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SCIENCE, TECHNOLOGY, ENGINEERING, MATH (STEM) IN HIGHER EDUCATION FROM THE PERSPECTIVE OF FEMALE STUDENTS: AN INSTITUTIONAL ETHNOGRAPHY

by

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Submitted to the Graduate Faculty

of the

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Title	Science, Technology, Engineering, Math (STEM) in Higher Education from the Perspective of Female Students: An Institutional Ethnography
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Laura J. Parson
April 30, 2016

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ABSTRACT

A persistent disadvantage for females is systemically embedded in Science, Technology, Engineering, and Math (STEM) education in postsecondary institutions. As a result, undergraduate women majoring in STEM fields face a uniquely difficult path; yet, for the most part, recommendations made and supported in the literature have focused on recruitment of women to STEM fields or on ways to make women more successful and comfortable in their STEM major. These recommendations have so far proved to be insufficient to remedy a gender gap and serve to replicate the existing male hierarchy. In order to truly make the STEM classroom one in which women are welcome and comfortable and to challenge the existing social and scientific systems, it is necessary to explore and understand the social and political implications embedded within teaching and learning choices. This institutional ethnography addresses that gap. The purpose of this study was to uncover and describe the institutional practices of STEM education at a Midwest research university (MRU) from the standpoint of female undergraduate students. Using the framework of feminist standpoint theory, this study explored the everyday “work” of female undergraduate STEM students to provide a unique perspective on the STEM education teaching and learning environment. Data collection began with in-depth interviews with female undergraduate math and physics students. As the institutional processes shaping undergraduate participant experiences were identified, subsequent data collection included classroom observations, additional interviews with students and faculty, and analysis of the texts that mediate these processes (e.g., syllabi and student handbooks). Data analysis followed Carspecken's process of ethnographic data analysis that began with low-level coding, followed by high-level coding, and concluded by pulling codes together through the creation of themes. Analysis of data led to three key findings. First, undergraduate participants reported being challenged by difficult and intimidating aspects of the teaching and learning environment. Second, undergraduate participants reported challenges meeting some of the characteristics of successful math and physics students (e.g., taking risks, asking questions, putting school first) and preferred a collectivistic environment. Third, participants described challenges from conflicting STEM academic expectations and institutional policies, which made it harder for them to meet STEM expectations. Findings indicate that efforts to reduce the "chilly" climate have been unsuccessful, largely because discourses that motivate the chilly climate have not changed. Those discourses are evidence of a masculine STEM institution, which also creates a male ideal that female students are expected to meet, further exacerbating their discomfort in the STEM environment. The masculinized nature of a STEM institution is reinforced by neoliberal policies that emphasize the importance of meeting gendered ideal STEM student characteristics. The result is that while women persist, they face stress, anxiety, and discomfort. Recommendations to improve the chilly climate include: revising the STEM institution from one that is masculine to one that is inclusive of women; and, to create a STEM educational environment that supports, validates, and gives women an equal voice.

CHAPTER I

INTRODUCTION

> We are now moving away from an emphasis on *'fixing the women'* to *'fixing the system'* . . . When we say '*fixing the women'*, we do not just mean measures of mentoring, networking, role models, etc., but also measures *'to fix the women so that they fit into the existing system'* (Šidlauskienė & Butašova, 2013, p. 53)

