. Autonomy, competence, and relatedness are unmistakable elements of her groundbreaking research, professional excellence, and commitment to inclusion and mentorship (Collins & Kubota, 2022; Cosco, 2022; Jarvis, 2022). While celebrating the achievements of women like Dr. Bertozzi, we must continue to assess and improve educational and organizational environments to support all women in STEM. By building systems to promote women's autonomy, competence, relatedness, and equity, current and future STEM practitioners may experience better persistence, resulting in positive effects for society.

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APPENDIX A

List of STEM and STEM-related Occupations from U.S. Census Bureau.

STEM Occupations:
Computer Occupations:
- Computer and information systems managers
- Computer and information research scientists
- Computer systems analysts
- Information security analysts
- Computer programmers
- Software developers
- Software quality assurance analysts and testers
- Web developers
- Web and digital interface designers
- Computer support specialists
- Database administrators and architects
- Network and computer systems administrators
- Computer network architects
- Computer occupations, all other

Mathematical Science Occupations:
- Actuaries
- Mathematicians
- Operations research analysts
- Statisticians
- Other mathematical science occupations

Engineering Occupations:
- Architectural and engineering managers
- Surveyors, cartographers, and photogrammetrists
- Aerospace engineers
- Agricultural engineers
- Bioengineers and biomedical engineers
- Chemical engineers
- Civil engineers
- Computer hardware engineers
- Electrical and electronics engineers
- Environmental engineers
- Industrial engineers, including health and safety
- Marine engineers and naval architects
- Materials engineers
- Mechanical engineers
- Mining and geological engineers, including mining safety engineers
- Nuclear engineers
- Petroleum engineers

- Engineers, all other
- Architectural and civil drafters
- Other drafters
- Electrical and electronic engineering technologists and technicians
- Other engineering technologists and technicians, except drafters
- Surveying and mapping technicians
- Sales engineers

Life Scientists Occupations:

- Natural sciences managers
- Agricultural and food scientists
- Biological scientists
- Conservation scientists and foresters
- Medical scientists
- Life scientists, all other

Physical Scientists Occupations:

- Astronomers and physicists
- Atmospheric and space scientists
- Chemists and materials scientists
- Environmental scientists and specialists, including health
- Geoscientists and hydrologists, except geographers
- Physical scientists, all other

Social Scientists Occupations:

- Economists
- Survey researchers
- Clinical and counseling psychologists
- School psychologists
- Other psychologists
- Sociologists
- Urban and regional planners
- Miscellaneous social scientists and related workers

Life, Physical, and Social Science Technicians:

- Agricultural and food science technicians
- Biological technicians
- Chemical technicians
- Environmental science and geoscience technicians
- Nuclear technicians
- Social science research assistants
- Other life, physical, and social science technicians

Total STEM-related Occupations:

Architecture Occupations:

- Architects, except landscape and naval
- Landscape architects

Healthcare Occupations:

- Medical and health services managers

- Chiropractors
- Dentists
- Dietitians and nutritionists
- Optometrists
- Pharmacists
- Emergency medicine physicians
- Radiologists
- Other physicians
- Surgeons
- Physician assistants
- Podiatrists
- Audiologists
- Occupational therapists
- Physical therapists
- Radiation therapists
- Recreational therapists
- Respiratory therapists
- Speech-language pathologists
- Exercise physiologists
- Therapists, all other
- Veterinarians
- Registered nurses
- Nurse anesthetists
- Nurse midwives
- Nurse practitioners
- Acupuncturists
- Healthcare diagnosing or treating practitioners, all other
- Clinical laboratory technologists and technicians
- Dental hygienists
- Cardiovascular technologists and technicians
- Diagnostic medical sonographers
- Radiologic technologists and technicians
- Magnetic resonance imaging technologists
- Nuclear medicine technologists and medical dosimetrists
- Emergency medical technicians
- Paramedics
- Pharmacy technicians
- Psychiatric technicians
- Surgical technologists
- Veterinary technologists and technicians
- Dietetic technicians and ophthalmic medical technicians
- Licensed practical and licensed vocational nurses
- Medical records specialists
- Opticians, dispensing

- Miscellaneous health technologists and technicians
- Other healthcare practitioners and technical occupations

APPENDIX B

Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS)

Below, we ask you about the kind of experiences you actually have in your life. Please read each of the following items carefully. You can choose the response that indicates the degree to which the statement is true for you at this point in your life.

1	2	3	4	5
Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

1. I feel a sense of choice and freedom in the things I undertake.
2. Most of the things I do I feel like "I have to."
3. I feel that the people I care about also care about me.
4. I feel excluded from the group I want to belong to.
5. I feel confident that I can do things well.
6. I have serious doubts about whether I can do things well.
7. I feel that my decisions reflect what I really want.
8. I feel forced to do many things I wouldn't choose to do.
9. I feel connected with people who care for me, and for whom I care.
10. I feel that people who are important to me are cold and distant towards me.
11. I feel capable at what I do.
12. I feel disappointed with many of my performances.
13. I feel my choices express who I really am.
14. I feel pressured to do too many things.
15. I feel close and connected with other people who are important to me.
16. I have the impression that people I spend time with dislike me.
17. I feel competent to achieve my goals.
18. I feel insecure about my abilities.
19. I feel I have been doing what really interests me.
20. My daily activities feel like a chain of obligations.
21. I experience a warm feeling with the people I spend time with.
22. I feel the relationships I have are just superficial.
23. I feel I can successfully complete difficult tasks.
24. I feel like a failure because of the mistakes I make.

