2-2022

How Female Stem Undergraduate Students Form Their Science Identity

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HOW FEMALE STEM UNDERGRADUATE STUDENTS

FORM THEIR SCIENCE IDENTITY

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A DISSERTATION

Presented to the Affiliated Faculty of

The College of Graduate and Professional Studies at the University of New England

Submitted in Partial Fulfillment of Requirements

For the Degree of Doctor of Education

Portland & Biddeford, Maine

February 19, 2022

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February 2022
Educational Leadership

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ABSTRACT

This qualitative case study describes how female science, technology, engineering, and mathematics (STEM) students choose their undergraduate major, the obstacles they faced when making that choice, and how they overcome gender-based obstacles. These descriptions illuminate the manner in which they form their science identity.

There is a gender gap in science, technology, engineering, and mathematics (STEM) disciplines (Viadero, 2009). This has been attributed to both biological and sociocultural causes. The biological basis for this disparity includes evidence of physiological differences between females and males, as well as the microaggressions and sexual harassment stemming from these differences (Bottia et al., 2015). The sociocultural basis for this disparity includes evidence of differences in females' thoughts and feelings about STEM fields, the forces and influences they experience, parental and peer involvement in college and career decisions, as well as the availability of social and academic supports and female role models (Cundiff et al., 2013). Further, educational causes have been identified which include reduced access to STEM resources and supports and unequal attention in classes.

Female students reconcile their own perceptions about their place in science with that of others and with their various other social identities to form a science identity, the intersection between their performance, their competence, and their recognition (Carlone & Johnson, 2007).

Science identity is a useful framework used to examine the changes that female students undergo as they choose academic majors, how they incorporate information related to the obstacles they face, and how they overcome those obstacles.

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ACKNOWLEDGEMENTS

I want to thank my wife, who gave me encouragement and support in more ways than one throughout our lives together. Her countless bits of wisdom about gender issues, my own implicit biases, and how I can constantly improve myself were essential to my work. She made me strive to be a better person.

I want to thank my parents, who always believed in me. They are true role models who never cease to prioritize the needs of their community ahead of their own needs. I credit them with instilling their morals and values in me. Above all, they have given me the desire to help others.

I want to thank my children, who sacrificed many weekend adventures so I could stay home and work. They pulled more than their own weight throughout the course of my educational journey. They made me want to continue, even when it was difficult.

I want to thank my daughter, who gave me my first glimpse of the issues that female students face as they consider STEM majors. Her struggles gave me the necessary impetus to complete this research.

I express my heartfelt gratitude to Dr. Amanda Harper-Leatherman and her colleagues, whose work with female urban disadvantaged students inspired me to examine interventions aimed at reducing the STEM gender gap. Her work gave me hope that gender parity was indeed achievable.

I also owe a debt of gratitude to Dr. Gizelle Luevano and Dr. William (Grinnell) Smith for their tireless efforts to help me complete this dissertation. Your mentorship was invaluable to me. Your help got me over the finish line.

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CHAPTER 1: INTRODUCTION

"Science is masculine, competitive, objective, impersonal—qualities that are at odds with our images of what girls are" (Brickhouse et al., 2000, p. 441). The issue is not whether female students are learning in science classes; it is what they are learning that assumes more significance.

There is pervasive evidence to suggest that females are not on track to achieve gender parity in the workforce (Graf et al., 2020; UNICEF, 2020; Viadero, 2009). They are denied equal promotion opportunities and earn less over their lifetimes than their male counterparts. This gender inequity is even more pronounced among the Black and Latina community, with estimates that their pay gap may not close for at least a century (Miller & Singh, 2020). We can all point to anecdotal evidence in our personal lives, in our local communities, in the media, and in the world around us that there are real gender differences both in the education sector and in the workplace.

Among scholars, there is a broad consensus despite females reaching parity in math and science achievement scores, that a gender gap exists in science, technology, engineering, and mathematics (STEM) disciplines (Viadero, 2009). Although some researchers view this as a perceived problem rather than a real one, advocating for little intervention (Camilli & Hira, 2019), most recognize this disparity is real and that it extends to other masculinized fields (Cain et al., 2020), is nearly universal (Buccheri et al., 2011), and can be attributed to many root causes (Beaman et al., 2006). Research suggests both a biological and a sociocultural basis for gender disparity. The biological basis includes evidence of hormonal, neural, reproductive, and other physiological differences between females and males, as well as the microaggressions and sexual harassment that inevitably arise from these differences (Bottia et al., 2015). On the other hand, the sociocultural basis includes evidence of female's thoughts and feelings about STEM fields, forces and influences they experience from childhood through adulthood, parental and peer involvement in college choice and career decisions, and the availability of social and academic supports and female role models (Cundiff et al., 2013).

There is increasing evidence to suggest that educational interventions employed within (Harper-Leatherman & Miecznikowski, 2012) and outside the classroom (Levine & DiScenza, 2018; Phelan et al., 2017) help females overcome many sociocultural factors such as peer pressure (Bottia et al., 2015), causing them to pursue different, non-STEM fields. Though primary and secondary education initiatives might work best to reduce the gender gap because they have the longest and most consistent contact with female students, they do not tend to get a lot of traction and are fraught with budgetary and other constraints (Levine et al., 2015). This qualitative case study describes how female STEM students choose a STEM major, the obstacles they face when doing so, and how they overcome those obstacles. The study examines these impacts through the lens of the undergraduate female student.

Evidence suggests that female students reconcile their own perceptions about their place in science with that of others and with their various other social identities to form a science identity (Carlone & Johnson, 2007). The science identity model elucidates a student as the intersection of their performance, their competence, as well as their recognition (Carlone & Johnson, 2007). In this context, Stanton-Salazar's (1997) social capital framework fits within the recognition domain of Carlone and Johnson's (2007) science identity model. Science identity is a useful framework with which it is possible to examine the changes that female students undergo as they choose academic majors, how they incorporate information related to the obstacles they face, and how they overcome those obstacles.

Statement of the Problem

There are real shortages of students entering STEM fields, especially when it comes to female participation in those fields. This is often referred to by the metaphor of a leaky pipeline (Cundiff, 2013). Goulden (as cited in Cabay et al., 2018) described the problem best:

> The 'leaky pipeline' [emphasis in original] metaphor commonly refers to the disproportionate exit of [females] from STEM at transitions from one educational or career level to another, the consequence of which is fewer and fewer [females] remaining in the 'pool' [emphasis in original] for subsequent advancement in STEM. (p. 1)

This metaphor and its various iterations are pervasive not only in the media and among the public but also among researchers who are keen to understand the root cause behind the loss of females in the sciences and identify ways to address this problem.

There is a historical basis for the gender gap that points to both biological and sociocultural causes (Tolley, 2003). Educational, policy, and political forces deepen the disparity. True equity may not be possible, as Buccheri et al. (2011) claimed "the aim of closing the gender gap completely might not be achievable, but the gap may be minimized [sic], albeit indirectly" (p. 173). Despite the challenges, successes have also been reported. Avendano et al. (2019) described an innovative program in California that minimized the impact of educational gender inequality at the college level, but Viadero (2009) found that females excelling in quantitative skills also tended to have high verbal skills affording them more academic choice.

Colleges have difficulty recruiting and retaining STEM undergraduates (Huvard et al., 2020). STEM attrition remains high (Betz et al., 2021). In addition, females account for less than 25% of those working in STEM occupations (Kricorian et al., 2020). Researchers, teachers, and parents need to develop an understanding of how female students develop their science identity to reduce the gender disparity in STEM fields.

Purpose of the Study

The purpose of this study is to describe how female STEM students choose their undergraduate major, the obstacles they face when making that choice, and how they overcome gender-based obstacles. These descriptions will illuminate the way in which they developed their science identity, and the resources they relied upon while doing so. To this end, a qualitative case study research design will be employed to answer this study's research questions. Undergraduate female STEM students will be interviewed virtually, due to COVID-19 constraints, to address the three research questions examined in this study.

Research suggests that teachers who use authentic learning techniques (Heidi & Neo, 2015) can approximate an apprenticeship-like relationship with their students. Notably, blended learning techniques engage students more deeply in the course content and afford a more active learning environment (Heidi & Neo, 2015). With little consistency, each state, and in some cases individual school districts, set course curricula. Those who choose to adopt authentic learning techniques in blended learning environments may be able to reach more students in general and keep more young females engaged in STEM courses. This study will use Carlone and Johnson's (2007) science identity model to describe the way female STEM students make academic choices, how they face obstacles, and the ways they overcome those obstacles.

Research Questions

This study uses Carlone and Johnson's (2007) science identity model to address the following three research questions:

RQ1. Why do female STEM undergraduate students choose to pursue STEM majors?

RQ2. What obstacles do they face as they make their STEM major choices?

RQ3. How do they overcome these obstacles?

The study examines these three research questions through semi-structured virtual interviews with female undergraduate STEM students.

Conceptual Framework

This study employs Mezirow's (1978) transformative learning theory (TLT) as its conceptual framework. TLT is a grounded theory, typically employed for studies of adult learners, but it has also been used to describe adolescent self-reflections on learning (Larson, 2017), and to explicate the development of agency and independence among teen mothers (Cheung et al., 2020). TLT divides critical learning into a series of steps through which learners are transformed (Mezirow, 1978). Learners begin with a disorienting dilemma (Howie & Bagnall, 2013), such as a mismatch between their academic interests and their knowledge, skills, and abilities. Then, they progress through a prescribed set of steps, emerging with a new perspective that resolves their dilemma.

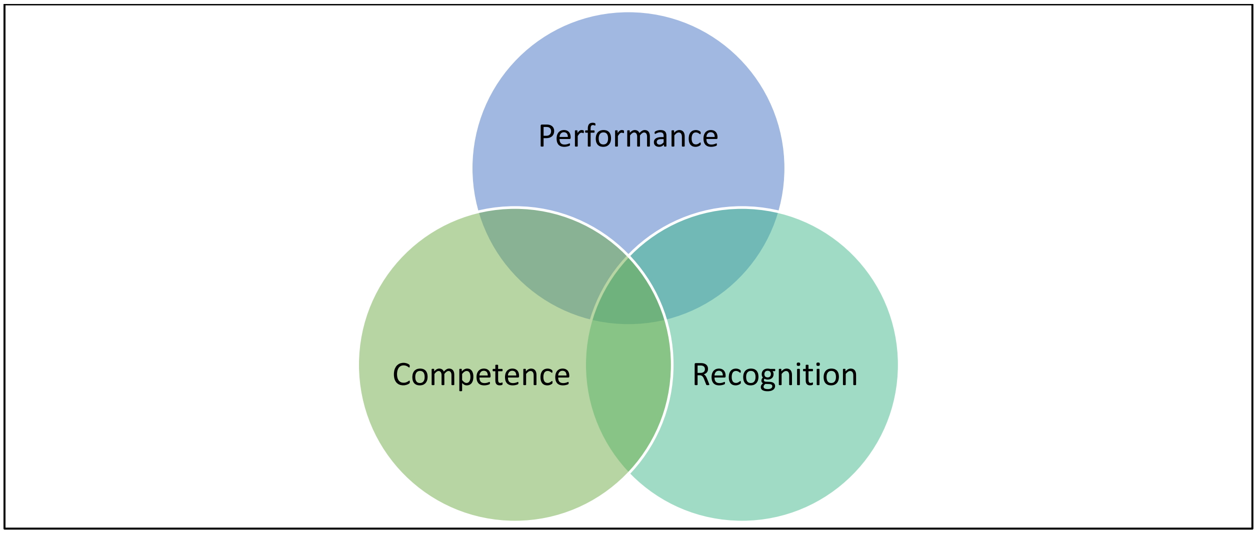
The ten steps, each of which is discrete, are as follows: disorienting dilemma; self-examination; critical assessment of assumptions; recognition that transformation is shared; exploration of options for new roles, relationships, and actions; planning a course of action; knowledge and skills acquisition; trying new roles; building competence and self-confidence in new roles and relationships; and integration of the new perspective into one's life (Mezirow, 1978).

Theoretical Framework

This study uses Carlone and Johnson's (2007) science identity model as its theoretical framework. Carlone and Johnson contend that science identity encompasses both how women make sense of their experiences in science and how society aids them in imposing possible meanings on their perceptions, considering both external structures and internal agency (Carlone & Johnson, 2007). Recognition is key to women forming a strong science identity in their model.

Figure 1

Carlone and Johnson's (2007) science identity model.



Note. Science identity refers to the intersection of student performance, competence, and recognition.

The model is based on the intersection, like that of a Ven diagram, which places equal weight on performance factors, competence factors, and recognition (Figure 1). The three factors may not always be equally weighted (Carlone & Johnson, 2007). Students with a high science identity are found to perform science-related tasks better and exhibit improved science course competence than their low science identity peers (Chen et al., 2021; Worchester, 2017). In this context, Zambrano (2018) showed evidence that recognition was predictive of "significant increases in science identity from the previous semester for women but not for men" (p. 18) and that recognition also improved women's sense of belonging in science. It is also notable that recognition can take various forms, including self-recognition and the recognition of others in science.

Assumptions, Limitations, and Scope

Several assumptions must be made at the onset of this study. First, participants are assumed to be frank and honest in answering the interview questions. This assumption is necessary to form accurate and precise conclusions based on participants' answers. Second, it is assumed that participants express a genuine interest in the study. This assumption is necessary to produce an authentic dialog between researcher and participant. And finally, it is assumed that female STEM students did encounter obstacles in their pursuit of a STEM major. This assumption is necessary to develop a comprehensive view of the obstacles faced by female STEM majors.

Two key limitations may impact this study. The first one is the sample size of available female undergraduate students. This study examines semi-structured interview data from study participants who attend various colleges and universities in the United States. The number of participants is limited by the use of social media for recruitment. No subsampling will be performed to reduce the impact of this limitation. Data from all participants who volunteer to participate in this research study will be included.

The second limitation relates to student self-reporting. Interview questions pertaining to affective domain issues do not always elicit honest and introspective responses. Subjects may feel uncomfortable in expressing their feelings and thoughts in response to interview questions designed to examine facets of self-esteem, values, motivations, and identity. These limitations can be reduced in semi-structured interviews by allowing participants to relate as much detail in their answers as they feel comfortable in sharing.

In the sciences, there is an inherent bias among participants' classes as students voluntarily choose which classes to take, a process that favors students who already have a positive view of STEM disciplines or an intention to explore or pursue a STEM-based career after high school. This bias is acceptable as it is the particular obstacles and science identities of these female STEM students that are at the center of this study. Social media was used to recruit participants for this study. This will be discussed further in Chapter three. The chosen research method will allow the scope of this study to remain focused on the research questions.

Rationale and Significance

There is a pronounced gender gap in undergraduate STEM admissions both in the United States and throughout the world (Viadero, 2009; Buccheri et al., 2011). This gender gap has been traced back to least to the 17th century (Tolley, 2003), is attributed to many internal and external causes (Bottia et al., 2015; Cabay et al., 2018; Ceci et al., 2009), and begins as early as age three (Todt et al., 1994). Many factors go into a female student's choice of undergraduate major. Among those who choose a STEM major, research has demonstrated that programs and initiatives that strengthen their science identity are most promising (Atkins et al., 2020; Carlone & Johnson, 2007; Huvard et al., 2020). Initiatives that have been investigated include mentoring programs (Betz et al., 2021; Godec et al., 2020; Kricorian et al., 2020) and outreach programs (Betz et al., 2021; Singer et al., 2020). While STEM-based outreach programs have shown promise in reducing this gender gap (Levine et al., 2015; Phelan et al., 2017) they are not impervious to funding constraints. Heidi and Neo (2015) suggest that teachers who expose students to authentic learning and blended learning techniques tend to engage students more deeply in the course content.

With little consistency in STEM curricula from state to state and the scarcity of resources employed in mentoring and outreach programs, female students face a range of obstacles in their pursuit of a STEM major. This study attempts to shed light on the obstacles that female STEM students face, how they overcome those obstacles, and how the process of overcoming obstacles impacts their science identity. I intend to utilize the insights gained by this study to help reduce the STEM gender gap.

Definition of Terms

The following define specific terms that are used throughout this study.

Biological factors are factors and effects related to brain organization, evolutionary pressures, and prenatal hormones (Ceci et al., 2009).

Gender is the position that a person is assigned to or identifies with on the continuum between female and male (Claahsen-van der Grinten et al., 2021).

Mezirow's Transformative Learning Theory is a theory that treats learning as a complex process involving the change in how a person views a problem and how that perspective, as well as the persons' expectations, affect the way he or she thinks, feels, and behaves (Mezirow, 1978).

Microaggressions are subtle and/or unintended statements or actions that discriminate or otherwise injure a marginalized person (Cabay et al., 2018).

Parity is equal status among two or more groups (Camilli & Hira, 2019).

Physiological factors are factors and effects related to the normal function of the human body and its anatomical parts (Ceci et al., 2009).

Sexual harassment is inappropriate behavior toward an individual because of their gender (Leaper & Starr, 2019).