Higher education has been a male-dominated institution since its inception, founded by men and designed to reinforce and replicate societal power structures (DuPre, 2010; Šidlauskienė & Butašova, 2013). DuPre (2010) asserted, "The gender gap is as old as higher education itself, with the idea of the higher educational institution originating as an enterprise by men for men, isolating women and limiting their participation" (p. 68). Although the status of women in higher education has improved, and more women than men enroll in undergraduate programs, a gender gap in enrollment and achievement persists, especially in Science, Technology, Engineering and Math (STEM) fields, with the singular exception of biology (Goldin, Katz, & Kuziemko, 2006; Wells, Seifert, Padgett, Park, & Umbach, 2011). In 2011-2012, 57.27% of bachelor's degrees awarded in the United States to U.S. citizens and non-resident aliens were to women (National Center for Education Statistics, 2013). While women earned 50.4% of STEM degrees, they received just 19.3% of physics degrees and 43.1% of mathematics degrees (National Girls Collaborative Project, 2015). Of additional concern, the share of women receiving bachelor’s degrees in Engineering, Computer Science, Physical Sciences, and Mathematics dropped from 2004 to 2014 (Research Center, 2015). Research indicates that the STEM climate is more beneficial to men as well: “They have more substantive engagements with their professors, are more likely to do undergraduate research, and tend to major in fields that steer them into better-paying jobs” (Sander, 2012, p. B14).

The STEM teaching and learning environment exacerbates the enrollment disadvantage for female students. Within the male-dominated classroom, female students perform considerably lower in their introductory math and science courses than male peers even though all students enter their freshman year in college with similar mathematic abilities (Carrell, Page, & West, 2010; Kreutzer & Boudreaux, 2012). A persistent disadvantage for females is systemically embedded in STEM education as an institution as noted by Šidlauskienė and Butašova (2013):

> Universities operate in highly institutionalized environments, such that many of the structures, rationales, regulations, orders and ceremonies which govern university life persist for reasons outside of their instrumental value. Professions, disciplines, study courses or research areas shape and constrain the nature and form of knowledge. . . . Therefore, the representation and advancement of women in academic STEM positions is affected by many external factors which are unrelated to a woman’s ability, interest and technical skills. . . . The cumulative effect of such diverse factors has led to the creation of infrastructural barriers which impact the number of women entering, persisting and advancing in STEM careers (p. 61).

Women, as a group, are less likely to major in STEM fields, and those who enter STEM fields as freshman are less likely than men to graduate (Gayles & Ampaw, 2014; London, Rosenthal, Levy, & Lobel, 2011). As a result of their marginalization, undergraduate women majoring in STEM fields face a uniquely difficult path that cannot be remedied by an approach that focuses on “fixing the women” to fit into STEM education. It requires, instead, that we focus on “fixing the system” (Šidlauskienė & Butašova, 2013, p. 53).

In this chapter, I begin by providing a brief overview of the history of women in higher education and the female enrollment advantage. Second, I discuss the current state of women in STEM education, which informs the problem statement that guided this study. Third, I describe feminist standpoint theory as it informs institutional ethnography, the theoretical framework through which this investigation was framed. Fourth, I present the research statement and rationale that guided this institutional ethnography. Fifth, I present the research benefits that motivated this exploration of the experiences of undergraduate women in STEM. Finally, I present the research questions that guided data collection, analysis, and conclusions for this exploration of STEM in a higher education institution.

Female Enrollment Advantage

The gender gap in STEM higher education persists despite a reversal of the gender gap in higher education enrollment (Goldin et al., 2006). Between 1900 and 1930, men and women enrolled in higher education at about the same rate due to the large percentage of men engaged in the war effort; after 1930, male enrollment began to outpace female enrollment and that trend continued until 1947 (Ball, 2012). This trend began to reverse in 1960, when men received 65% of all bachelor's degrees awarded. Parity between the sexes in enrollment was reached in 1982, and female enrollment and graduation rates have continued to increase since then. As Buchmann (2009) stated, "By 2003, women received 58% of all bachelor's degrees and constituted 55% of all college students" (p. 2321). In 2009, almost 35% of women between 25 and 29 had a bachelor's degree, compared to 27% of men, and it is projected that women will make up 60% of college students by 2016 (Wells et al., 2011). These increases are not at the expense of men, but are driven by increasing rates of enrollment by women, not decreasing enrollment by men or changing completion rates (DuPre, 2010; Flashman, 2013).