Scoring information:

Autonomy satisfaction: items 1, 7, 13, 19
Autonomy frustration: items 2, 8, 14, 20
Relatedness satisfaction: items 3, 9, 15, 21
Relatedness frustration: items 4, 10, 16, 22
Competence satisfaction: items 5, 11, 17, 23
Competence frustration: items 6, 12, 18, 24

APPENDIX C

Embedded Mixed Methods Survey Instrument

1. Considering your academic degrees, which were awarded in a STEM subject? Please check all that apply.
    a. Undergraduate; Bachelor's level degree
    b. Graduate; Master's level degree
    c. Graduate; Doctoral level degree
2. How many total years of experience in STEM have you completed? Please include college, graduate school, and STEM career experience. (Years do not need to be continuous.)
    a. 6-8 years
    b. 9-15 years
    c. 16-29 years
    d. 30-45 years
    e. 45+ years
3. Please indicate your age group.
    a. 18-26 years
    b. 27-42 years
    c. 43-60 years
    d. Over 60 years old
4. Which best describes your current STEM occupation?
    a. Computer scientist (information systems, programming, software developer, database administration, web developer, etc.)
    b. Mathematical scientist (actuary, mathematician, statistician, etc.)
    c. Engineer (architectural, cartography, aerospace, agricultural, biomedical, chemical, civil, materials, mechanical, mining, nuclear, etc.)
    d. Life scientist (natural, agricultural, food, biological, conservation, forestry, medical scientist, etc.)
    e. Physical scientist (astronomer, physicist, atmospheric, space, chemist, materials, environmental, geoscientist, hydrologist, etc.)
    f. Social scientist (economist, survey researcher, psychologist, sociologist, etc.)
    g. Other (please specify)
5. What was your previous STEM occupation (if any)?
    a. I haven't had a previous STEM occupation
    b. Computer scientist (information systems, programming, software developer, database administration, web developer, etc.)
    c. Mathematical scientist (actuary, mathematician, statistician, etc.)
    d. Engineer (architectural, cartography, aerospace, agricultural, biomedical, chemical, civil, materials, mechanical, mining, nuclear, etc.)

   e. Life scientist (natural, agricultural, food, biological, conservation, forestry, medical scientist, etc.)
   f. Physical scientist (astronomer, physicist, atmospheric, space, chemist, materials, environmental, geoscientist, hydrologist, etc.)
   g. Social scientist (economist, survey researcher, psychologist, sociologist, etc.)
   h. Other (please specify)
6. Choose one or more races that you consider yourself to be:
   a. White
   b. Black or African American
   c. American Indian or Alaska Native
   d. Asian
   e. Native Hawaiian or Pacific Islander
   f. Other
7. How many people live or stay in this household at least half the time?
   a. Only me
   b. 2-3
   c. 4-5
   d. 6+
8. In what region is your primary residence?
   a. US Northeast US Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont) (1)
   b. US Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin) (2)
   c. US South (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia) (3)
   d. US West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming) (4)
   e. Outside the US (5)
9. How would you describe the area of your primary residence?
   a. Urban
   b. Rural
   c. Suburban
10. Do you participate in STEM-specific social media groups?
   a. Yes
   b. No
11. If Do you participate in STEM-specific social media groups? = Yes: How does participating in STEM-specific social media affect your motivation to stay in STEM?
12. If Do you participate in STEM-specific social media groups? = No: Why have you chosen not to participate in STEM-specific social media groups?

13. Please provide a short explanation of why you stay in STEM. Has this changed or stayed the same through your life/career?
14. What do you wish you had known earlier in your life or career about persisting in STEM?
15. What are some strategies you use to overcome obstacles so that you can persist in STEM?
16. Is there anything else you think might be helpful for me to know as I try to understand the lived experience of a woman persisting in STEM?
17. I feel a sense of choice and freedom in the things I undertake.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
18. I feel that the people I care about also care about me.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
19. I feel confident that I can do things well.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
20. I feel that my decisions reflect what I really want.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
21. I feel connected with people who care for me, and for whom I care.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
22. I feel capable at what I do.
    a. Strongly disagree
    b. Somewhat disagree

c. Neither agree nor disagree
d. Somewhat agree
e. Strongly agree

23. I feel my choices express who I really am.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
24. I feel close and connected with other people who are important to me.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
25. I feel competent to achieve my goals.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
26. I feel I have been doing what really interests me.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
27. I experience a warm feeling with the people I spend time with.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree
28. I feel I can successfully complete difficult tasks.
    a. Strongly disagree
    b. Somewhat disagree
    c. Neither agree nor disagree
    d. Somewhat agree
    e. Strongly agree

APPENDIX D

IRB Documentation

Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: June 02, 2023

Protocol Investigator Name: Heather Saigo

Protocol #: 23-03-2119

Project Title: Examining Women's Persistence in STEM: An Embedded Mixed Methods Study on Autonomy, Competence, and Relatedness

School: Graduate School of Education and Psychology

Dear Heather Saigo:

Thank you for submitting your application for exempt review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46.101 that govern the protections of human subjects.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Since your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,

Judy Ho, Ph.D., IRB Chair

cc: Mrs. Katy Carr, Assistant Provost for Research