Sociocultural factors are experienced by an individual that pertain to their membership in a social or cultural group (Cundiff et al., 2013).

STEM fields are the combined academic fields and workforce involved in the study and advancement of science, technology, engineering, and mathematics (Bottia et al., 2015).

Conclusion

This study uses a qualitative case study research design to examine three research questions related to how female students choose an undergraduate STEM major, the obstacles they face in making that choice, and how they overcome those obstacles. This information helps me understand how female STEM students construct their science identity. The study's participants are female undergraduate STEM students that were recruited using social media.

Chapter two provides a detailed, traditional narrative style review of the extant literature about gender in STEM education. It commences with the historical context of gender disparities and theories and models elucidating the underlying gender inequities, continues with the basis of gender differences, and ends with interventions designed to reduce the gender gap. Chapter three provides a detailed explanation of the methodology used to study this problem. Chapter four presents the interview data related to this study. Chapter five concludes the study by answering the research questions and providing recommendations based on its findings.

CHAPTER 2: LITERATURE REVIEW

This chapter presents a traditional-narrative style discussion of the existing body of literature on the topic of gender disparities in STEM. The discussion initially focuses on the history of gender disparities, tying them to theories and models designed to describe and predict the underlying inequities. Then the discussion shifts to an overview of this study's conceptual framework, Mezirow's (1978) TLT, with its strengths and weaknesses, followed by an overview of this study's theoretical framework, Carlone and Johnson's (2007) science identity model. Thereafter, the discussion focuses on the underlying reasons for gender differences, and their biological and sociocultural basis. Finally, the chapter examines instructional interventions designed to reduce the barriers to females entering STEM majors.

There are conflicting accounts in the media about whether females are on track to achieve gender parity in the workforce (Jakobsdóttir, 2019; Turner, 2017). Females are often paid less for equal work, are denied equal promotion opportunities, and earn less over their lifetimes than their male counterparts (Graf et al., 2020). There is significant evidence that there are real gender differences in the education sector and in the workplace (UNICEF, 2020). Educational gender disparities may accentuate the gender gap in STEM disciplines despite the evidence that females have achieved parity in math and science achievement scores (Viadero, 2009).

Camilli and Hira (2019) view the gender gap as a perceived rather than a real problem, advocating for little intervention, even going so far as to accuse STEM-focused educational programs of contributing to "the rise of the useless" (p. 6). Real or perceived, this disparity is a cross-national problem (Buccheri et al., 2011) and extends to other masculinized fields including many types of sports (Cain et al., 2020). This can be attributed to many root causes.

Some researchers have proposed a biological basis for gender disparity (Bottia et al., 2015), citing hormonal, neural, reproductive, and other physiological differences between females and males (Ceci et al., 2009), as well as the microaggressions and sexual harassment that inevitably stem from those differences (Cabay et al., 2018; Leaper & Starr, 2019). A majority of research points to sociocultural causes (Bottia et al., 2015; Cundiff et al., 2013; Schuster & Martiny, 2017). These causes include females' thoughts and feelings about STEM fields (Levine et al., 2015), their science identities (Carlone & Johnson, 2007), the forces and influences they experience from childhood through graduation (Ferguson & Hull, 2019), parental and peer involvement in college choice and career decisions (Lee et al., 2020; Muenks et al., 2020), as well as the availability of social and academic supports (Avendano et al., 2019; Bertocchi & Bozzano, 2016).

Mentorship programs have shown promise in "foster[ing] scientific identity and STEM career pathways" (Atkins et al., 2020, p. 2) for females in STEM. According to Godec et al. (2020), the intersection between students and their teachers and mentors, the time, place, and content being learned, and power relationships among individuals form science identity. There are strong cases for colleges to provide STEM intervention programs to attract STEM students. These programs have included those that provide peer mentors to students (Betz et al., 2021), research opportunities (Huvard et al., 2020), university-led STEM enrichment programs (Atkins et al., 2020), and those designed to expose female STEM students to female role models (Singer et al., 2020).

Other promising programs are science summer camps for middle and high school girls that have been used to boost STEM enrollment in many colleges and universities (Levine et al., 2015; Phelan et al., 2017). These programs have used the positive experiences of females in STEM fields to generate excitement among participants. Although the literature is rich with examples of these programs, the extent to which they bring about positive and lasting change has not been quantified.

Science, Technology, Engineering, Mathematics Gender Gap

There is a well-known and comprehensively documented gender gap in the physical sciences in the United States (Harper-Leatherman & Miecznikowski, 2012; Levine & DiScenza, 2018; Levine et al., 2015; Phelan et al., 2017). This gender gap has been attributed to several causes. In their compilation of twenty years of research, Sadker and Sadker (1995) showed how differently boys and girls are treated by teachers in primary and secondary school classrooms. They argued that one cause was the different and sometimes unfair treatment of girls, which impacted how they choose majors and careers, and how they ultimately act within the college environment (Sadker & Sadker, 1995). Meanwhile, Tolley (2003) traced the history of pre-college science education of girls from the 17th century through the end of the 20th century and exhaustively discussed how changes in science curriculum, teaching methods, and science content delivery resulted in unequal education of girls seen even today. Kelly (1988) performed a meta-analysis of over 80 studies and concluded that boys got more attention from their teachers than girls did, adding that girls received less criticism but also less instruction, although they raised their hands more often. Comparing their meta-analysis to that of Kelly (1988), Beaman et al. (2006) found that differences in teacher attention and instruction had not changed.

Researchers have examined many feminist theories as educators made efforts to reduce the science gender gap (Blue et al., 2019). According to Rosser (1990), science classes were taught in a way that alienated girls and advocated using methods drawn from females' studies to help attract and retain female students in the sciences. On the other hand, Roychoudhury et al. (1995) applied a feminist science lens while analyzing educational reforms and discussed a case study incorporating feminist standpoint theory into a science classroom. Brickhouse (2001) showed the degree to which science learning theories aligned with feminist research with the goal of providing equity in the science classroom.

In their attempt to describe the origins of the gender gap problem, researchers have applied heuristic models (Todt et al., 1994) and casual models (Ceci et al., 2009). Others have used motivation (Gagnon and Sandoval, 2020) or proposed their own theory (Krapp, 1992) to provide explanations for it. Todt et al. (1994) developed a heuristic model of global and specific interests in children and showed that children choose gender normed objects and activities starting at around three years of age and progressing throughout their development. Ceci et al. (2009) developed a causal model to explain gender differences in STEM professions based on biological differences, student environment, motivation, attitudes and interests, brain function and development, abilities, assessed performance, status, and broad contextual expectations that also quantified the relative magnitudes of the linkages among the various nodes in their model. Krapp (1992, 2005) chose to focus on the individual instead of the objects and activities in his German Person-Object Theory of Interest. Gagnon and Sandoval (2020) explained that the motivation to pursue a STEM career typically begins in adolescence, a phase of development where gender disparities already appear, and suggested that interventions are needed in earlier phases of development.

Mentoring Programs

According to Atkins et al. (2020), students with STEM mentors strongly identified as scientists, and females' scientific identities are "shaped" (p. 2) by the recognition they receive from their STEM mentors. "Mentors link students to career resources and research opportunities, provide emotional support, foster students' confidence and science self-efficacy, and facilitate their valuing of scientific research" (Atkins et al., 2020, p. 3). Godec et al. (2020) state that science identity is formed by the intersection between students and their teachers and mentors, the time, place, and content being learned, as well as power relationships among individuals. Mentoring gives students the opportunity to obtain recognition; it validates their sense of self-confidence, strengthening their science identities (Betz et al., 2021). Females exposed to female role models demonstrated stronger science identities and increased persistence in STEM programs (Singer et al., 2020).

To intervene, colleges have developed programs that provide mentorship and research opportunities to keep students supported and engaged, although research into the long-term effectiveness of these programs is limited (Betz et al., 2021). Students who had the opportunity to perform research, or who had STEM mentors had an improved and stronger science identity over time (Huvard et al., 2020). Mentorship assists in students' sense of belonging, which improves academic performance and persistence in STEM, especially among women (Kricorian et al., 2020).

Science, Technology, Engineering, Mathematics Interventions

One strategy that improves female participation in STEM is the implementation of formal, university-led STEM enrichment programs that aim to build a scientific community, provide mentorship to students, and improve student academic performance and career readiness (Atkins et al., 2020). Successful programs often allow students to produce physical artifacts (such as a model of a cell) or digital artifacts (such as an operational computer program), which can be used to augment their science identity (Godec et al., 2020). Peer inreach and outreach programs have also shown some promise. For example, inreach programs allow undergraduate students to support and mentor their undergraduate peers, whereas outreach programs allow undergraduate students to support and mentor kindergarten through 12 students. These programs increase STEM knowledge and interest and have been linked to students' metacognition and their development of a strong science identity (Huvard et al., 2020).

Lombardi (2007) defined authentic learning as learning environments that enable students to solve complex, real-world problems. Authentic learning introduces multiple perspectives and interdisciplinary approaches to students, improves student empathy, and aids in their understanding of theoretical concepts (Singer et al., 2020). Students' STEM identity is also strengthened by engaging in hands-on activities in a discovery-based learning community, which enhances their self-efficacy (Betz et al., 2021). Authentic learning environments allow students to develop communication skills and higher-order critical thinking skills that Heidi and Neo (2015) claimed would benefit students later in life. They described how authentic learning strategies create more student-centered, learner-focused learning environments (Heidi & Neo, 2015). Besides contributing to stronger science identities, increases STEM persistence through college, authentic learning improves academic performance and student retention, and correlates strongly with higher self-efficacy (Singer et al., 2020).

Students who engaged in undergraduate research opportunities engaged in the scientific process and gained insight into potential career fields in STEM (Betz et al., 2021). Betz et al. (2021) argued that "undergraduate research experiences enhanced student interest in becoming a scientist" (p. 3) by increasing their understanding of science and improving their professional self-confidence.

Science summer camps extend these research experiences to younger students. Gagnon and Sandoval (2020) described STEM science camps as one part of a solution to the gender gap as:

> The links between supportive staff behaviors, camper engagement, and camper outcomes illustrate how quality STEM summer programs (e.g., science camps) can lead to greater engagement with STEM coursework, greater aspirations toward STEM college majors, career interests, and improved self-confidence among males and females (p. 2).

Harper-Leatherman and Miecznikowski (2012) elucidate the marked success they had using authentic learning strategies during a college science course, blending literature with forensics in a laboratory environment. To inspire urban economically and educationally disadvantaged girls to pursue careers in STEM careers, Levine et al. (2015), Phelan et al. (2017), and Levine and DiScenza (2018) all describe similar successes using immersive, authentic learning techniques in a science-based summer camp environment. Singer et al. (2020) brings these types of programs back into the lens of science identity by stating that three factors contribute to science identity: (1) the use of role models to teach diversity and inclusion; (2) triggering students' sense of belonging; and (3) the use of authentic learning techniques.

Conceptual Framework

This study uses Mezirow's (1978) TLT as its conceptual framework. Mezirow's (1978) TLT is a grounded theory that describes learning as a discrete series of steps, transforming a learner from an initial state called a disorienting dilemma to a final state where the learner integrates a new perspective into their lives (Howie & Bagnall, 2013). The disorienting dilemma can be as simple as a mismatch between a learners' strengths and their interests. The new perspective reconciles the mismatch by incorporating classroom learning events as well as other inputs from friends, peers, and family.

Prominent Authors

Prominent authors in the field of TLT include Mezirow and Marsick (1978), who collectively developed the early framework for TLT (Luft et al., 2019). Mezirow continued to develop and refine the theory (Mezirow 1997, 2012) incorporating evidence and criticism (Taylor and Cranton, 2012). Luft et al. (2019) advanced Mezirow's (1978) TLT as an essential element when considering career trajectories. TLT has been expanded and revised (Mezirow, 1997, 2011) to account for advances in learning science and in response to critiques. TLT recognizes that learners have a "frame of reference that is transformed in response to different situations" (Luft et al., 2019, p. 65). While Luft et al. (2019) adopted TLT as a framework for science teacher career development, it has also been used to explain how graduate students learn about leadership (Burns, 2016), how people reframe their ideas about race (Gambrell, 2016), and other fields and contexts about adult learning (Taylor & Cranton, 2012).

Transformative Learning Theory Strengths

The literature accumulated since its early development by Mezirow and Marsick (Mezirow, 1978) comprises more than four decades of evidence (Luft et al., 2019), the preponderance of which (Burns, 2016; Gambrell, 2016; Taylor & Cranton, 2012) supports Mezirow's (1978) TLT. A vast majority of work in support of TLT examines research problems through a qualitative lens (Luft et al., 2019). Initially, TLT was applied almost exclusively to adult learners, but researchers are increasingly expanding its reach to younger learners (Cheung et al., 2020; Larson, 2017), correlating the transition from adolescence to adulthood and its associated "major psychosocial transition that carries with it the task of reevaluating, adjusting, or relinquishing formerly held beliefs" (Larson, 2017, p. 40) with TLT's disorienting dilemma.

TLT offers provides the researcher with a lens to examine the way learners synthesize their old beliefs with new ones (Luft et al., 2019). Choice of academic major is an expression of students' current belief about their place in the future workforce. Students' interactions with their teachers, families, friends, and peers will exert forces that attempt to change the students' beliefs through reflection (Mezirow, 1997). Female students enter their academic career choice process with a set of beliefs based on internal and external factors that may not necessarily be in alignment with their strengths. TLT provides a framework to explain how female students reconcile these factors (Larson, 2017) to arrive at their undergraduate major.

Transformative Leadership Theory Weaknesses

Howie and Bagnall (2013) contend that many theorists neatly but improperly fit their evidence into the metaphor and that some circular arguments need to be explored. They argue c that the weakness of TLT falls into four categories (Howie & Bagnall, 2013). Its first weakness is highlighted by research that suggests some TLT elements are lacking during learning events, or require further elucidation. As a case in point, Baumgartner (2012, as cited by Howie & Bagnall, 2013) describes learning events that do not easily fit into TLT's ten steps, touching on steps in different orders or omitting them altogether. TLT's second weakness involves the way researchers often support TLT by creating circular causality traps (Howie & Bagnall, 2013). For instance, criticism of this type argues that since transformative learning and critical reflection are mutually dependent, one cannot precede the other (Collard & Law, 1989, as cited in Howie & Bagnall, 2013), creating a "chicken-or-egg argument" (p. 820). Its third weakness is that some researchers reject TLT theory entirely on philosophical grounds. Hart (1990, as cited in Howie & Bangall, 2013) criticized TLT due to the lack of explicit treatment of power relationships. Pietrykowski (1997, as cited in Howie & Bagnall, 2013) rejected TLT as being "too modernist and emancipationist" (p. 820). TLT does incorporate power considerations as they bear on step five, exploration of options for new roles, relationships, and actions, as well as step nine, building competence and self-confidence in new roles and relationships (Mezirow, 1978). TLT's fourth weakness is a minor but consequential criticism of the overall theory itself (Howie & Bagnall, 2013). These include semantic arguments, for example, that the word *transformative* was itself meaningless (Brookfield, 2000, as cited in Howie & Bagnall, 2013) and "a divergence of academic views of the theory's components and its methods" (Kokkos, 2010, as cited in Howie & Bagnall, 2013, p. 820). Overall, I opine that the strengths of Mezirow's (1978) TLT outweigh its weaknesses.

Theoretical Framework

As mentioned before, this study uses Carlone and Johnson's (2007) science identity model as its theoretical framework. The science identity model is based on the intersection of performance factors, competence factors, and recognition (Carlone & Johnson, 2007). These three factors do not need to be equally weighted. Science identity encompasses both the way females make sense of their experiences in science and the way society aids them in imposing possible meanings on their perceptions, taking into consideration external structures and internal agency. According to Carlone and Johnson (2007), recognition is key to women forming a strong science identity. In this context, three prime science identities were identified: (1) research science identity, which expresses a passion for science and emphasized self-recognition and the recognition of others in science; (2) altruistic science identity, which expresses science as a means to an end and relies on a nonconventional definition of science and an innovative construct of recognition; and (3) disruptive science identity, which needs but often does not get recognition from others (Carlone & Johnson, 2007). These have been expanded and reorganized into five salient identities (Dwyer et al., 2020): research scientist, STEM-career focused, STEM apprentices, STEM humanists, and STEM seekers. It is also notable that Stanton-Salazar (1997) employed the social capital framework to explain forces and mechanisms at play with female learners. His social capital framework fits well within the recognition domain of Carlone and Johnson's (2007) science identity model.

The development of a student's scientific identity is accompanied by improved "academic performance, retention and persistence in STEM, and STEM degree completion" (Atkins et al., 2020, p. 2). Betz et al. (2021) opine that a strong science identity improves STEM persistence. A key component of the development of science identity is the ability to get recognition from "relevant others" (Betz et al., 2021, p. 3). Students with the strongest science identities were those who demonstrated competence in their knowledge of science, possessed the skills to perform science, and were recognized by others (Betz et al., 2021).