The discourse surrounding the female enrollment advantage has been used to suggest that women no longer face structural constraints to success or that the privileged group itself is a minority, as seen in reverse discrimination claims (Moller, Stearns, Southworth, & Potochnick, 2013; Yakaboski, 2011). This discourse places the onus on the individual for success or failure and allows men to continue to occupy their privileged place. However, the statistical advantage of female college enrollment does not represent an overall female advantage in higher education. First, much of the increase in female enrollment is occurring at 2-year colleges, which means that enrollment at traditional 4-years universities may not be as gender differentiated as overall statistics suggest (Flashman, 2013).

Exploring intersectional factors such as race and class changes the picture even more. For example, in 2012, only 11.2% of bachelor's degrees in science and engineering were awarded to minority women (National Girls Collaborative Project, 2015). Similarly, women from lower income households score lower than their male and female peers in high school math and science courses (“State of girls and women in STEM,” 2015). Finally, higher education administration and faculty are still largely male. Women hold fewer faculty positions and are less likely to have tenure; female administrators are more likely to work in female-dominated fields, and women are more likely to be faculty at community colleges and 4-year teaching institutions than elite universities (Šidlauskienė & Butašova, 2013; “Women's status in higher education,” 2011). As a result, female undergraduates still see more men than women among their faculty and administration. Undergraduate women have become “the invisible majority within higher education even though they gained majority enrollment status” (Yakaboski, 2011). Asserting that an enrollment advantage equals a female advantage in higher education reinforces discourses that encourage stereotypical gendered performance and behavior and oppose merit-based opportunities and the construction of high standards for women (Yakaboski, 2011). These discourses reinforce the policies, practices, culture and environment that marginalize female students.

STEM Education

In STEM education, the gender gap in higher education is amplified due to cultural and structural factors, such as gender role socialization, STEM institutional culture, policies, processes, and procedures. Recent research has found that discrimination persists in STEM education, despite efforts to increase the number and presence of female faculty and administration (Charleston, George, Jackson, Berhanu, & Amechi, 2014; Monroe, Ozyurt, Wrigley, & Alexander, 2008). Both individual and institutional discrimination still exist in STEM education, but overt discrimination, though not totally gone, has largely been replaced with entrenched but subtle inequalities.

For example, professional culture in STEM education is still based on a traditional, linear male model (Monroe et al., 2008). This linear male model measures success based on an unencumbered ideal male worker with an uninterrupted tenure timeline (Monroe et al., 2008).

For female STEM students, this masculine environment often creates a classroom environment that is male-normed, highly impersonal, and individualistic (Morganson, Jones, & Major, 2010; Vogt, Hocevar, & Hagedorn, 2007). Referred to as a “chilly climate,” STEM courses are frequently viewed as, “competitive, weed-out systems that are hierarchically structured with impersonal professors. These characteristics are traditionally acknowledged as customary, even respectable, teaching practices in traditional research university science, mathematics, and engineering classrooms" (Vogt et al., 2007, p. 339). The classroom climate and lack of support creates a disconnect that restricts female enrollment and persistence in STEM fields (Sartorius, 2010). Additionally, the chilly climate is often evidence to women of a perceived incompatibility between their gender and STEM fields (Sartorius, 2010). Altogether, the chilly climate prevents many women from entering STEM fields and pushes out many women who initially enroll. For example, in 2011-2012, 32% of female students switched from a STEM to a non-STEM major compared to 26% of their male peers (Chen & Soldner, 2014). This concept is referred to as the leaky pipeline (Kreutzer & Boudreaux, 2012).

As a result of the chilly climate, women in STEM fields frequently must revise their lives and expectations in order to be successful (or perceive themselves as successful) in these majors. This revision may include adapting their classroom behavior, asserting themselves in the classroom, developing a “thick skin,” taking on “masculine” characteristics of individualism and competitiveness, and either ignoring or actively combatting negative perceptions of their intelligence or academic capabilities made by faculty, fellow students, and administration (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013).