Science identity has been a useful conceptual lens with which to understand inequities in STEM (Godec et al., 2020). STEM participation is governed by students' identification "by gender, social class, ethnicity, dis/ability, and other social axes" (Godec et al., 2020, p. 2). This explains why some students find it easier to identify as scientists than it is for others with comparable knowledge and skills.

Science identities are developed by the different and shared experiences of students, together with their perception of the world (Huvard et al., 2020). They make meaning of their perceptions and assign themselves roles based on their identities. A student has many identities, each of which is designed to reconcile a particular set of meanings they create (Huvard et al., 2020). A person will identify as a scientist if they think and behave like other scientists. They are regarded as a scientist by others by demonstrating knowledge and skills that others view as science. Students do not form their science identity in a vacuum. Rather, science identity is a feedback loop governed by the student as well as the reinforcement of others (Huvard et al., 2020). Others in this context are students' peers, their parents, and teachers, together with the various traditional and social media that students consume.

"Intrinsic psychological factors and external environmental variables" (Kricorian et al., 2020, p. 2) influence student participation in STEM. Students often face obstacles related to gender and ethnicity that impact their acceptance. To build strong science identities, students need to feel a sense of belonging or acceptance by others in the STEM community or classroom. Diversity and inclusion correlate to students' sense of belonging, as it may help students overcome negative science identities already formed through childhood (Singer et al., 2020). Students who take classes among a diverse student body tend to have more self-confidence, better critical thinking skills, and improved agency (Singer et al., 2020). Also, students who feel accepted tend to develop a strong science identity (Kricorian et al., 2020).

Media also plays a role in shaping female science identity. Students' gender roles are typically formed in childhood in part by exposure to media. Typical white male STEM classrooms, as often depicted in the media, marginalize women and other minorities, thus creating a sense of privilege for white maleness. Diverse classrooms are known to minimize this privilege effect (Singer et al., 2020). Media images of STEM as the realm of white males negatively impact aspiring women's science identities (Kricorian et al., 2020). Positive science identity experiences in youth are predictive of a strong science identity and STEM persistence in college (Kricorian et al., 2020).

As students form their science identities, they reconcile the social expectations of those around them apart from their own interests and values (Naukkarinen & Bairoh, 2021). Students have multiple identities that correspond to each social context. These identities reference where students fit in terms of their roles within a group, the identity of groups to which students belong, as well as the characteristics that make a student unique (Dwyer et al., 2020). Often, a student's science identity may be at variance with the student's personal identity. According to Dwyer et al. (2020), science identity involves more than simply describing oneself as a scientist. It involves self-efficacy, a genuine interest in science, and the accumulation of validation from the scientific community. Science identity is multidimensional and changes over time as students acquire new experiences. Science identities also reconcile with other identities that relate to how a student fits within a larger group, such as an ethnic group or a race, how a student fits within an intermediate group such as their neighborhood or their school, and how a student fits within proximate groups like their peers and families (Dwyer et al., 2020). All of these identities combine to form a students' overall identity.

Hazari (2010) presents a higher-order model of student identity that provides a lens with which to derive Carlone and Johnson's (2007) science identity model. In the Hazari model (2010) students are represented by the intersection among their personal identity, their social identity, and their identity within any science field. They expand on Carlone and Johnson's (2007) model of identity within a field of science by adding the element of interest to recognition, performance, and competence.

To facilitate a stronger science identity, science learning needs to include not only factual science but how students can relate to science (Brickhouse et al., 2000). Students transform their identities through interaction with their communities and through what they learn. If they have positive learning experiences in science and a supportive community, they will build strong science identities (Brickhouse et al., 2000).

Review of the Literature

This study uses Mezirow's (1978) TLT as a conceptual framework, and Carlone and Johnson's (2007) science identity model as a theoretical framework to describe the changes in the way undergraduate female students learn about and relate to science as they transition to the university environment. Researchers need to understand the contributions that social forces, differences in gender perspectives, the underlying basis of gender disparity, and science teaching pedagogy have on female students to unravel the impacts facing female students.

Educational Science, Technology, Engineering, Mathematics Interventions

There is increasing evidence that educational interventions employed within and outside the classroom help female students overcome many of the sociocultural factors causing them to pursue different, non-STEM fields (Harper-Leatherman & Miecznikowski, 2012; Heidi & Neo, 2015). Though primary and secondary education initiatives have the longest and most consistent contact with female students, which can make them effective against the gender gap, they tend to get little traction and suffer from budgetary and other constraints (York, 2008).

Researchers have successfully implemented programs using an interdisciplinary approach, blending STEM learning with the humanities (Harper-Leatherman & Miecznikowski, 2012), or adopting authentic project-based learning (Beier et al., 2019). These programs address both the biological and the sociocultural basis of the gender gap (Phelan et al., 2017), and individual colleges need to attract a gender-diverse student body to their STEM programs (Levine & DiScenza, 2018; Phelan et al., 2017). Although the research is clear on the short-term impact of these programs, little longitudinal data exist to assess the overall effectiveness of STEM summer camps in improving what Cundiff et al. (2013) refer to as the “leaky pipeline” (p. 550).

The leaky pipeline metaphor and its various iterations are pervasive among researchers who wish to understand and reduce the loss of females in the sciences (Beier et al., 2019; Cundiff et al., 2013). Any effective program designed and implemented to address this shortage needs to account for the gender differences that historically drive many females into other fields.

Gender Perspectives

Anecdotal and peer-reviewed research points to gender disparity in STEM fields as being an old problem (Bertocchi & Bozzano, 2016). While overall gender norms and gender roles at home and in the workplace, in general, are beyond the scope of this dissertation, gender disparity and gender inequity are not new. Throughout time, plenty of evidence has emerged suggesting that males and females occupied discrete but complementary roles (Bertocchi & Bozzano, 2016). According to Bertocchi and Bozzano (2016), personal and societal forces have always acted to keep the status quo despite the scope of overlap. In looking at gender perspectives, researchers have tended to focus on four central themes: females' tendency to have limited access to quality STEM education (Avendano et al., 2019), gender-based STEM inequities (Viadero, 2009), the gender gap in STEM careers (Camilli & Hira, 2019), and models for gender trends (Cabay et al., 2018). The following sections discuss these themes further.

Female Students Access to Science, Technology, Engineering, Mathematics Education

Evidence suggests that the "disproportionately low number of minority students [including females] entering STEM fields is the result of limited access" (Avendano et al., 2019, p. 68). Bertocchi and Bozzano (2016) argue that female students' limited access to educational programs, though existing already throughout ancient history, became more pronounced because of a "medieval pattern of commerce . . . fundamental economic incentives, institutional legacy, and cultural beliefs" (p. 498). Even when there is access to equal educational resources, female students underutilize these supports. Avendano et al. (2019) states:

> Marginalized populations do not have equal access to STEM education. In K–12 education, students . . . face issues such as teacher retention, a lack of STEM programmes

[*sic*], low funding for field trips or materials, limited school resources, teachers who are more concerned about high-stakes state testing than about STEM exposure, and the limited number of STEM programmes [*sic*] in urban areas, etc. (p. 68)

Koch et al. (2014) put it aptly as they contended that educational institutions need to roll out a “welcome mat” (p. viii) to these services. Female students always have been and are still marginalized as observers and learners of the scientific community, and later as members of that same scientific community (Koch et al., 2014).

Gender-Based Science, Technology, Engineering, Mathematics Inequities

Some gender inequity arises from fiscal constraints in our public schools (Avendano et al., 2019). Often programs are cut that disproportionately impact academic content-related extracurriculars including math, science, the arts, and music, in favor of continuing sports programs. Even though female students fare equally well on science and math-based achievement tests, they often opt to pursue *caring sciences* such as biology and medicine while male students opt for engineering and math fields (Viadero, 2009, p. 1). The author explained that female students who excel in quantitative fields tend to also have high verbal scores, a combination that affords them more future career choices. Blue et al. (2019) suggest caution in relying on statistics-based approaches to analyze gender diversity, “number-based ‘diversity’ [accent in original] efforts are likely to fail if they address only a symptom . . . and not the underlying problems” (p. 626).

Gender Gap in Science, Technology, Engineering, Mathematics Careers

The gender gap in STEM careers persists even though the achievement gap is narrowed or gone when it comes to analytical and quantitative knowledge and skills (Cundiff, 2013; Viadero, 2009). As Viadero (2009) mentioned:

> At a time when growing numbers of studies show that U.S. females have achieved parity, or are close to it, on science and math achievement tests, [males] still outnumber [females] at the top levels of many of those fields, particularly in quantitative sciences such as engineering and math. (p. 1)

Not all researchers believe that there is a real STEM gender gap, or that we should be concerned if there is a problem (Camilli & Hira, 2019). They claim the gap is perceived, and that future job trends will depend on “organizational and social sciences, on the arts, on new business processes” (Camilli & Hira, 2019, p. 5), rather than on the natural sciences and engineering. Their position lacks much scientific consensus, and a vast majority of literature points to a real gender gap (Blue et al., 2019; Viadero, 2009), and the necessity to remedy that gap for a variety of individual and societal reasons (Avendano et al., 2019).

Models for Gender Trends

Researchers have not reached a consensus on the fundamental differences between the meanings of basic terms such as gender (Fausto-Sterling, 1993, as cited in Blue et al., 2019) and sex (Ainsworth, 2015, as cited in Blue et al., 2019). This situation is exacerbated by the application of cultural and societal norms. Blue et al. (2019) offer references to underlying theories about gender in general, feminism in the sciences, and the influence of gender theories on teaching and education, again cautioning that "we must be thoughtful about the interplay and differences between diversity, inclusion, and equity" (p. 626). Researchers attempt to fit historical and occupational gender trends into models that fit and predict future change (Cabay et al., 2018; Todt et al., 1994). Todt et al. (1994) modeled the development of gender-specific general interests and found they correlated strongly with various science disciplines and career vocations.

Cabay et al. (2018) offers models based on microaggressions against females, arguing against gender deficit models and explaining both general identity and science identity models for gender differences. York (2008) has proposed an economic human capital model that cleverly fits both sets of data, finding that females chose less-selective colleges and chose lower-paying jobs despite achieving equal grade point averages (GPA) and Scholastic Aptitude Test (SAT) test scores. York (2008) claims that “with fewer years in the labor market due to caregiving needs for children or other family members, [females] received a lower return on their educational investment and hence invested in less education" (p. 578).

Basis for Gender Disparity

There is significant evidence in the literature to suggest that gender disparity arises from many complementary forces (Bottia et al., 2015; Camilli & Hira, 2019; Ceci et al., 2009). Females accumulate thoughts and feelings related to STEM fields throughout their formal primary and secondary educations (Avendano et al., 2019). For better or worse, they are exposed to news and politics, peer groups, their parents, and others (Cain et al., 2020). All of these factors combine with real biological and physiological differences to form a female’s feelings about, comfort with, and relationship to science and math (Ferguson & Hull, 2019; Leaper and Starr, 2019). It is necessary to examine inequity in education, policy and political considerations, the biological and sociocultural basis of gender disparity, and STEM interventions based on gender disparity to understand the basis of gender disparity.

Inequity in Education

Teachers have made great strides in their efforts to overcome historical gender norms in the classroom, but they still exist in many places (Avendano et al., 2019; Viadero, 2009). The Center for Innovation in STEM Education (CISE) at the California State University at

Dominguez Hills was successful in minimizing the impact of educational inequality and was successful in recruiting, training, and retaining students in STEM fields (Avendano et al., 2019). Its focus was on rebuilding the STEM pipeline by examining equity in STEM education programs and the educational leadership implications of these programs.

Policy Issues

Camilli and Hira (2019) examined trends in federal STEM education policy and its impact on career choices, emphasizing a need to achieve a balance between STEM and humanities education; this was more in line with the skills needed in our current workplace. Policies that act to influence technology job creation in areas with an ill-equipped workforce, or policies that force technology jobs out of an area with adequate local talent are examples of a mismatch between workers' STEM skillsets and the locally available jobs. Cain et al. (2020) point to the necessity to address gender policy issues as well as to set up practices that are conducive to change to fully address gender across disciplines.

Biological Basis

There are profound biological and physiological differences between females and males (Bottia et al., 2015; Ceci et al., 2009). Females lose valuable time on the job (Ceci et al., 2009), tenure opportunities (Ginter & Kahn, 2006, as cited in Ceci et al., 2009), career advancement (Halpern, 2007, as cited in Ceci et al., 2009), and retirement savings simply by having and caring for their children (Ceci et al., 2009). In a transactional society, this does put females at a disadvantage (Schwanke, D. (2013). Ceci et al. (2009) reviewed over 400 peer-reviewed studies, more than 20 meta-analyses, and several meta-analyses of meta-analyses to find that physiological and biological differences failed to account for gender differences in STEM fields. They concluded that among other factors, "much of the explanation for [female's] underrepresentation in math-intensive fields can be found in the career-family trade-off and in a greater preference for . . . 'home-centered' [emphasis in original] lifestyles" (p. 232). According to them, this is less a function of biology than it is of a female's free or constrained choices that a female can choose a career over parenthood. Their study showed that although there were hormonal, neural, and reproductive differences, those together with sociocultural factors played a smaller role in gender bias than previously thought.

We extend the biological basis for gender inequity to the need of many females to overcome sexual harassment and gender bias (Leaper & Starr, 2019). Gender inequity has often led to microaggressions against females (Cabay et al., 2018). In this regard, Leaper and Starr (2019) claim that gender bias and sexual harassment both reduced female motivation in STEM classes, adding that sexual harassment is a larger problem than was previously thought. Alarmingly, that study found that "the majority of [females] in our sample reported experiencing STEM-related gender bias (60.9%) or sexual harassment (78.1%) at least once in the past year" (p. 165). As a result, females will disproportionately choose career pathways that allow them to feel safe so they can avoid sexual harassment and other harmful behaviors (Leaper & Starr, 2019; Starr & Leaper, 2019).

Sociocultural Basis

There is an enormous amount of evidence (Bottia et al., 2015; Cundiff et al., 2013; Schuster & Martiny, 2017) that a significant portion of the gender inequity in STEM career pathways is attributed to sociocultural factors. These factors include stereotyping, external factors in a women's environment and surroundings, internal factors they feel and think about, and their ability to make informed choices.

Stereotypes. People tend to correlate individuals who work in STEM fields with nerdy white males (Starr & Leaper, 2019, p. 1110). Cundiff et al. (2013) correlated gender-science stereotypes to science career aspirations among undergraduate science majors. They emphasized the vital role played by stereotypes in a female's association with science, their identification with science, and their ultimate career choice, stating "personal choices are made within particular social contexts, and stereotypes are part of that context" (Cundiff et al., 2013, p. 551). In their research, Schuster and Martiny (2017) took it a step and found that stereotypes also impact a female's ability to identify her own math and verbal abilities. They affirm that females "need a higher ability self-concept and self-efficacy in math and science, and they need to value these subjects more, in order to pursue them" (Schuster & Martiny, 2017, p. 53), and that "counselors and teachers should thus pay attention to the triggers of positive affect in STEM" (Schuster & Martiny, 2017, p. 53).

The effect of gender stereotypes can be mitigated (Bottia et al., 2015). Bottia et al. (2015) examined the role that female teachers play in reversing STEM gender stereotypes. According to their findings, gender composition among high school math and science teachers affected their female student's choice to pursue a STEM career, and the impact was more pronounced among higher-skilled students (Bottia et al., 2015). "A preponderance of female math and science faculty may be necessary for countering the pervasive gender stereotypes that math and science are masculine domains, especially for the female high school students who score the highest in math" (Bottia et al., 2015, p. 24).

Starr and Leaper (2019) opine that the impact of stereotypes on a female student's choice to pursue a STEM career appears to be myopic. They found that stereotypes had a threat effect but not a boost effect, meaning a negative stereotype acted to reduce but a positive stereotype did not act to increase high school female students' self-concept related to STEM fields (Starr &

Leaper, 2019). They found that "self-concepts, stereotypes, and social roles become especially salient" during adolescence (Starr & Leaper, 2019, p. 1110). Bottia et al. (2015) remind us that "it is important during the pre-college years to help disrupt the pervasive stereotypes regarding which individuals are suitable for a job in science, technology, engineering and mathematics" (p. 25), and that we "must work against the entrenched stereotypes that STEM fields are 'manly' [accent in original] fields" (p. 16).

External factors. In addition to the ramifications of gender stereotypes, females also face impediments involving the learning environment itself (Miller & Hurlock, 2017), parental beliefs (Lee et al., 2020; Muenks et al., 2020), and teacher impacts (Bottia et al., 2015). Miller and Hurlock (2017) examined the factors influencing young females who chose to pursue a STEM career. They found that class size, classroom environment, and overall campus environment were the primary factors influencing them. They posited that students do have a choice and that academic institutions need to know what factors affect STEM-promising females to attract them more effectively and close the leaky STEM pipeline (Miller & Hurlock, 2017).

Lee et al. (2020) examined the role that parents play in forming children's values and the opinions of their children toward STEM fields. They found a high correlation between parental values and male students' science motivation, but little correlation between parental values and female students' science motivations (Lee et al., 2020). Lee et al. (2020) postulated that parents treat STEM performance differently between their sons and their daughters, leading to this differential effect. "Parents transmit their gender bias regarding male sex-typed tasks toward children both implicitly and explicitly through modeling" (Lee et al., 2020, p. 87). Muenks et al. (2020) took it a step further, claiming that even a parent's beliefs in their children's abilities are gender-biased and that a parent's beliefs about their children's abilities determine their encouragement to pursue STEM careers. "These gendered beliefs could lead parents to treat young [males] and [females] differently, which may contribute to the persistent gender gap in certain STEM fields including physical science, computer science, and engineering" (Muenks, et al., 2020, p. 571).

Bottia et al. (2015) explained the role that teachers play in female students' career choices. Female students with strong female math and science teachers are more likely to pursue STEM careers. Buccheri et al. (2011) examined students from Switzerland, Finland, Australia, and Korea, finding that teachers and parents both impact student career choice by providing context to what students learn. "Teachers, like parents, are not only the providers but also the interpreters of experiences; thus, they influence the inferences children make about their successes and failures" (Buccheri et al., 2011, p. 174).

Ferguson and Hull (2019) examined external and internal factors influencing females in their career choices and found that both have an impact. Gottfredson (as cited by Ferguson & Hull, 2019) argues "a better integration of the psychological [internal] and non-psychological [external] approaches would provide a more comprehensive explanation of the development of vocational aspirations" (p. 546).

Internal factors. Many nuanced and interrelated internal or psychological factors influence a female's choice of career (Dennis et al., 2019; Sadolikar, 2019; Sax et al., 2015). The body of research is both broad and deep in this area. A full treatment of these factors is beyond the scope of this study, but a broad cross-section includes the impact of confidence and knowledge (Dennis et al., 2019), self-concept (Sax et al., 2015; Starr & Leaper, 2019), socialization, and life orientation (Sadolikar, 2019), perceptions (Heidi & Neo, 2015), interest, motivation, and attitude (Ferguson & Hull, 2019), as well as an appreciation for and relationship to science (Levine et al., 2015). These factors acting alone or in conjunction with other factors can have a profound impact on the interests and career pursuits of anyone (Levine et al., 2015).

Choice. Ceci et al. (2009) argued that hormonal, neural, and reproductive differences among the sexes as well as other socio-cultural factors play less of a role in leading female students down a STEM career path than the role of personal choice. When looking at colleges, Miller and Hurlock (2017) examined the set of institutional characteristics considered by students and found that non-research-intensive colleges offer smaller class sizes and supportive services that make them more desirable to STEM-promising female students. They advise that since STEM-promising female students do have more choice, colleges need to tailor their support service offerings, and recruitment efforts to attract them (Miller & Hurlock, 2017).

Science, Technology, Engineering, Mathematics Interventions

Research surrounding the real and perceived gender disparity in STEM fields, examined through a historical lens or a root cause analysis lens, offers a rich basis for the growth and development of educational initiatives specifically aimed at lowering the gender gap (Phelan et al., 2017). Programs have been developed that harness students’ abilities in non-STEM subjects to aid in their understanding of STEM subjects (Harper-Leatherman & Miecznikowski, 2012). These draw on developmental psychology and learning science to pair content knowledge and skills with real-life applications (Harper-Leatherman & Miecznikowski, 2012). Some researchers are also interested in making curricular changes (Avendano et al., 2019). STEM interventions fall into three broad categories: improvements in educational programs, the introduction and inclusion of interdisciplinary programs, and STEM summer camps. The following sections discuss this further.

Educational Programs

Highlighting the relative importance of loosely and tightly coupled administration within an educational organization, a study by Hautala et al. (2018) offered guidance to enhance school leadership to improve all course outcomes, but not specifically STEM courses. The authors examined students' perceptions after completing an authentic learning program within a blended learning environment. They claimed that:

> Authentic learning focuses on complex, open-ended real-life problems and solving these ill-defined problems. With the support of technology, valuable experiences can now be obtained through safe and controlled environments and not just through internship or apprenticeship programs. (p. 129)

Their study showed that students responded positively to authentic blended learning environments, engaged with the content more, and were more actively involved in the learning process (Heidi & Neo, 2015).

Luft et al. (2019) examined the use of science education trajectories in science teachers continuing career development to avoid simply focusing on content knowledge. This approach caused science teachers to feel more empowered and enhanced the classroom performance of both teachers and their students. Their study examined career development holistically, including changing the knowledge, practice, and soft skills needed to effectively teach and manage a classroom (Luft et al., 2019). According to their findings, "there is a need to provide science teachers with learning opportunities that support their transformations as teachers" (p. 74).

Interdisciplinary Programs

Researchers have examined the use of different interdisciplinary approaches to augment traditional STEM subject classroom approaches (Harper-Leatherman & Miecznikowski, 2012).

Harper-Leatherman and Miecznikowski (2012) developed a chemistry laboratory course that combined analytical chemistry knowledge and skills with a forensic examination of Shakespeare's *Romeo and Juliet,* wherein students were presented with the literary evidence and samples to analyze for poison. The study showed that students are not typically engaged in or inspired by science can re-engage by using an auxiliary topic or approach. In a study by Beier et al. (2019) students were allowed to engage in authentic, project-based STEM learning. It was found that authentic, project-based learning improved student career aspirations by altering their perceptions of STEM skills (Beier et al., 2019). This style of teaching is resource-intensive, and the study found that it is difficult to "engage STEM instructors [in project-based learning or] other active learning" (Beier et al., 2019, p. 19).

Science, Technology, Engineering, Mathematics Summer Camps

Three former STEM summer camp programs were examined through extensive phone and in-person discussions with the principal investigators involved in the development and implementation of each. Levine et al. (2015), together with her chemistry graduate students, implemented a week-long summer day camp for middle school female students that used intensive hands-on science laboratory activities to address the gender gap in STEM careers. Students performed hands-on experiments and attended field trips that propelled their interest in environmental, chemical, and biological sciences (Levine et al., 2015). According to Levine et al. (2015), the camp experience improved students' attitudes and perceptions of science. Apart from the influence of the instructors, it is difficult to determine the impact of the program, as all role models were female (Levine et al., 2015). According to Levine et al. (2015), the "gender gap may start as early as elementary school, with female students having a more negative attitude toward science than males starting as early as fourth grade" (p. 1639).

Levine and DiScenza (2018) created a second STEM day-camp program for underprivileged high school girls. That day camp was found to have a similar impact on participants' appreciation for and relationship to science, with students performing experiments ranging from crystallography to rocketry, all of which were based on sugar as a starting ingredient (Levine & DiScenza, 2018). Levine and DiScenza (2018) suggest that there are three reasons why females do not develop and maintain an interest in science:

> (i) the rigor and/or difficulty of science classes, especially at the high school and college levels; (ii) public mistrust of science and misunderstanding of the scientific enterprise, which results in relatively little value placed on science-related majors and professions; (iii) the perception that the scientific enterprise is not one in which a student feels he/she belongs. (p. 1316)

There seems to be a mismatch between the abilities of female students, their trust and understanding of science, and their perceptions about science (Levine & DiScenza, 2018). Phelan et al. (2017) created a two-week STEM day camp to focus on making chemistry more accessible to underrepresented high school females in southern Connecticut. Phelan et al. (2017) found that programs that engage female students in unique STEM experiences aid in their recruitment and retention in STEM fields. The study advised institutions to prioritize similar programs to engage underrepresented students during high school before opting for alternate career pathways (Phelan et al., 2017). She claimed that "students coming from poor urban areas lack adequate pre-college science exposure and mentoring and are often lost by the STEM disciplines because of poor performance” (Phelan et al., 2017, p. 65). Phelan et al. (2017) further claim that:

> Adequate exposure to science content and the excitement of scientific inquiry throughout

> the high school years are important factors in attracting students into the sciences and ensuring the success and retention of these students in STEM (science, technology, engineering, and math) in and after college. (p. 65)

Programs designed to make science learning fun and accessible can help guide female students onto STEM pathways (Phelan et al., 2017).

Offering an alternate viewpoint, Gagnon and Sandoval (2020) contend that these STEM summer camp experiences have less of an impact than previously reported. Their study concedes that STEM summer camps enhance female students' views of STEM careers but adds that they impact male students' career choices even more (Gagnon & Sandoval, 2020). There is "no significant direct effect of camper gender on career decidedness" (Gagnon & Sandoval, 2020, p. 6). Gagnon and Sandoval (2020) reported that the lack of effect could be attributed to the abundance of alternative programs aimed at developing STEM skills in females, which makes it difficult to determine which program is generating the effect.

Conclusion

Female students abandon their initial interest in STEM careers due to a plethora of factors ranging from biological to sociocultural (Avendano et al., 2019; Bottia et al., 2015; Ceci et al., 2009; Sadolikar, 2019). High school teachers have the opportunity to engage and inspire young female students to resist these factors and to pursue careers in STEM disciplines (Beier et al., 2019). Research has demonstrated that the use of authentic learning techniques (Leatherman and Miecznikowski, 2012) within an immersive environment (Heidi & Neo, 2015) can help steer female students into the sciences (Harper-Leatherman & Miecznikowski, 2012; Levine et al., 2015; Levine & DiScenza, 2018; Phelan et al., 2017). This study examines undergraduate female students' perspectives of their STEM career choices as they encounter and overcome obstacles throughout their educational journeys. The next chapter discusses the methodology adopted for this study.

CHAPTER 3: METHODOLOGY

This research study used a qualitative case study research design, drawing data from one-on-one virtual interviews with female STEM undergraduate students. According to Creswell and Guetterman (2019), this type of research design can provide general and detailed information about a research question.

This study used one-on-one virtual interviews with questions designed to assess the way female undergraduate students chose their STEM major, the obstacles faced by female STEM students as they made their STEM major choices, and how they overcame those obstacles. These answers enabled me to understand how female STEM students constructed their science identities. This study was conducted using participants recruited through social media during the fall semester of the 2021–2022 academic year. Data collection was completed in late December 2021. Data analysis was completed by early January 2022, and this dissertation was completed in February, 2022.

Purpose of the Proposed Study

The purpose of this study was to examine and describe the way female STEM undergraduate students chose STEM careers, the obstacles they encountered while making that choice, and the way overcoming those obstacles impacted their science identities. This study employed Mezirow's (1978) TLT model as the conceptual framework and Carlone and Johnson's (2007) science identity model as the theoretical framework to examine how female students arrived at their career choice. A qualitative case study research design was utilized to answer the study's research questions. Insights gained may be translated into pedagogic, instructional, or relational changes that high school science teachers and undergraduate STEM professors could implement to improve the retention of female students in STEM pathways.

Research Questions

Using Mezirow's (1978) TLT model, and Carlone and Johnson's (2007) science identity model, this study examined the following research questions:

RQ1. Why do female STEM undergraduate students choose to pursue STEM majors?

RQ2. What obstacles do they face as they make their STEM major choices?

RQ3. How do female students overcome these obstacles?

These research questions were examined through virtual one-on-one interviews with female STEM undergraduate majors recruited through social media.

Study Setting

The study's setting includes information about the specific site chosen for the study and the study participants. In order to represent undergraduate STEM students, participants were selected from a variety of physical and natural science majors, as well as engineering and math majors. They had all attended not only courses specific to their own majors but also those that were required for students in other majors.

Site

For this study, participants were recruited through social media. This methodology was chosen to reduce the impact of COVID pandemic restrictions on recruitment efforts. Though no brick-and-mortar site was used, the participants represented an array of private and public undergraduate colleges from around the United States, Mexico, and Ukraine.

Student participants were assigned a pseudonym. There were no one-on-one in-person interactions with the students, and interviews were conducted virtually with audio being recorded. Participation was voluntary, and students were allowed to withdraw at any time. I complied with all university internal review board's (IRB) policies and procedures. This research was conducted under the supervision and direction of a committee of professors who ensured compliance with confidentiality and anonymity requirements and ethical standards.

Participants

The target population for this study was female undergraduate STEM students who were above the age of 18. Criteria for selection of participants included: (1) willingness to participate in virtual interviews, (2) current full-time female undergraduate STEM students at a college or university, enrolled in a science course, (3) intention to complete at least a four-year STEM degree at the University. Only participants who identify themselves as female were selected.

I estimated that this study would need from six to twelve participants, which was in line with Dworkin (2012) who recommends a sample size of five to 50 participants for qualitative case study research designs. Only five participants volunteered for this study due to COVID-19 pandemic restrictions.

Sampling Methods

This study employed a qualitative case study research design. Sampling began upon approval for an IRB waiver, which assured compliance with all ethical and institutional standards, without requiring a full IRB-approved application. The researcher contacted each female STEM undergraduate student (who responded to the social media recruitment posts) individually by email to discuss the goals of this study. Had more than twelve students responded to the social media recruitment posts, only the first twelve students would be allowed to participate. All study participants were required to acknowledge they had read and understood this study's information sheet. This set of participants was representative of the female STEM undergraduate population. Participants were scheduled for a 60-to-90-minute virtual interviews. There was no subsampling: data from all participants was used.

Data Collection

This qualitative case study collected qualitative data related to how female students choose their STEM careers, the obstacles they faced in making that decision, and how they overcame their obstacles. Students were recruited by social media. Participants were provided the study's written overview and an information sheet by email if they opted into the study. At the beginning of each virtual interview, verbal agreement with the terms of the information sheet was verified. Students under 18 years of age were not allowed to participate.

I initially communicated with participants by email to screen out any underage respondents and others not meeting the requirements for study inclusion. One-on-one virtual meetings were scheduled, at which time I discussed the study, the information sheet, and obtained verbal consent from the participants for audio recording.

Each interview followed a semi-structured format using interview questions (Appendix A) designed to achieve a deeper understanding of the research questions. Participants were given the option to terminate the interview at any time, and for any reason. Each interview was expected to last between 60 and90 minutes. Interview questions were primarily open-ended, offering the participant the opportunity to expound on their responses. Participants were interviewed virtually one-on-one and audio of all interviews was recorded. This qualitative data set was transcribed by Otter.ai and coded by using Atlas.Ti® into themes that fit the research questions. Themes were selected to reflect how female STEM undergraduate students relate to and identify with science, their comfort with using the scientific process, factors influencing their academic decisions, as well as the resources they used throughout that process. All identifying information was removed. A participant number was used for all quotations that were cited. No personally identifiable information was collected or retained by me.

Data Analysis

Interview data were transcribed by Otter.ai and coded using Atlas.Ti® to provide a basis for claims to be made in a broader context (Schram, 2003). Data were coded into themes related to how students relate to science, where they see themselves in the context of science, their comfort with the scientific process, as well as the factors that influence their future academic choices. These themes were chosen after reviewing interview transcripts to ensure they align with the data and to reduce researcher bias. Bloomberg (2008) discussed how this type of analysis ensures the transferability of results to other contexts and settings. This analysis provided insight into all three research questions. I applied Mezirow's (1978) TLT process to describe students' changed perspectives after looking at the questions interspersed throughout relating to transformations in the way students thought about themselves in STEM settings, and how those thoughts changed considering what obstacles they encountered in their STEM education.

The analysis consisted of compiling the interview data and looking for patterns and themes that might have emerged. An inductive analysis was used to identify each participant's experiences. Inductive analysis condenses raw data into a summary format, establishes clear and defensible links between summary findings and research objectives, and allowed me to develop a model based on the experiences of the participants (Thomas, 2006).

All participants had an opportunity to review their interview transcripts as a member check to assure accuracy and completeness of their responses. Transcripts of each interview were then reviewed to identify observable patterns in responses and to determine any emerging themes in the interview responses. Identified themes were then used as the basis for coding the data using Atlas.Ti® R and themes were correlated using tables or matrices for providing clarification and analyzing the coded data. Conclusions are based on the raw transcripts, themes derived by coding, and rich descriptions of study findings.

Limitations

No study is impervious to limitations. Limitations included weaknesses identified before the study began, over which some caution could be exercised, and weaknesses that arose throughout the study that the researcher needed to address before making conclusions (Creswell & Guetterman, 2019). Two key limitations could have impacted this study. The first limitation pertained to the sample size of participating students. This study examined interview data from among participants recruited through social media. The number of program participants was therefore limited, which made it difficult to extrapolate qualitative data to the entire population. However, no subsampling was performed to reduce the impact of this limitation. All participants' data were included.

The second limitation stemed from conducting interviews virtually. Virtual meeting tools such as Skype, Zoom, or Teams tended to show participants from the shoulders up, as a result of which many important nonverbal communication elements may have been lost. Nonverbal cues are often vital in achieving a rich understanding of interview subjects and can often be at odds with what is being verbalized during the interview. Only audio was recorded, so information related to nonverbal responses to interview questions could have been lost.

These limitations were reduced, and the study methodology was adjusted to account for them. There was no previous relationships with study participants, nor any other stakeholders. There were no undisclosed researcher biases or other conflicts of interest.