The diminished status and negative experiences of women in STEM education has been a topic of research since the mid-1980s. Within the research on female success in STEM fields, consensus has been reached that women are not biologically deficient in cognitive skills needed for STEM success or less able than men (Ceci, Williams, Ginther, & Kahn, 2014; Riegle-Crumb, King, Grodsky, & Muller, 2012). Instead, environmental, social, and cultural factors contribute to women’s non-start or early exit from STEM majors and their diminished performance when compared to male peers (Ceci et al., 2014; Deemer, Thoman, Chase, & Smith, 2014; Isaac, Kaatz, Lee, & Carnes, 2012; Lips, 2004; London et al., 2011; Riegle-Crumb et al., 2012; Yaboski, 2011).

Research to help women students be successful in the STEM environment has found that university characteristics, demographics, programs, and pedagogies have a positive effect on female experiences in higher education. First, the presence of visible women in STEM is important to female undergraduate retention and success. Several studies have linked the increased presence of female faculty to female student success (Carrell et al., 2010; Charleston et al., 2014; Gorman, Durmowicz, Roskes, & Slattery, 2010; Tatum, Schwartz, Schimmoeller, & Perry; 2013). Second, research has also found that several interventions improve female student experiences and persistence in STEM fields. Those interventions include mentoring, providing undergraduate research experiences, implementing active learning in the classroom, inclusive teaching, increasing academic support for female undergraduate students, living/learning communities, and providing support programs for female students that focus on social coping and feelings of inclusion (Campbell & Skoog, 2004; Cantu, 2012; Charleston et al., 2014; DuPre, 2010; Deemer et al., 2014; Gorman et al., 2010; Grossman & Porche, 2014; Isaac et al., 2012; Kreutzer & Boudreaux, 2012; London et al., 2011; Morganson et al., 2010; Szelenyi, Denson, & Inkelas; 2013; Tatum et al., 2013; Vogt et al., 2007; Yelamarthi & Mawasha, 2010). For the most part, the recommendations supported in the literature have focused on the recruitment of women to STEM fields or on ways to make women more successful and comfortable in their STEM major (Mayberry, 1999).

Spurred by the recognition that a focus on changing women to fit the existing system is insufficient to remedy a gender gap (Charleston et al., 2014; Mayberry, 1999), a limited but growing body of research focuses on the STEM education institution as problematic (Linley & George-Jackson, 2013; Morimoto, Zajicek, Hunt, & Lisnic, 2013; Šidlauskienė & Butašova, 2013). This research explores how the institution itself perpetuates gendered experiences and societal gender norms and suggests that institutional culture needs to be a significant consideration in the study of underrepresented and underserved populations (Cantu, 2012; Linley & George-Jackson, 2013; Morimoto et al., 2013). As a result, the National Science Foundation (NSF) began funding research to explore and address ways to change STEM institutional cultures and structures that disadvantage women and minorities because, “institutional transformation is needed to catalyze change that will transform academic environments in ways that enhance the participation and advancement of women in science and engineering”

(National Science Foundation 2001, p. 8). NSF research shows that institutional changes have a significant positive impact on feelings of inclusion and success measures for women and minorities (Wieman, Perkins, & Gilbert, 2010; Yelamarthi & Mawasha, 2010). Additional research suggests that type of higher education institution has an effect on female student success. For example, institutions that focus on the undergraduate population, instead of graduate programs and research, are correlated with higher female enrollment and success in STEM majors (Griffith, 2010; Sonnert & Fox, 2012). Altogether, meeting the needs of female undergraduate students requires a focus on the institution and movement away from a deficit model that views women as in need of "fixing" as discussed by Linley and George-Jackson (2013):

> Approaching the issue of underrepresentation and inequity in STEM in such a manner that will render intervention programs unnecessary should be a goal of institutions of higher education. However, without systemic change where cultural differences are managed, such programs and services will always be needed (p. 98).

This institutional ethnography expands the existing literature on female persistence and retention in STEM programs by exploring institutional factors that coordinate the work of being a female STEM student. By identifying how and where work is organized, described or directed, this study heeds the call for research on the experiences of female undergraduate students with a specific focus on the institution.