Data Credibility, Dependability, and Transferability

This study involved the collection of qualitative data. Bloomberg and Volpe (2019) suggest that to ensure internal and external validity, quantitative data needs to be examined as well. Creswell and Guetterman (2019) suggest that qualitative data also needs to be examined for dependability and transferability. Credibility refers to trustworthiness. Dependability refers to reliability. Transferability refers to applicability. All three principles are essential in a qualitative research study (Creswell & Guetterman, 2019).

Qualitative Data

Credibility was assured by following the interview protocol for all participants, accurately reporting all data collected, and accurately reporting all study findings (Creswell & Guetterman, 2019). Study findings underwent a triangulation process, which improved the trustworthiness of data. This study employed member checking and a rich description of my conclusions to demonstrate how the data converge, and to allow me to draw conclusions from the data (Bloomberg & Volpe, 2019). I maintained transparency to improve data trustworthiness. Interview questions were designed to correlate directly to this study's research questions. To verify the interview questions aligned to this study's research questions, I tested the interview protocol on others who would not be selected as participants for this study. Questions that did not map to one of the study's research questions were changed or omitted.

Dependability was assured by peer review. Study findings were shared with at least one peer who would not be a participant in this study. That individual reviewed the findings and anonymous supporting data and offered suggestions to improve dependability.

Transferability was assured by including detailed information about interview questions, descriptions of the study site and student population, and a vivid description of interview responses and the coding process. Detailed information about the interview protocol is included in the appendices.

Participant Rights and Ethical Concerns

All research participants have the right to be treated ethically. That right is inclusive of a reasonable expectation of anonymity and confidentiality (Bloomberg & Volpe, 2019). Participation was voluntary, and participants were given the option of opting out of this research study without any penalty. Participants were informed that their participation would be entirely voluntary and that they may withdraw their consent at any time, and for any reason. Students who chose to participate in this study verbally acknowledged understanding the information sheet that included a statement of the study being done, a description of the foreseeable risks involved, details of any benefits they would receive, a detailed elucidation of how their anonymity and confidentiality would be maintained, my full contact information, an explanation of their rights, as well as a statement that participation is entirely voluntary (Health and Human Services, 45 C.F.R. § 46.116(a), 2018; Roberts & Hyatt, 2019).

Anonymity was assured throughout this study. Participants were interviewed virtually, and audio was recorded. No personally identifiable data, such as name, age, date of birth, or contact information was collected from participants. Bulk demographic data was observed without identifying any students. Interview responses were screened to remove any identifiable information. Confidentiality was assured by assigning a non-ethnocentric pseudonym or participation number to all interview subjects. Interview recordings were secured to protect participant information, and no information about any research subject was accessed, used, disclosed, or modified without seeking the written consent of the participants. Any perceived or actual conflicts of interest would immediately be discussed with my study advisors. It is also pertinent to point out that I have no supervisory role over any study participants and there are no power differential issues and no opportunity for coercion.

Researcher and Participant Bias

There is an inherent bias among participants in undergraduate STEM classes as students largely and voluntarily choose to enroll, a process that favors students who already have a positive view of STEM disciplines or an intention to explore or pursue a STEM-based career. Therefore, students from a wide range of STEM programs were allowed to participate such that they had a wide range of dispositions toward STEM careers, capturing students who were taking STEM courses because they are mandatory for another program, as well as those that are in line with participants' programs of study. While student participants were aware of the broad goals of this research study, their responses to interview questions were designed to reduce bias among study subjects. Interview questions were probing, to assess participants' thoughts and feelings related to science. These were less susceptible to bias on the part of study participants.

The largest potential source of bias would be in the analysis and interpretation of the study data. I came from a background in STEM and have significant personal experiences with female family members' struggles with STEM engagement. To that end, I employed bracketing. Bracketing refers to a process wherein researchers set aside their own personal biases to prevent those biases from influencing the data. This requires that I use self-reflection, examining my own perspectives, beliefs, and thoughts (Creswell & Guetterman, 2019). I sincerely hoped to find ways that female students could overcome their obstacles, remain engaged in STEM pursuits, and reduce the gender gap. However, I believed that the study methods employed here would reduce or eliminate that bias.

I was not personally or professionally involved with any study participants. In addition, no power differential existed between me and any participants. Interview questions were identical among participants to avoid leading or effectively coercing their responses. I attempted to follow up with each participant whenever there was a need for clarification.

Summary

This qualitative case study used one-on-one virtual interviews with questions designed to assess the impact of high school teachers on students pursuing a STEM career, and participants' thoughts, feelings, and relationship to science. All study data were collected, analyzed, and retained with constant consideration of individual participants' ethical rights, including a right to anonymity and confidentiality. The study was conducted in a manner that reduced the impacts of its research limitations, my own biases, and the biases of participants. Study guidelines were in place to protect the subjects from conflicts of interest and coercion.

A pronounced gender gap exists in undergraduate STEM admissions both in the United States and throughout the world (Buccheri et al., 2011; Viadero, 2009). This gender gap is a consequence of many internal and external causes (Bottia et al., 2015; Cabay et al., 2018; Ceci et al., 2009). This study attempted to describe how female students decided to pursue STEM majors, the obstacles they faced when making that decision, and how they overcame those obstacles. I intended to use the insights derived throughout this study to highlight the mechanisms and supports that female STEM students used to overcome the many obstacles they faced while navigating through their academic and career choices.

CHAPTER 4: RESULTS

The purpose of this study was to describe how female STEM students choose their undergraduate major, the obstacles they face when making that choice, and how they overcome gender-based obstacles. Participant descriptions and answers to these questions shed light on how they developed their science identity and the resources they depended upon while doing so. This study employed a qualitative case study research design and used Carlone and Johnson's (2007) science identity model to elucidate the way in which female STEM students made their academic choices, how they faced obstacles along the way, and the ways they overcame those obstacles.

The following three research questions were addressed:

RQ1. Why do female STEM undergraduate students choose to pursue STEM majors?

RQ2. What obstacles do they face as they make their STEM major choices?

RQ3. How do they overcome these obstacles?

These three research questions were examined through semi-structured virtual interviews with female undergraduate STEM students.

I employed a heuristic approach to data content analysis using a hybrid coding technique, following a conceptual and thematic scheme. Drawing on elements from the literature review and the conceptual and theoretical frameworks, data were coded first using a deductive (top-down) process. Then, data were coded using an inductive (bottom-up) process, drawing from elements of the interviews themselves. This combined coding process is referred to as hybrid coding (Swann, 2020). Hybrid coding afforded me the tools necessary to test the applicability of both conceptual and theoretical frameworks, while also identifying and analyzing concepts drawn directly from the data.

Analysis Method

Rather than using pseudonyms, participants who met the criteria for inclusion detailed in Chapter three were assigned a participant number to avoid the problem of selecting suitable, race-neutral names. All identifying information was stripped from the data immediately after each interview was completed. Audio of each interview was processed using Otter.ai ® to generate a transcript. No video was recorded. Before data were coded, transcripts of each interview were emailed to the participant for review as a member check.

A coding scheme was developed following the conceptual content analysis process outlined by Swann (2020). This thematic approach quantified the frequency of coded themes. A mixture of deductive and inductive schemes, referred to as a hybrid scheme, was used as it enabled the research questions, and the theoretical and conceptual framework to drive initial coding while also allowing the data to determine some coding. Atlas.TI ® was used for coding.

Groups were defined based on gender disparity, interventions used in addressing gender disparity, the TLT (Mezirow, 1978) conceptual framework, Carlone and Johnson's (2007) science identity model as the theoretical framework, and all three research questions of the study. Codes' definition was based on themes of the literature review, the research questions, the theoretical and conceptual frameworks, and the interviews themselves. These codes were associated with their appropriate group in Atlas.TI ®.

After coding, salient examples of each group and code were chosen from the interview transcripts. Given that this was a qualitative study, not a lot of statistical analysis was performed. Rather, a frequency was noted for each group and code. Code groups and codes were defined according to Table 1. This heuristic coding provided an objective framework to analyze the data, ensuring the analysis was performed repeatably.

Table 1

Groups and Coding Scheme

Group	Code	Frequency
Biological Basis for Gender Disparity	Gender Bias	10
	Microaggressions	4
	Safety	8
Educational Basis for Gender Disparity	Sexual Harassment	6
	Limited Access to STEM	5
	Unequal Attention	11
Sociocultural Basis for Gender Disparity	Appreciation for and Relationship to Science	7
	Availability of Supports	31
	Confidence and Knowledge	13
	Family and Peer Involvement	37
	Interests, Motivations, and Attitudes	36
	Outside Influences	23
	Science Ability	12
	Self-Concept	27
	Social and Life Orientation	16
	STEM Perceptions	3
	Stereotypes	4
	Thoughts and Feelings about STEM	14
Interventions	Female Role Models	14
	Mentorship	15
	Opportunities for Research	3
	STEM Programs	4
TLT	Transformed Frame of Reference	13
Science Identity Model	Competence Factors	12
	Performance Factors	10
	Recognition Factors	16

Presentation of Results and Findings

Only five participants were successfully recruited via social media, a situation exacerbated by the COVID-19 pandemic in December 2021. The pool of participants represented a broad cross-section of female STEM majors, comprising two traditional students, and three non-traditional students. Two participants were students who began their STEM journeys in other countries, specifically from Mexico and Ukraine. One participant began a family before attending college. Study data were collected during approximately 60-minute virtual interviews with each participant. Each participant was allowed to review their transcript as a member-check before their data was coded and analyzed through the lens of Carlone and Johnson's (2007) science identity model and TLT (Mezirow, 1978). A follow-up discussion was conducted with three participants to get clarification on some of their interview responses.

Coding

Table 1 describes the coding used for this study. After the participants completed the member check, the transcript of each interview was imported into Atlas.TI ®. The grouping and coding scheme was entered using a hybrid approach, drawing from elements of the literature review for the basis of gender disparity in STEM, successful interventions to overcome gender disparity, the conceptual and theoretical frameworks, as well as the study's three research questions. Once themes were defined, each transcript was reviewed and coded using the developed groups and codes.

Organization

Codes were assigned into groups, after which each transcript was reviewed to extract important content related to each of the groups and codes, referred to by themes. Quotations in support of each group and code are presented together with the frequency that corresponded to a component of Carlone and Johnson's (2007) science identity model mentioned in Table 1.

Interpretation

The science identity model (Carlone & Johnson, 2007) and TLT (Mezirow, 1978) were used to guide the interpretation process. Data were organized first by participants' responses related to the basis of gender disparity in STEM. This data was viewed through the science identity model (Carlone & Johnson, 2007) lens to explore the way in which each impacted the participants' sense of competence, performance, and recognition. Then, the same data organization was examined through the TLT (Mezirow, 1978) lens to assess whether that theory explained the participants' learning process.

Interventions used to overcome gender disparity in STEM were similarly examined, organizing the data by intervention, and viewing it first using the science identity model (Carlone & Johnson, 2007) then using TLT (Mezirow, 1978). Finally, data were organized using Carlone and Johnson's (2007) science identity model and examining co-occurrence with the five salient science identity types (Dwyer et al., 2020). I could avoid the biases discussed in Chapter 3 by adopting this heuristic approach.

Presentation of Results

Here, the data are presented by groups and codes (the themes) emerging through the data analysis and interpretation process. The group structure is organized in the following manner: (a) Biological Basis for Gender Disparity, (b) Educational Basis for Gender Disparity, (c) Sociocultural Basis for Gender Disparity, (d) Competence Factors, (e) Performance Factors, and (f) Recognition Factors.

Participants

Five participants met the selection criteria for inclusion in this study. Before the recorded interview, I took some time to discuss each participant's background to get to know them a little better. Having begun a family before attending college and returning as an older student, one participant self-identified as a non-traditional student. Two participants attended primary school outside the United States, one in Mexico, one in Ukraine. The remaining two are traditional students, transitioning directly from high school to college without a gap year.

Participant 1

Participant 1 identified as a traditional student, attending a community college directly after high school graduation. She lived with her parents to reduce her living expenses and educational costs. After graduating from community college, she began attending a private four-year college while still living with her parents. As a commuter student, she is not an active participant in many extra-curricular activities. She also admits to having few close colleagues at her college, primarily relying on her friends from high school and community college to be her peer supports. When asked why she was drawn to the sciences, she replied "I like to feel that science has more practical applications. And it [allows me to] deals with more people." This participant was available for a follow-up discussion to clarify some of her interview responses.

Participant 2

Participant 2 identified as a non-traditional student. She began a family after high school, and her son was a toddler when she went back to college. While in school, she had very little support. Her family provided her with minimal assistance. She bitterly reminisced about borrowing money from her father for books during her first semester and receiving incremental debt forgiveness each birthday and Christmas, rather than gifts, until the debt was entirely repaid. Being a single parent made things challenging for her, and issues related to childcare, food insecurity, unreliable transportation, and a general lack of support often took her attention away from her studies. Despite these impediments, she graduated from a community college.

However, this took her three years instead of two. She transferred to a public four-year college, where her obstacles persisted. Her peer group consisted of several other non-traditional students who actively worked together. When asked why she was drawn to the sciences, she replied “I've always been interested in how things work. I guess just natural curiosity led me to the sciences.” This participant was available for a follow-up discussion to clarify some of her interview responses.

Participant 3

Participant 3 identified as a traditional student. She attended a boarding-style high school in Ukraine, where she lived in a dorm environment away from her family. The separation made it difficult for her to return home often, but she did maintain a strong relationship with her parents and her older brother through social media. Other than specific examples where she drew on her brother for support, her support system primarily comprised her peer group. She had the advantage of UNICEF [formerly the United Nations International Children’s Emergency Fund, now the United Nations Children’s Fund] and other adult mentors at her boarding school. She had applied to several private four-year colleges in the United States and was accepted to two of them. Since her family’s financial resources were minimal, her choice of college was a function that could offer her the best financial aid package. When asked why she was drawn to the sciences, she replied “I used to have a good base knowledge level for math classes and I kind of liked all the STEM classes since high school. So, I decided to go with it.” This participant was available for a follow-up discussion to clarify some of her interview responses.

Participant 4

Participant 4 identified as a traditional student. After high school, she went directly to a public four-year college. She commutes, living at home with her parents and younger brother.

Commuting made it difficult for her to build and maintain a strong sense of belonging to her peer group. She also admits to often working alone. Participant 4 seemed averse to an idle discussion, and much of her identity was drawn directly from her responses to interview questions. When asked why she was drawn to the sciences, she replied “Because I've always liked science and I just wanted to keep pursuing that.” This participant was unavailable for follow-up after the initial interview.

Participant 5

Participant 5 identified as a traditional student. She attended high school in Mexico and began college near her hometown. At that time, she was a commuter student, living at home to save money. Despite being a commuter, she maintained a strong social network of friends and peers, most of whom provided academic and emotional support to her. She entered the United States to continue her education and currently attends a public four-year college. She got married while still in college and is helping to raise two stepchildren. When asked why she was drawn to the sciences, she replied “Because I wanted to be in the sciences and specifically the environmental area and I found that major as an opportunity to pursue my dreams.” This participant was unavailable for follow-up after the initial interview.

Biological Basis for Gender Disparity

Biological causes for gender disparity specifically refer to differences in how students are treated based on their physiological differences. These were coded into four themes: gender bias, microaggressions, safety, and sexual harassment. Coding based on these themes was derived from the literature review.

Gender Bias

Four of the participants reported experiencing some form of gender bias from their teachers. This bias took many forms, including favoritism, overt and covert sexism, differences in class treatment and grading, fewer opportunities for participation, as well as sexual comments and jokes. When asked if she had experienced negative situations in class, participant 1 stated, "I think so. I mean, I mentioned my one teacher in elementary school, and he definitely picked favorites in regards to gender, he had certain things that he wouldn't let the women in the class do."

When asked if she could provide specific examples of negative situations in class, participant 2 replied:

> I had a study partner that we studied together with and we're in the same class. And I went to my teacher with both our tests and said, Here's mine. Here's his. We answered the same way. But he got 20 points for the question, and I got five. And I asked him why the discrepancy? And he told me that I was a woman in a man's field and that more would always be expected of me so that I should be prepared for that.

Participant 3 was a bit vague, as she only stated that "I definitely know of a lot of biases related to women and STEM for a fact," and "my physics teacher was biased [about] women in STEM." After being asked if she had experienced examples of negative situations in class, participant 5 said,

> Ah, yes, I have a few teachers that would be a little bit sexist in the aspect of making comments that would be out of place just because I was a woman. They would give more chances or I would feel that like other of my classmates would have more opportunities on participating just because of their gender.

Microaggressions

All five participants reported experiencing microaggressions or constantly anticipating microaggressions due to their gender. Upon being asked to explain, participant 3 replied that "[I] was the only girl pursuing computer science my first year of school … however, I also had like a lot of support, so it canceled it out kind of." Notably, she did not explicitly encounter microaggressions, but anticipated issues related to being the only female in her class and built a peer group to support her through it. When asked the same question, participant 1 replied:

> When I used the computer lab at my college, sometimes I would have computer troubles. I feel like the attending staff treated me less than sympathetically. Like, these are problems that they think I should easily be able to solve. And I think that they're a bit condescending about it.

Participant 4, meanwhile pointed out that anticipating microaggressions was "always in the back of my mind." Microaggressions were in verbal form for participant 5. She said, "[Teachers] made comments that would be out of place just because I was a woman."

Safety

Four of the participants reported feeling some degree of vulnerability due to their gender. When participant 4 was asked if she felt unsafe in her classes, she replied without giving specifics, "Yes, and no. I felt safe because nothing's ever happened to me, but I know that something could, it's not out of the ordinary for something like that to happen."

Participant 5 went so far as to change majors due to safety concerns. When asked to explain, she stated "Well, one of it was security, I could say that was one of the reasons I didn't decide to go to engineering, environmental engineering. And that was for security reasons. And that would be one because as a woman I would be more susceptible in that area specifically."

Attending her first-choice college implied that she would have to live alone, not only in a different state in Mexico, but in a “not so nice area.”

Participant 3 reported, “In terms of safety, yeah, it wasn’t only the discrimination going on in classes. I wasn’t in any kind of danger, but it’s always a possibility.” Participant 1 was vague when replying to questions about safety, stating “I don’t feel exactly vulnerable, but I don’t feel exactly safe.”

Sexual Harassment

Three participants reported anticipating or experiencing sexual harassment at school. Participant 5 endured the most, stating “Just as in when I was in college, in high school, there were also a couple of teachers that would make comments that would be uncomfortable. They would like, touch the girls in an appropriate way, or make sexist jokes in the classroom.” Participant 4 stated, “So it's always in the back of my mind.” When asked if she referred to discrimination or sexual harassment, she stated “Both.” She did not provide specific examples or elaborate further. Participant 2 reported “In high school, I wore a skirt, like a mini-skirt or whatever, that came above the knees. And, I had on a cardigan that had like some type of airborne type of insignia, and I had a teacher comment that airborne is looking better every day.” This statement made her feel uncomfortable because it was a teacher that she admired. She added that she did not wear that outfit again.

Biological and physiological differences are not the only basis for gender disparity. Female students also need to take educational differences into consideration.

Educational Basis for Gender Disparity

Educational causes for gender disparity specifically refer to differences in how students are treated in the classroom or in the school based on their gender. These were coded into two themes: limited access to STEM, and unequal attention. Coding based on these themes was derived from the literature review.

Limited Access to Science, Technology, Engineering, Mathematics

Only two participants reported experiencing limited access to STEM in high school. After being asked what resources or supports female STEM students need in high school, participant 3 replied:

> They definitely need a powerful community, a lot of support, and a lot of information about all the things they could participate in. Because a lot of girls at a young age are not aware of all the openings they could have. And I feel like it really helped me to … like some kind of more STEM environment.

Participant 5 said, "I think that it would be helpful to have more programs that involve stem in high school and maybe besides programs … like a contest [related to the] real world so people would seem motivated to participate also, maybe more scholarships available for stems students."

Unequal Attention

Four participants stated that they received unequal attention from STEM teachers and staff. Participant 1 reported, "I did have a few teachers who definitely picked favorites in some regards." Participant 2 said, "I never had a female teacher in the sciences. And as I got further along in chemistry compared to my male peers, it seemed like I got lower grades, despite studying together and answering similarly on tests." When asked how many of her teachers provided unequal attention, participant 5 replied, “I would say most of them but not all of them.” Participant 4 also stated, “In the specialist STEM classes, [teachers] will pay a little bit more attention to boys and focus more on boys.”

Sociocultural differences are another source of disparity in STEM. Therefore, in addition to biological and physiological differences, and educational differences, female students need to consider their overall environment.

Sociocultural Basis for Gender Disparity

Sociocultural causes for gender disparity specifically refer to differences in how students see themselves, and how they relate to others in the classroom, in the school, as well as in their communities based on their gender. These were coded into twelve themes: appreciation for and relationship to science, availability of supports, confidence, and knowledge, family and peer involvement, interests, motivations, and attitudes, outside influences, science ability, self-concept, social and life orientation, STEM perceptions, stereotypes, and thoughts and feelings about STEM. Coding based on these themes was derived from the literature review.

Appreciation For and Relationship to Science

All five participants reported having an appreciation and positive relationship to science. Despite the change in her choice of major change, participant 1 stated, “When I was younger, I was interested in a different STEM field. I was interested in veterinary medicine, but I guess as I got older, I decided I wanted to go into [a different STEM field] instead.” She went on to say:

> I had a lot of people tell me that it wasn’t really a field I’d be able to go into, because I’d have to do things that people thought I wouldn’t be able to do like, for it to be even possible I’d have to, like do dissections and stuff. And a lot of people thought I wouldn’t be able to do that sort of thing. And I guess that kind of dissuaded me a bit.

Participant 2 remarked, "I've always been interested in how things work. And I guess just natural curiosity led me to the sciences. I enjoyed earth science. I enjoyed physics, I enjoyed chemistry and biology." Participant 3 said, "[I've always wanted to be] some kind of software developer or work with artificial intelligence or machine learning." Participant 4 stated, "I've always liked science, like science in high school, and I just wanted to keep pursuing that." Participant 5 pointed out, "Because I wanted to be in the science and specifically the environmental area and I found that major as an opportunity to pursue my dreams."

Availability of Supports

Availability of supports was found to play an enormous role in all five participants. When asked how she overcame impediments in her STEM classes, participant 1 stated, "I had people in my life, mostly my parents who were especially encouraging and willing to help me through it." Participant 2 had more support from her teachers than her friends, stating:

> I had a discussion with my organic chemistry teacher in the first semester of organic chemistry, and I did really well. And he said … that I should consider majoring in chemistry, or paper science and not biology. I didn't really discuss it much with my friends. They were neither supportive nor unsupportive.

Participant 2 also highlighted the lack of support she had to deal with during the early phases of her college experience, stating:

> Since I'm a non-traditional student, I didn't feel like most of it was assessable to me, because I commuted to class and would leave shortly after my last class to get back home because I have my son to take care of. So, I didn't get to participate in the college community.

Participant 3 used participation in competitions as her supports, stating "I was participating [in] the Mathematical Olympiad contest, and then moved on to computer science and started participating more in computer science contests." Participant 4 expressed the difficulty in finding support, noting that "You have to seek that out yourself."

Participant 5 used family, teachers, and friends as her supports, stating "I just try to I guess meet with my friends and be able to study together. So, it wouldn't feel that it was a burden to study but I was able to study with someone else." She goes on to explain her mixed supports:

> [My family] helped me get the certain requirements for studying science, like books or helped me, my parents and my uncle helped me to buy a computer that had enough power to run some of the systems that we would use on school and, and I guess just supportive when it came to starting late or like, I don't know, food, stuff like that.

Participant 5 gave the following reply when she was asked to elaborate on how someone was particularly supportive of her interest in STEM:

> [A teacher] was very, very supportive and gave me examples and told me how I did the certain environmental science and after like, I could do a chemistry environmental chemistry Master['s] degree. So, she explained to me what because she was a teacher in the environmental chemistry master's degree. So, she would like encourage me to continue.

Confidence and Knowledge

Each participant expressed some degree of confidence and knowledge in their respective fields. Participant 1 reported that her confidence was shaken when teachers and peers told her that STEM would not be a good fit for her. On the other hand, participant 2 reported, "I was always good at math, but it was never a particular favorite. But I was always interested in the sciences. I was very curious as to wanting to understand how things worked." Participant 3 leveraged her network of peers to develop confidence. She said, "I started reaching out to people more and started, like collecting some kind of network of people I can talk to if I have some kind of issues." Participant 4 exhibited some self-doubt, stating "I don't think I naturally excel in anything at this point. I'm just chugging along." Participant 5 viewed the real-life applications she found in her chosen field as opportunities to make a difference, gaining more knowledge and confidence by working as an intern at a company "involved in the conservation of endemic species in Mexico."

Family and Peer Involvement

Family and peer involvement emerged as a very important theme in all the interviews, and all participants reported both needing and receiving supports, especially from family. After being asked who she considered most important in helping her choose a STEM major, participant 1 replied "My parents, I think I also had a few friends who were going into STEM fields themselves. So I guess that's what pushed me to want to go into a STEM field." Participant 2 expounded on her parents' involvement, stating:

> Well, my mom was somewhat of an influence because she worked at a landfill in our county, and she saw a lot of waste and knew of the testing happening and the pollution that was present there. And being a part of the county government she often knew some of the politics behind what was happening at the landfill. So, it really made me want to help the environment. [My parents] were supportive of me going to college and my original major they understood and supported me. They were a little surprised when I

went off into chemistry because neither of them had a background or understood chemistry.

Participant 3 singled out her brother as being particularly involved. She stated:

> Back in high school in Ukraine, I only had a couple of teachers who were encouraged and asked me to participate in contests. And maybe my peers who were creating this same competitive environment, which kind of makes you want to learn more things. But there's my brother who mentored me, and then several programs, but not in the school itself.

When asked about her biggest STEM influences, participant 4 replied "I guess my parents because they both are working in STEM and life sciences, so I guess they influenced me to sort of going down that path." Participant 5 cited instances of positive as well as negative family and peer involvement, stating:

> [My parents] would seem interested in whatever I was talking to them about my major and then they were like, yeah, just I guess seem supportive in whatever I would like to tell them if I was struggling or something. [But] my boyfriend would try to tell me not to go to school. So, we can like go party or somewhere else.

Interests, Motivations, and Attitudes

Interests, motivations, and attitudes played a huge role in all five interviews. When asked about the career in STEM she wanted to pursue, participant 1 said, "I guess if I had to pick an ideal, it would be something that would have more of a practical application helping people … something where I can use myself to help people." Participant 2 stated, "I was always interested in the sciences. I was very curious as to wanting to understand how things worked." Meanwhile, participant 3 used her interests to create a network of supports, stating "I started reaching out to people more and started, like collecting some kind of network to who I can talk if I have some kind of issues." On the other hand, participant 4 stated, "I just really like working in a lab. It doesn't really matter where, whether it's like, I don't know, a pharmaceutical company or like just more academia I guess I just rather be in a lab." Participant 5 said that the followed her heart, stating, "I wanted to be in the science and specifically the environmental area and I found that major as an opportunity to pursue my dreams."

Outside Influences

All participants experienced both positive and negative outside influences in forming their career goals. Participant 1 explained the mixed influence of her friends:

> I mean, with my friends, I've definitely had some pretty long-form talks about, you know, what I feel like I should do in terms of like a future career college majors. And it's mostly questioning if, you know, that's really what I want to do.

Highlighting the positive influences of some of her teachers, participant 2 said, "There were a few teachers in high school and in college that made me go down this path." Participant 3 said that "one of the UNICEF programs that provided a mentor … [and another] mentor from Ukraine global scholars" as positive influences. Meanwhile, participant 4 pointed out graduate students teaching assistants, some of whom were positive and some of whom were negative. Participant 5 was inspired by "Mario Molina, [a famous] Mexican [Nobel Prize winning chemist]. I don't have anyone else in my mind."

Science Ability

Four participants reported situations that highlighted their science ability and made them question their science ability. Participant 1 reported mixed feelings about her science ability saying, "I think I would rate myself fairly average. I don't think I'm particularly good. But I don't think I'm bad. I'd say maybe around average, if not a little bit, above average." In this regard, participant 2 stated, "I know in high school chemistry, I did well and enjoyed that. And early on, I was identified as being above average in the science area and was encouraged to pursue courses in science and math and technology." Here, she refers to her own self-identified science ability, and that identified by teachers or counselors in her school. Both seemed to play an important part in her perceived science ability. When asked why she had changed her major, participant 4 replied, "Calculus. I don't like calculus at all. So, I changed [my major] so I didn't have to do higher-level math." Her inability to master calculus led her to pursue a different career field. Participant 3 emphasized her math ability as a reason to "go with it."

Self-Concept

Participants' self-concept, or how they saw themselves in the context of STEM, emerged as an important theme throughout all interviews. That is exemplified in the statements of participant 2:

> At one point, I almost quit school. I had a bad semester and [I] was dismissed. But I had to appeal the decision. And I thought of my son, and how important it was to continue and finish. Because when he goes to college, he needed to see that I didn't just quit.

When asked why she likes her current science and math classes, participant 3 replied "It brings a lot of joy to being able to solve problems. And like some kind of academic, fulfilled mentality." To help her improve her self-concept, participant 5 said "I try not to listen to what could go wrong and how difficult it could believe in myself setting goals." Participant 1 said that people attempted to shake her self-concept, stating "I've had people tell me that my field isn't like a real science and like they don't recognize that it should be treated as a STEM career."

Participant 4 credits her competitive environment in school for improving her self-concept, stating, “Since it was kind of competitive environment in class [it was] really nice for learning.”

Social and Life Orientation

Four participants were found to exhibit strong social and life orientation. This concept refers to how participants plan to relate their educational journeys to their future lives, as well as how they envision their science identity in the future. Participant 1 emphasized her desire to help others:

> If I had to pick an ideal [career], it would be something that would have more of a practical application helping people sort of things so I guess I would be maybe like an I’d be like a doctor like a psychologist. Something where I can use myself to help people.

Both participants 2 and 5 expressed an interest in helping the environment. Participant 2 stated, “I’d like to be a chemist. And if I can do that in a capacity that helps the environment that would be ideal.” Participant 5 remarked, “I have been always interested in recycling and like, give like another way to modify energy in objects.” Participant 3 did not remember a time when she identified with any career other than STEM, stating “I always knew I wanted to major in computer science in college.”

STEM Perceptions

There was little indication that participants had interactions with guidance or career counselors who helped them build on their STEM perceptions. According to participant 2, she had completed “a career profile [which] indicated that engineering was my most proficient skill.” Similarly, participant 5 said, “I guess we did have one kind of a test, but we didn’t have a specific person that would guide us in my like our choices for a career.” This lack of guidance meant that participants were forced to draw from their thoughts and experiences when they were required to consider where they fit into STEM majors.

Stereotypes

Two participants' memories of negative stereotypes go back as far as elementary school. Participant 1 recalls, "I did have a teacher specifically in elementary school who, who made it kind of obvious that he was openly sexist." She added, "I can't remember any specifics, but one of my teachers would always say sexist stuff, both to kids and to teachers. This was very common so I can't remember anything in particular." Participant 2 experienced unfair grading in one class. She said," I was a woman in a man's field, and that more would always be expected of me so that I should be prepared for that." She added:

> A professor, he taught general biology I and II, so any topic we were talking about would somehow always go off on a tangent sometimes related to sex. On one occasion he even said that he married an Asian woman because they keep house better and are more obedient.

However, none of the participants indicated that the negative stereotypes they had experienced played a major role in their academic choices.

Thoughts and Feelings about Science, Technology, Engineering, Mathematics

Participants' thoughts and feelings about STEM played an important role in their academic choices. This included the feeling of self-doubt. For example, participant 1 stated, "I've definitely had people tell me like that Psychology isn't like a real science and like, they don't recognize that it should be treated as a STEM career." It also includes feelings of self-determination, which was evidenced by the following statement of participant 2: "I did well in all my subjects. But if there's something that I don't understand, I just go back over the material until

I review it enough to understand it." Participant 3 expressed her feelings about STEM by saying, "It brings a lot of joy to being able to solve problems. And like some kind of academic, fulfilled mentality." On the other hand, participant 4 battled thoughts of "self-doubt and self-sabotage" throughout her educational journey. Finally, participant 5 overcame negativity from others by using her thoughts and feelings, stating "I try not to listen to what could go wrong and how difficult it could be to believe in myself setting goals."

Interventions

Several interventions exist to help female students overcome the biological, educational, and sociocultural bases for gender disparity in STEM. These were coded into four themes: female role models, mentorships, opportunities for research, and STEM programs. Coding based on these themes was derived from the literature review and participant responses.

Female Role Models

All five participants had positive female role models in their lives. These role models helped them counteract many of the previously discussed bases of gender disparity that the participants had when exploring and deciding on an academic major. Participant 1 mentioned her mother, stating "my [mother] was especially encouraging and willing to help me through it." She goes on to say she "took inspiration from my parents since they're both in STEM fields. And that was kind of inspiration enough for me to keep going on, I guess." Although participant 2 did expressly mention her mother as a positive female role model, she also added, "I never had a female teacher in the sciences. [Females] need mentors. Because I wasn't seeing any female people in the sciences to look up to." Participant 3 established a network of female role models in the form of mentors, international resources from UNICEF, as well as female mentors and teachers. Participant 4 also highlighted the need for more female science teachers, stating "I feel like they just need more female teachers in general and they also need more teachers that like, will like reach out or like, actually try.” Participant 5 mentioned an aunt who “helped me to pursue [an] internship and in the like company that … I had to pay for.”