Statement of Problem

As a group, women who enter STEM fields as freshman are less likely than men to graduate with a STEM degree (Ceci et al., 2014; Gayles & Ampaw, 2014; London et al., 2011; Morgan, 2008). This leaky pipeline is indicative of a number of societal, institutional, and academic factors that prevent women from selecting STEM majors, while other women face pressure to change to a non-STEM major in the course of their undergraduate education. These factors lead to the core assumption of the proposed study: Female undergraduate students enrolled in Science, Technology, Engineering and Math (STEM) fields encounter distinctive challenges and obstacles to their success. The female student experience in STEM fields is uniquely problematic; and, while many institutions of higher education have implemented programs to improve the experience and persistence of women, the differential between enrollment and graduation between men and women persists. This gap persists because recommendations made and supported in the literature primarily focus on recruitment of women to STEM fields or on ways to make women more successful and comfortable in their STEM major (Mayberry, 1999). As a result, such recommendations are insufficient because they do not address the institutional factors that lead to a STEM environment and culture that is not welcoming for women.

Failing to address the factors that lead to a chilly climate and the leaky pipeline in STEM education means that social and academic interventions to improve the experiences of women will continue to be necessary, because institutional conditions that disadvantage women persist. Interventions will continue to fall short because a major portion of the chilly climate is a gendered institutional culture that forces women to attain a version of success that is defined by male-oriented standards. It is necessary to explore and understand the social, political, and scientific systems that are embedded within teaching and learning choices in order to remake the STEM classroom into a welcoming and comfortable environment for women (Linley & George-Jackson, 2013; Mayberry, 1999). That exploration requires a focus on the STEM education institution. This exploration of STEM education institutional factors provides insight into where the policies, processes, and procedures that coordinate the chilly climate are located and why the chilly climate persists in order to make recommendations to the field to improve the retention of female students.

Theoretical Framework

This study explores the experiences of female undergraduate students through the framework of feminist standpoint theory (Harding, 1987; Hesse-Biber & Nagy, 2014; Smith, 2005). Feminist standpoint theory provides the theoretical underpinnings of institutional ethnography, the methodology for the proposed study (Smith, 2005). Feminist standpoint theory emerged in the late 1970s as a response to Marxist feminism; by reworking materialism, feminist standpoint theory provides a lens through which to explore how power is gendered (Hartsock, 1987; Hesse-Biber & Nagy, 2014). The central premise of feminist standpoint theory is that knowledge develops from lived experiences, which means that it is complicated, contradictory, and contingent on social and historical context (Harding, 2004; Hesse-Biber & Nagy, 2014). As contextual, experience-based knowledge, standpoint theory does not privilege one dimension over another, and unlike essentialist feminist theory that seeks to identify a singular female experience, it is not additive or essentialist:

> Feminist standpoint is different from women's viewpoint or specific women's experiences . . . a standpoint is achieved as a consequence of self-reflective analysis from a specific social actor, social group, or social location rather than

> available simply because one happens to be a member of an oppressed group or share a social location. Rather than view standpoints as individuals' possession of disconnected actors, most standpoint theorists attempt to locate standpoint in specific community contexts with particular attention to the dynamics of race, class, and gender (Hesse-Biber & Nagy, 2014, p. 28).

As such, feminist standpoint theory goes beyond empiricism; knowledge of society comes from a certain position, and women are privileged epistemologically by being members of an oppressed group (Harding, 1987; Smith, 2005). As an oppressed group, standpoint theory asserts that women can see more clearly the forces that keep them oppressed because those forces directly affect their lives (Smith, 2005). This exploration of the STEM institution from the perspectives of female students is framed through feminist standpoint theory in order to explore the experiences of being a woman in STEM from women's perspectives as a traditionally oppressed group.

Institutional Ethnography

Research framed by feminist standpoint theory often incorporates an intersectional analysis of the structural aspects of social life, such as gender, race, ethnicity, and class (Hesse-Biber & Nagy, 2014). For Smith (2005), the feminist standpoint lens is the foundation for an everyday world sociology, the theoretical foundation of an institutional ethnographic exploration, which situates knowledge in women's experiences (Hesse-Biber & Nagy, 2014). The participant standpoint is understood as a site from which to begin a mode of inquiry (Harding, 2009; Smith, 2005). Inquiry begins with an active knower who is connected with other people in identifiable ways; her expressions are not disconnected from her social location and daily activities

(Smith, 2005). The researcher must pay attention to social relationship embedded in women's everyday activities in order to inform an exploration of how power dynamics are organized and experienced in a community context, the purpose of an institutional ethnography (Hesse-Biber & Nagy, 2014). With a goal of collapsing the duality (and hierarchy) of mind over body, research from the standpoint of the embodied knower begins in her experience where, "she is an expert" (Smith, 2005, p. 24). However, she is not an expert in the organizational forms that coordinate her daily activities and work. For institutional ethnography, identifying and exploring institutional factors that coordinate daily activities becomes the problematic, or the project of research and discovery according to Smith (2005), "working from the actualities of people's everyday lives and experience to discover the social as it extends beyond experience," (p. 10). An institutional ethnographic exploration seeks to uncover ruling relations, "the functions of 'knowledge, judgment, and will' [that] have become built into a specialized complex of objectified forms of organization and consciousness that organize and coordinate people's everyday lives" (Smith, 2005, p. 18).

This institutional ethnography of a STEM education institution through the framework of feminist standpoint theory shifts the standpoint of knowing, moving epistemic privilege away from one that is androcentric (Hesse-Biber & Nagy, 2014) to one that recognizes women's ways of knowing as equally valid (Belenky, Clinchy, Goldberger, & Tarule, 1997). Validating women's ways of knowing, "offer[s] alternative understandings of knowledge that expanded more positivist epistemologies, which, they argued, had relied on empirically positivist ideals" (Hesse-Biber & Nagy, 2014, p. 22). The shift away from androcentrism is especially important when exploring STEM fields.

Traditionally, epistemic privilege has been located in academic disciplines, such as physical sciences (Hesse-Biber & Nagy, 2014):

> The disciplinary training of many physical scientists eschews alternative paradigms of knowledge production and produces structural challenges to thinking and researching outside of these frames, thereby potentially limiting opportunity and ability to develop feminist ways of knowing in these disciplines. (p. 23)

Validating women's ways of knowing by exploring a STEM institution through women's perspectives provides important insight into the STEM institution structured around masculine epistemic privilege, although more than just epistemic privilege is involved, as knowledge and morality are bound in relationships (Gilligan, 1993). To gain insight into the epistemological privilege that exists in higher education, an institutional ethnography, "creates a point of entry into discovering the social that does not subordinate the knowing subject to objectified forms of knowledge of society or political economy" (Smith, 2005, p. 10). As my theoretical lens, I explored women's standpoints, "not as a given and finalized form of knowledge but as ground in experience from which discoveries are to be made" (Smith, 2005, p. 7). In that way, I began from the perspective of undergraduate female STEM students and explored their experiences as the entry point to understanding the STEM institution.

Research Statement

The purpose of this institutional ethnography was to uncover and describe the institutional practices of STEM education at a Midwest research university (hereafter referred to as MRU) from the standpoint of eight female undergraduate students.

Institutional practices consist of university, college, and department policies, documents, and procedures that organize day-to-day activities of students and faculty; those activities are referred to as “work.” Using the framework of feminist standpoint theory informed by Acker’s (2000) theory of gendered institutions, this study explored the everyday work of female undergraduate STEM students to provide a unique perspective on the STEM education teaching and learning environment. Data collection and analysis focused on how the interface between female students and STEM education was organized as a matter of everyday encounters between students, faculty, and administration through exploration of their experiences inside and outside the classroom (Smith, 2006). This exploration began with in-depth interviews of female undergraduate STEM students and extended, as the institutional processes shaping their experiences were identified, to classroom observations, additional interviews of students and faculty, and analysis of texts that mediate these processes (e.g., syllabi and student handbooks). I explored the institutional practices of administrators, faculty, staff, and students (e.g., the creation of plans of study; student counseling and advising; the selection of required courses, policies, such as those found in student handbooks; practices of student governance; the distribution of student work; and the teaching and learning environment, which included teaching methods, content selection, course documents, assessments, and grading).