Mentorships

All participants also mentioned participation or the need for additional mentorship opportunities. Participant 1 mentioned, “So I think support and kind of reassurance that, you know, you don't have to be a man to be in the sciences would be a pretty good resource to have.” When asked if it would have made a difference if she had had a mentor, participant 2 replied “I think it would have because it wouldn't have seemed like such an uphill battle. If we saw other people that had achieved it.” After being asked who she thought was most helpful to her, participant 3 stated “a lot of mentors I've had in my life, especially female mentors who have some success in STEM.” Participant 4 specifically mentioned her genetics professor who acted like a mentor, stating “my previous genetics professor was pretty supportive of me like getting involved in like the genetic side of like, the molecular and cellular Bio Major, which is why I'm in the lab I'm in right now.” Similarly, participant 5 specifically mentioned her biology teacher; she said, “I had a biology teacher and she like would talk to me about what she would do and that's how I got more interested in biology and all the environmental science.”

Opportunities for Research

Only two participants expressed a desire for more opportunities in research. Participant 4 stated:

> I did recently have a couple of conversations with both a grad student in the lab I'm in and the professor that's like the head of it. So we were just talking about like, where I

wanted to go in terms of like, more independent research, and like, how that would like, lead into what I wanted to do later.

Once she had secured the enrollment cost from an aunt, participant 5 became involved in an internship at an environmental company. She was unavailable when contacted later for clarification.

Science, Technology, Engineering, Mathematics Programs

Only two participants were found to have any experience with the STEM program. Participant 3 participated in some STEM programs in Ukraine during high school but lamented "they don't have really well-advanced programs. And they're kind of all dated, but I feel like it's pretty good." Participant 5 requested that there be more STEM programs and scholarship opportunities, stating:

> I think that it would be helpful to have more programs that involve stem in high school and maybe besides programs … like a contest [related to the] real world so people would seem motivated to participate also, maybe more scholarships available for stems students.

Competence Factors

Competence refers to the first of three domains in Carlone and Johnson's (2007) science identity model. All five participants gave evidence that they had a strong sense of competence in their chosen STEM field. Speaking about competence, participant 1 said:

> Oh, that's pretty important. I mean, I think for my field you have to keep pretty conscious about like, what you're learning and you have to constantly be like, learning new things, even past like college age, you have to constantly be refreshing your knowledge and learning new things.

When asked about the importance of competence in her chosen field, participant 2 replied "Subject matter competence is very important." When asked about her challenges in gaining competence, participant 3 replied, "I have a mindset of wanting to be above average. So I still want to be, I'm ready to do a little bit more effort to be a little bit better than most of the experts in the field." Participant 4, perhaps expressing anxiety over her looming final exams, stated "I want to lean towards just coasting through because that's how I feel right now. But I know there are things that are important that I need to at least sort of remember for later." Finally, participant 5 said that it was important to have an advanced degree in order to have subject matter competence. She said, "You have to do a Master's degree to show competence because it's not enough with your Bachelor's [degree]."

Performance Factors

Performance refers to the second of three domains in Carlone and Johnson's (2007) science identity model. The responses of four participants indicated a need to highlight their performance. Participant 1 stated "I don't think I'm particularly good. But, I don't think I'm bad." She went on to say, "I will be interning in the spring 2022 semester, but I haven't really had a way to display my skills at this point, only knowledge." Participant 2 spoke about the need for more career aptitude testing to highlight adults' assessment of students' performance, stating that "a career profile indicated that engineering was my most proficient skill." She did not know what she would have considered her most proficient skill had she not taken a career profile. Meanwhile, participant 3 used participation in contests to demonstrate her performance, stating "I was participating [in] the Mathematical Olympiad contest, and then moved on to computer science and started participating more in computer science contests." Participant 4 used her demonstrated poor performance in one subject as a reason to change majors, which is reflected in this statement: “I don't like calculus at all. So, I changed [my major] so I didn't have to do higher-level math.”

Recognition Factors

Recognition refers to the third of three domains in Carlone and Johnson’s (2007) science identity model. Participant 1 revealed that she did not get the recognition she felt she deserved, stating “I don’t think I’d really received any recognition at all.” Participant 2 did get recognition, stating “I was identified as being above average in the science area and was encouraged to pursue courses in science and math and technology.” Participant 3 got recognition from participation in various contests in Ukraine, stating “I definitely had a lot of academic validation through competitions and participating in this.” However, she was unavailable for a follow-up discussion on this issue. Participant 4 said, “I haven't received any recognition unless you're talking about just general offhand compliments, but like official like certificates and stuff. I haven't got any of those.” Expressing similar sentiments, participant 5 said, “I didn’t win, but I participated in a math contest, like high school level, which I think it’s a little good.” For her participation, she was recognized by her community. These three factors, competence, performance, and recognition help female STEM students form their science identity.

Summary

The purpose of this study was to describe how female STEM students choose their undergraduate major, the obstacles they face when making that choice, and how they overcome gender-based obstacles. This study employed a qualitative case study research design and used Carlone and Johnson’s (2007) science identity model to describe the way female STEM students made their academic choices, how they faced obstacles along the way, and the ways they overcame those obstacles. Participants were recruited using social media and those who met the study criteria were interviewed virtually one-on-one. All participants were asked questions from a script, with open-ended questions that could lead to more detailed responses. Only audio was recorded, transcribed, member-checked, and coded. The results were presented here.

Six broad groups (themes) emerged: the biological basis for gender disparity, the educational basis for gender disparity, the sociocultural basis of gender disparity, interventions used to overcome these, TLT (Mezirow, 1978), and the science identity model (Carlone & Johnson, 2007). These broad groups were then subdivided into 31 codes to analyze the transcript data.

In the biological basis for gender disparity, participants discussed gender bias, microaggressions, safety issues, and sexual harassment. In the educational basis for gender disparity, participants discussed their limited access to STEM and unequal attention from teachers. In the sociocultural basis for gender disparity, participants discussed the following: their appreciation for and relationship to science, availability of supports, confidence, and knowledge, family and peer involvement, interests, motivations, and attitudes, outside influences, science ability, self-concept, social and life orientation, STEM perceptions, stereotypes, as well as their thoughts and feelings about STEM. In interventions, participants discussed female role models, mentorships, opportunities for research, and STEM programs. These were coded against the three domains of Carlone and Johnson's (2007) science identity model and Mezirow's (1978) transformative learning theory. Finally, responses were coded to determine the science identity type of each participant, which will be discussed in Chapter 5.

CHAPTER 5: CONCLUSION

The purpose of this study was to examine the ways that five female STEM students arrived at their choice of undergraduate major, the obstacles they faced leading up to them making that choice, and how they overcame gender-based obstacles. Answering these questions will illuminate how they developed their science identity, and the resources they relied on while developing their science identity. This study used a qualitative case study research design and used Carlone and Johnson's (2007) science identity model to describe the way female STEM students made their academic choices, how they faced obstacles along the way, and the ways they overcame those obstacles. The three research questions this study sought to answer were:

RQ1. Why do female STEM undergraduate students choose to pursue STEM majors?

RQ2. What obstacles do they face as they make their STEM major choices?

RQ3. How do they overcome these obstacles?

These research questions were examined through the lens of both Carlone and Johnson's (2007) science identity model as well as Mezirow's (1978) transformative learning theory during semi-structured virtual interviews with female undergraduate STEM students recruited through social media. Participants who met the criteria for inclusion in this study, as described in Chapter three were interviewed, one-on-one, virtually. Interviews were transcribed using Otter.ai ® and each participant was allowed to review the transcript of her interview and make corrections. Their responses to interview questions were coded using Atlas.TI ® before being organized, analyzed, and interpreted to provide descriptive answers that were used to examine each of the three research questions.

Seven broad themes emerged through this process: disparity based on biological differences, disparity in education, disparity based on sociocultural factors, successful interventions, competence factors, performance factors, and recognition factors. Each broad theme was divided into various sub-themes.

All participants had experienced gender disparity, including biologically based forms ranging from simple gender biases and microaggressions, to more serious issues such as feeling unsafe or experiencing sexual harassment. All had also experienced some form of educationally-based gender disparity, including limited access to STEM resources and unequal attention from teachers compared to their male counterparts. Each participant also related instances of disparity based on sociocultural aspects of their lives recalling, sometimes, very hurtful and painful experiences they had had throughout their educational journeys.

The intricate way that each participant weighed and prioritized the various positive and negative influences and feedback they got from their teachers, families, and peers helped them develop a sense of competence in their field. Though few had the opportunity to exhibit formal performance, each also derived some sense of their informal performance through other mechanisms. Recognition was lacking for most of the participants, though they seemed to reconcile this by assigning a degree of self-recognition in the absence of outside recognition. While all participants could be classified as achieving some degree of competence, performance, and recognition in their fields, the extent of involvement for each domain was not the same for each participant. This will likely manifest in some participants developing stronger science identities than others.

Mezirow's (1978) TLT was not found to be a suitable conceptual framework. Few participants had a disorienting dilemma requiring a transformed frame of reference. Consequently, no full examination of TLT was undertaken. In the following sections, I will discuss how the findings answer the study's three research questions. I will also discuss how findings align with the literature and provide recommendations for further action and future research.

Interpretation and Importance of Findings

Despite society's best efforts to address the many differences female students face throughout their educational lives in comparison to their male counterparts, there is still much work left to do. Admittedly, the sample size here is small, but all of my participants experienced disparities related to biological causes, educational causes, and sociocultural causes. This section will focus on findings that relate to the study's three research questions.

Research Question One

To answer the first research question, "Why do female STEM undergraduate students choose to pursue STEM majors?" I directly asked each of my participants that question. Then I looked for evidence in support of their answers in other parts of their interview transcripts, detailed in Chapter 4. What follows is a reconciliation of their responses to the extant literature.

Personal Interest

Under the theme of Sociocultural Basis for Gender Disparity, as presented in Chapter four, I provided examples of how personal interest in the sciences acted to overcome many of the personal obstacles each participant faced in the sub-theme of Interests, Motivations, and Attitudes. Personal interests were also an important factor because Howie and Bagnall (2013) identified a mismatch between students' academic interests and their knowledge, skills, and abilities, as being a common source of a disorienting dilemma. A disorienting dilemma is the required first step in Mezirow's (1978) TLT. Todt et al. (1994) showed that global and specific interests were formed among children as early as age three, typically progressing according to gender norms from that time. Students tend to form their science identities by reconciling their social expectations with their interests and values (Naukkarinen & Bairoh, 2021). Then they adapt their science identity to reduce conflict with their other identities (Dwyer et al., 2020).

Participant 1 specifically stated that her chosen STEM field "has been a topic that always has interested me. And I like to feel that it's a science that has more of a practical application. And it deals with more people." Though participant 2 did not specifically mention her STEM field, she stated "I was always interested in the sciences. I was very curious as to wanting to understand how things worked." Participant 3 surrounded herself with other students having similar interests to develop a support network, stating "I started reaching out to people more and started, like collecting some kind of network to who I can talk if I have some kind of issues." On the other hand, participant 4 was primarily interested in working in a lab; she stated "I just really like working in a lab. It doesn't really matter where, whether it's like, I don't know, a pharmaceutical company or like just more academia I guess I just rather be in a lab." Participant 5 related her interest in the environment, stating "I wanted to be in the science and specifically the environmental area and I found that major as an opportunity to pursue my dreams." While participant 1 was the only person who considered her personal interest in a STEM-based field as the direct basis for her decision to pursue a specific major, participants 2, 4, and 5 used their interests as the basis for their decision to broadly pursue a STEM major. Participant 3 used her interests to build a social support network for support. Personal interests, whether broad or very targeted, seemingly play a role in the way participants choose a STEM major, and how they form their science identities. Hazari (2010) found that interest was so important that he proposed adding it as a fourth domain in Carlone and Johnson's (2007) science identity model. None of the participants expressed a difference between their interests and their knowledge, skills, and abilities, resulting in a disorienting dilemma, which is why an analysis of their responses through the lens of Mezirow's TLT was not possible.

Confidence and Knowledge

Under the theme of Sociocultural Basis for Gender Disparity, as presented in Chapter four, I provided examples of how confidence and knowledge in the sciences acted as both a positive and negative influence on my participants in the sub-theme of Confidence and Knowledge. Building competence and self-confidence denote step 9 in Mezirow's (1978) TLT. Researchers have used confidence and self-confidence as justification for programs such as mentoring and undergraduate research opportunities. These programs provide students with opportunities to gain recognition, validate their sense of self-confidence, strengthen their science identities, and increase their understanding of science while also improving their professional self-confidence (Betz et al., 2021). Confidence and knowledge are key interrelated psychological factors that influence how females make their career choices (Dennis et al., 2019).

Participant 3 specifically stated that she "used to have a good base knowledge level for math classes and I kind of liked all the STEM classes since high school. So I decided to go with it." For participants 1 and 4, confidence was an obstacle, with participant 1 reporting that her confidence was shaken when teachers and peers told her that STEM would not be a good fit for her. Participant 4 expressed low confidence, in the form of self-doubt when she stated "I don't think I naturally excel in anything at this point. I'm just chugging along." Participant 2 claimed to knew her strengths, stating with confidence "I was always good at math, but it was never a particular favorite." Participant 5 gained confidence and knowledge by working as an intern at a company, using what she had learned in school in real-life applications, performing research "involved in the conservation of endemic species in Mexico." As my participants had varied experiences (both positive and negative) regarding their confidence and knowledge, each can be expected to apply those experiences to form their science identity (Betz et al., 2021). Confidence and knowledge are themes that overlap the competence, performance, and recognition domains of the science identity model (Carlone & Johnson, 2007). Analysis of confidence and knowledge through the lens of Mezirow's (1978) TLT was not done, as none of the participants had exhibited the earlier stages of this ten-step process.

Life Orientation

Under the theme of Sociocultural Basis for Gender Disparity, presented in Chapter four, I provided examples in the sub-theme of Social and Life Orientation where participants used their personal identities to influence their science identities. Sadolikar (2019) refers to life orientation as a key psychological factor influencing a female's choice of career.

Participant 1 identified her desire to help others as an important factor in her major choice, citing a desire for a career that had a "practical application helping people." She wanted the opportunity to use what she learned to help others. Participants 2 and 5 identified their desire to help the environment as an important factor in their major choice. Participant 2 stated she wanted to be a chemist with "a capacity that helps the environment would be ideal." Participant 5 wanted to help the environment by studying recycling techniques and working to restore endemic species, whereas participant 3 could not remember a time when she did not want to have a career in STEM. Participant 4 expressed raw determination when asked why she wanted to pursue a STEM major, stating she "always liked science, liked it in high school, and just wanted to keep pursuing that. Participant 2 took determination as a life orientation further. She said that although she did well in most of her subjects, "if there's something I don't understand, I just go back over the material until I review it enough to understand it." Her determination was also applied when she had a bad semester and was dismissed. She thought about her son "and how important it was to continue and finish. Because, when he goes to college, he needs to see that I didn't just quit." The theme of life orientation was found to have mixed impacts on science identity (Carlone and Johnson, 2007). Having a positive life identity, such as when participants have a clear picture of how they want to use what each has learned or having the determination to continue leads to improved competence and performance. By contrast, negative life orientation events may shake a persons' sense of competence and performance, or it may provide the spark to improve as it did for participant 2. Analysis of confidence and knowledge through the lens of Mezirow's (1978) TLT was not done, as none of the participants had exhibited the earlier stages of this ten-step process.

My participants drew on their personal interests in STEM, their confidence and knowledge, as well as their overall life orientation while making their career choices. Each of these acted in positive ways to strengthen one or more of the three domains in Carlone and Johnson's (2007) science identity model. Each participant had a strong sense of competence in STEM, and most had some developed sense of performance. Only a few had received significant recognition because they are still early in their STEM careers.

Research Question Two

To answer the second research question, "What obstacles do they face as they make their STEM major choices?" I directly asked each of my participants that question. I then sought evidence in support of their answers in other parts of their interview transcripts, detailed in Chapter four. What follows is a reconciliation of their responses to the extant literature.

Biological Issues

Under the theme of Biological Basis for Gender Disparity, as presented in Chapter four, four sub-themes were discussed. Under Gender Bias, I provided examples where participants experienced biases from others in their schools, peer groups, and from society, based on their gender. Under Microaggressions, I provided examples where participants experienced hostility that they attributed to their gender. Under Safety, I provided examples where participants felt unsafe in their STEM environments. Finally, under Sexual Harassment, I provided examples where participants either anticipated experiencing or did experience some forms of sexual harassment in their STEM environments. There is a long historical basis for the gender gap that points to both biological and sociocultural causes (Tolley, 2003).

Gender Bias. Gender bias is known to reduce female motivation in STEM classes (Leaper & Starr, 2019). They reported that in 2018, a majority of their sample, 60.9% "had reported experiencing STEM-related gender bias … at least once in the past year" (p. 165). Only one of my participants reported never experiencing some form of gender bias in her STEM classes. The biases they reported included favoritism, overt and covert sexism, differential treatment in class, different grading, fewer opportunities to participate in class, and sexual comments, innuendos, and jokes. One participant reported she had "a few teachers who definitely picked favorites in some regards." Another participant stated that the males would be allowed to get "further along in chemistry" compared to the females. Participant 3 stated, "I definitely know a lot of biases relating to women, with women and STEM, for a fact" but refused to elaborate. Instances reported occurred as early as elementary school and were recalled as if they happened more recently. Gender biases erode female students' sense of competence and recognition, which makes it more difficult to form a strong science identity (Carlone & Johnson, 2007).

Microaggressions. Microaggressions often arise due to biological differences between female and male students (Bottia et al., 2015; Cabay et al., 2018; Leaper & Starr, 2019). Gender inequity has often resulted in microaggressions against females (Cabay et al., 2018). All participants reported either experiencing or constantly anticipating experiencing microaggressions based on their gender. These ranged from anticipating microaggressions due to being the only female in a class or lab to an instance where assistance was reluctantly given to Participant 1 in a computer lab, to situations where teachers made inappropriate comments to Participant 5. Microaggressions, such as gender bias, erode female students' sense of competence and recognition, making it more difficult to form a strong science identity (Carlone & Johnson, 2007).

Safety. Safety is a concern for all students, but females will disproportionately choose career pathways that allow them to feel safe (Leaper & Starr, 2019; Starr & Leaper, 2019). Four of my participants reported that they felt either vulnerable or unsafe at their schools. Participant 4 pointed out that although nothing had happened to her, it was ordinary for situations to occur where female students would feel unsafe. One participant was compelled to change majors and colleges, because her original college was in an unsafe area, though this only slightly changed her career trajectory. Another participant stated, "it wasn't only discrimination going on in classes." Female students need to feel safe to remain in STEM. When they do not feel safe, some female students will pursue other career choices. Safety concerns directly impede a student's ability to focus on academics, reducing their sense of competence and performance, making it difficult to form a strong science identity (Carlone & Johnson, 2007).

Sexual Harassment. Sexual harassment stems due to the physiological differences between females and males (Bottia et al., 2015; Cabay et al., 2018; Leaper & Starr, 2019). Leaper and Starr (2019) argue that sexual harassment reduces female students' motivation in STEM classes, and that it is a larger problem than was previously thought. In their study, 78.1% of female students had experienced at least one incidence of sexual harassment in school (Leaper & Starr, 2019, p. 165). Three of my participants reported experiencing or anticipated experiencing sexual harassment in their schools. They were exposed to inappropriate comments and jokes that made them feel very uncomfortable in class or touched inappropriately. One was even objectified and teased due to her clothing. Being sexually harassed, like feeling unsafe, forces some female students to pursue other career choices. Sexual harassment also impedes female students' ability to focus on academics and reduces their sense of competence and performance, thus making it very difficult to form a strong science identity (Carlone & Johnson, 2007).

Educational Issues

Under the theme of Educational Basis for Gender Disparity, presented in Chapter four, two sub-themes were discussed. Under Limited Access to STEM, I provided examples where participants reported being unaware that STEM educational supports that were available, and the need for additional STEM educational supports and programs. Under Unequal Attention, I cited examples where participants experienced being passed over in favor of their male counterparts, where they saw few female STEM teachers to model, and where teachers would pay more attention to male students. Female students are also known to have more limited access to STEM education (Avendano et al., 2019). Bertocchi and Bozzano (2016) point to this as being a problem stemming from ancient history, and one that became more pronounced during medieval times. Koch et al. (2014) take it further, claiming that female students always have been and continue to be marginalized as observers and learners of the scientific community, and later as members of that same scientific community.

Limited Access to Science, Technology, Engineering, Mathematics. Limited access to STEM was not found to be a significant problem among my participants. One participant reported that although she know of the supports available to her, “a lot of girls in young age are not aware of all the openings they could have.” Another participant expressed the need for more STEM programs and incentives to steer female students to STEM. Overall, the issue of limited access to STEM, which may have significance in other studies, played no role in impacting my participants’ competence, performance, or recognition. Limited access to STEM was not an issue that impacted these participants’ science identity (Carlone & Johnson, 2007).

Unequal Attention. Unequal attention was more of an issue among my participants. According to them, teachers paid more attention to male students, called on them more often, and even picked favorites among them. One participant reported experiencing differences in grading, painfully recalling that she failed a test despite answering similarly to her male study partner who passed. Unequal attention erodes female students’ sense of recognition, making it more difficult for them to form a strong science identity (Carlone & Johnson, 2007).

Sociocultural Issues

Under the theme of Sociocultural Basis for Gender Disparity, presented in Chapter four, twelve sub-themes were discussed. Only two of those themes presented obstacles for my participants. Under Outside Influences, I discussed how participants had experienced people telling them they would not be good in STEM, that they lacked requisite skills to pursue a STEM field or were jealous of them attending school at all. Under Stereotypes, I discussed how participants experienced both field-based and gender-based stereotypes. The literature considered outside influences as mainly comprising the learning environment itself (Miller & Hurlock, 2017), parental beliefs (Lee et al., 2020; Muenks et al., 2020), and teacher impacts (Bottia et al., 2015). Cundiff et al. (2013) emphasized the important role that stereotypes play in a female's association with science, their identification with science, and their ultimate career choice, stating "personal choices are made within particular social contexts, and stereotypes are part of that context" (p. 551). Evidence in the literature suggests that stereotypes also impact a female's ability to identify her own math and verbal abilities (Schuster and Martiny, 2017) as mentioned by Participant 4, who switched majors from chemical engineering to biology, and then to molecular and cellular biology because of her dislike for calculus.

Outside Influences. Outside influences that impeded my participants' plans were not the ones identified in the literature, as none reported issues related to the learning environment itself, parental beliefs, and only a few cited teacher impacts as obstacles. Their obstacles instead took the form of peers, distant family, and a boyfriend. One participant said that her peers were persuade her to switch majors to avoid difficult tasks in the lab. She also expressed frustration at distant family members who do not believe in modern science, an issue that is widely prevalent in the media.

Another participant explained how a boyfriend tried to convince her to avoid school altogether, an influence she did not follow. The negative outside influences my participants experienced may act to erode female students' determination, making it more difficult to continue in STEM, but I do not believe it directly impacted their sense of competence, performance, or recognition. If the negative outside influence were from the learning environment itself, related to a parental belief, or due to the impact of a teacher, this may have impacted their sense of competence and recognition, making it more difficult for them to form a strong science identity (Carlone & Johnson, 2007).

Stereotypes. Stereotypes were an issue that was mentioned by only two of my participants. One participant elaborated that she had a teacher who acted “openly sexist” who would exhibit differences in his instructional approach depending on his student's gender. He would tell his students that some of the STEM fields were not real science. Another participant “told me I was a woman in a man’s field, and that more would always be expected of me so that I should be prepared for that.” Stereotype situations like these can impact female students’ sense of competence and recognition, thus making it more difficult for them to form a strong science identity (Carlone & Johnson, 2007).

My participants experienced a variety of obstacles while making their career choices. Those obstacles took the forms of gender bias and sexual harassment, limited access to STEM and unequal attention at school, and negative outside influences and stereotypes. These factors each acted to diminish one or more of the three domains in Carlone and Johnson’s (2007) science identity model. Each participant needed to find ways to overcome these obstacles to successfully form a strong science identity. The ways that each used to overcome their obstacles is the focus of research question three.

Research Question Three

To answer the third research question, “How do they overcome these obstacles?” I used data that I pulled my participants’ answers to related questions. Then I looked for evidence in support of their answers in other parts of their interview transcripts, as detailed in Chapter four. What follows is a reconciliation of their responses to the extant literature.

Sociocultural Influences

Under the theme of Sociocultural Basis for Gender Disparity, as presented in Chapter four, twelve sub-themes were discussed. Only two themes presented routes for participants to overcome the obstacles they faced in making their STEM major decisions. Under Availability of Supports, I discussed how important these supports were to all of my participants. These supports included teachers, mentors, and structured STEM programs. Under Family and Peer Involvement, I discussed how important family and peers were in guiding my participants as they made their academic choices. Evidence in the literature suggests that female students need social and academic supports and female role models (Cundiff et al., 2013). However, even when those supports exist, evidence suggests that female students underutilize these supports (Avendano et al., 2019). Evidence also exists in the literature that parental and peer involvement in college and career decisions is critical (Cundiff et al., 2013; Lee et al., 2020; Muenks et al., 2020). Peers can be both a positive and negative influence, Bottia et al. (2015) give evidence that peer pressure can be negative. The way female students see themselves within a larger community, such as an ethnic group, a race, or how well they fit into a neighborhood or school and the way they fit in with their peers and families informs their various personal identities (Dwyer et al., 2020).

Availability of Supports. The availability of supports was a key component to all of my participants overcoming their career choice obstacles. One participant cited her organic chemistry professor who gave her career and major advice while also pointing out the lack of supports in her earlier educational journey and the relative difficulty she had in accessing other supports at college. The difficulty in accessing supports was mentioned by another participant as well. Another participant accessed supports within her school, as well as those provided by

UNICEF and a Ukrainian math competition, which she used for support. Another participant cited her environmental science and environmental chemistry professors as being key supports to her.

Family and Peer Involvement. Family and peer involvement played the largest role for my participants in helping them overcome their career choice obstacles. Each pointed to instances where her parents of friends were encouraging and helped her get through tough times. Two participants had the benefit of having one or both parents also employed in a STEM field. Parental influence may go further than guiding a female student down a STEM pathway. One participant discussed how her mother's job influenced her to pursue chemistry first, then branch into environmental chemistry rather than her original major. This influence was unintentional, as her mother was never aware of her role in determining my participant's major. Two participants were unaware of their potential until they discussed their career aspirations with a brother in one case and an aunt in another.

All my participants used the support they found available to them, and interactions with family members and peers to overcome their career choice obstacles. Had those supports and interpersonal relationships been absent, my participants may have faced different paths. Each used these combined resources to reduce the impact of their various obstacles to form a strong science identity (Carlone & Johnson, 2007) and these data supported the literature.

Implications

During the early phase of this study, while conducting the literature review and devising the study method, Mezirow's (1978) TLT was selected as the conceptual framework and the grounded science identity model (Carlone & Johnson, 2007) was chosen as the theoretical framework. TLT was chosen as it offered a mechanistic approach to examine how participants assimilate new knowledge and experiences to alter their perspectives and make important life decisions. This framework was abandoned during data analysis as none of the participants identified as having a disorienting dilemma, or later steps used in describing learning according to TLT.

This study's theoretical framework, Carlone and Johnson's (2007) science identity model was utilized to understand and describe how female STEM undergraduate students decide on an academic major. Analysis of the study data supported the assertion, first proposed by Hazari (2010) that interest be added as a fourth domain. Interest among this study's participants played a larger role than recognition of participants' choice of academic major. The original three domains, competence, performance, and recognition (Carlone & Johnson, 2007) were sufficient to describe how participants' science identities are influenced by the obstacles they face throughout their academic lives, as well as the means each utilized to overcome their obstacles.

Fully understanding how female students form their science identity is critical to reducing or eliminating the systemic problems that lead to our current STEM gender gap. Since the motivation to pursue a STEM career begins in adolescence (Gagnon & Sandoval, 2020), a phase of development where gender disparities already appear, any steps we can take to reduce their prevalence in schools may keep female students on their STEM trajectories. The results of this study may influence how schools can improve in delivering STEM education to female students, offering more equal educational opportunities, free of gender biases, stereotypes, and sexual harassment, and better access to STEM resources such as mentorships and other enrichment programs. The results may also reinforce the need for cooperation between schools and female students' parents or other family members, given that the influence of family and peer groups was a key resource that students used to overcome their various obstacles.

Recommendations for Action

This study's findings suggest that female students pursue a STEM major because they have a personal interest in STEM, have a degree of confidence and baseline knowledge in STEM, and have a life orientation that allows their personal and science identities to reconcile. These factors fostered a sense of competence, performance, and recognition (Carlone & Johnson, 2007) among the participants. Biologically based barriers they faced, such as gender bias, microaggressions, and sexual harassment, and educationally based barriers such as unequal attention and limited access to STEM supports acted to erode their sense of competence and to a lesser degree their senses of recognition and performance. Female students need to learn in environments free of gender bias, gender-based microaggressions, and sexual harassment (Cabay et al., 2018; Leaper & Starr, 2019). Consequently, schools need to provide better STEM environments devoid of these impediments. Teachers and guidance counselors need additional training to identify and reduce their own implicit and explicit biases, whereas administrators need to be aware that inequity in the classroom still exists. STEM resources and supports need to be readily available, and access to resources that do exist needs to be improved. Schools need to be aware of the negative outside influences that female students face. Influences such as parental beliefs (Lee et al., 2020; Muenks et al., 2020), and negative stereotypes (Cundiff et al., 2013) may be at odds with the messaging students get in school. Schools need to work more closely with parents to assure that students are getting the support they need. Media and society need to be aware of the pervasive negative stereotypes surrounding females in STEM, and actively work on reducing this obstacle.

Recommendations for Further Study

Due to the limitations of this study, and on the basis of this study's findings, the following further research is recommended:

- This study was conducted with five participants recruited through social media. Future research should, therefore, draw on a larger sample size to expand on and generalize this study's findings.
- This study focused on relating the experiences of participants to the three domains (competence, performance, and recognition) of Carlone and Johnson's (2007) science identity model. Findings indicate that identity was important as well. Hazari (2010) proposed adding identity as a fourth domain. Thus, further research is needed to determine if identity should be added to the science identity model.
- Though study participants were recruited who attended high school in Mexico and Ukraine apart from the United States, they represented only two data points. Further research, therefore, is needed to determine the nature and degree of gender disparity in other countries, and if there are significant differences compared to the United States.
- This study focused on gender differences among STEM students in general. Further research, therefore is needed to delineate differences that may exist among the different STEM branches to achieve more granularity. For instance, the experiences of female life science students and those of female physical science students may be different.

Conclusion

There is a real shortage of female students entering STEM fields. This leaky pipeline (Cundiff, 2013) has a historical basis, and both biological and sociocultural causes (Tolley, 2003). Educational, policy, and political forces deepen the disparity. Colleges are known to have difficulty recruiting and retaining STEM undergraduates (Huvard et al., 2020). STEM attrition remains high (Betz et al., 2021). Females account for less than 25% of those working in STEM occupations (Kricorian et al., 2020). We need to have a fundamental understanding of how female students develop their science identity to reduce the gender disparity in STEM fields.

The goal of this study was to describe how female STEM students choose their undergraduate major, the obstacles they face when making that choice, and how they overcome gender-based obstacles. Descriptions of these processes illuminate how they developed their science identities, and the resources they relied upon while doing so. Carlone and Johnson's (2007) science identity model formed the theoretical framework for this study. An analysis of the responses that participants gave to interview questions revealed important themes related to why they chose a STEM major, the obstacles they faced when doing so, and the resources they used to overcome those obstacles. This study's results show that female STEM undergraduate students faced many obstacles throughout their elementary and high school education, both at school and at home. These obstacles were often preventable, had they been identified in a timely manner. Results also showed that female STEM undergraduate students drew on a combination of formal STEM resources and their family and peer networks to help them overcome their obstacles. More still needs to be done to reduce the leaky pipeline.

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APPENDIX A - INTERVIEW QUESTIONS

Please tell me what your major and minor are.
Why did you choose to pursue a STEM career?
What groups of people did you consider important in helping you choose a career?
What were the biggest STEM influences that you can remember?
Were you always interested in STEM as a career? Please explain your answer.
Were you ever considering an alternate career? Please explain your answer.
What led you to choose not to follow your alternate career choice?
What subjects are or where your favorite?
Did you like your science and math classes? Please explain your answer.
What were your least favorite science and math courses?
What subjects did you excel in?
If you did not excel in subjects that were your favorites, how did you overcome this?
What career aptitude testing or career planning did you have in high school?
Who were your biggest STEM influencers?
Describe any career discussions you have had with your friends, family, teachers, or staff.
Do either of your parents have a STEM degree? Please explain their influence in your career decision.
What obstacles did you face as you made your career decisions?
Was your family supportive of your decision? Please explain your answer.
Were your friends supportive of your decision? Please explain your answer.
Were any teachers of staff supportive of your decision? Please explain your answer.
Did you ever experience any negative situations in any class that you think were related to gender? Please explain your answer.
Did your teachers treat all students equally? Please explain your answer.
Do you feel that your high school experience was typical? Please explain your answer.
Do you describe yourself to be a traditional student? Please explain your answer.
Have you always felt safe in your classrooms? Please explain your answer.
Have you ever felt uncomfortable discussing your enthusiasm or interest in STEM with anyone? Please explain your answer.
Please describe your typical class size, classroom environment, and the overall campus environment. Did these factors influence your choice of a STEM major?
What obstacles have you faced as you work through your choice of major?
Please discuss how you rate your performance at scientific tasks compared to others?
Describe any recognition that you have received (or not received) related to science? How important is subject matter competence to your career aspirations?
Please give an example where someone was supportive of your career goals? Please give an example where someone was not supportive of your career goals?
What science resources or supports do you think aspiring female scientists need?
Describe how you overcame the obstacles you faced in making your academic choices.