Rationale

Calls for research at the institutional level have increased in order to re-make the STEM classroom into one in which women are welcome and comfortable. To challenge the existing social and scientific systems, it is necessary to explore and understand the social and political implications embedded within teaching and learning choices (Cantu, 2012; Griffith, 2010; Linley & George-Jackson, 2013; Mayberry, 1999). First, research needs to move beyond a focus on women as the problem and the assumption that the obstacles that impede women in STEM fields are innate or the result of gender role socialization. Instead, research needs to look at the institution and explore how women have collectively fewer opportunities in science (Campbell & Skoog, 2004). Second, research is needed from a feminist framework that explores the experiences of women in STEM education. Traditional methods of measurement, such as measures of academic success such as GPA and graduation rates, are insufficient to understand women's experiences (Nielson, Marschke, Shelf, & Ranking, 2005). This exploration requires qualitative data to provide the nuanced information necessary to comprehensively understand institutional factors that create marginalization of women in STEM fields. Third, an institutional analysis is critical in the context of race and socioeconomic status. As Keels (2013) concluded, gender is mediated by race and socioeconomic status; therefore, improving minority success requires extending the analysis beyond academic preparation to creating more supportive college environments (Keels, 2013). This analysis requires a system-wide investigation of the STEM institution; yet few studies have approached the gender gap in STEM education from such a systemic view. This study addressed that gap by exploring the experiences of undergraduate female STEM students from their perspectives through qualitative means, using interviews and observations. As an institutional ethnography, this study explored female students' perceptions and descriptions of their undergraduate academic work in order to understand the processes, policies, cultures, and environment of a STEM education institution that perpetuates marginalization of women. This study represents a movement that supports what Šidlauskienė & Butašova (2013) called “moving away from . . . ‘*fixing the women*’” (p. 53) and moving towards “*fixing the system*” (p. 53). Focusing on the institutional system is necessary, to understand how and why the gender gap exists and persists, for the purpose of making significant and meaningful recommendations.

Significance and Benefits of the Study

Understanding institutional policies and practices that marginalize female undergraduate students informs institutional transformation and interventions to improve the chilly climate and leaky pipeline and to subsequently improve female experiences, feelings of belonging, and academic success. Improving experiences of female undergraduate students has the potential to increase the number of female students who enter, persist, and graduate from STEM fields. As a result, increasing the number of female STEM graduates might have a positive impact on reducing a gender wage gap and fill anticipated STEM employment vacancies in the United States. While the wage gap is closing, it persists in American society at all levels of employment and across nearly every industry. Women earn, on average, $0.77 for every dollar a man makes (Corbet, 2014). The gender wage gap is greater in STEM fields, and it widens as the STEM worker ages and moves up through the ranks of management (Evers & Sieverding, 2014). One reason the gender wage gap persists is the absence of women in STEM fields, where salaries are often higher than in non-STEM fields (Zhang, 2008). Increasing the number of women entering and graduating from these STEM fields would have a significant positive impact on reducing the gender wage gap that persists in society (Zhang, 2008). Additionally, an increase in women's representation in STEM fields will bolster the United States’ ability to be innovative and competitive globally (Shapiro & Sax, 2011), by ultimately increasing the number of people entering science and engineering careers (Shapiro & Sax, 2011).

This study explored the experiences of undergraduate women in STEM fields to understand the processes that perpetuate a chilly climate and contribute to the leaky pipeline. Understanding those factors will help to make recommendations for STEM education to make institutional changes designed to meet the needs of women and improve their entry, persistence, and graduation from STEM fields. Facilitating increased women's achievement in STEM fields will help to reduce the gender wage gap and infuse the labor pipeline with greater diversity enhancing the United States' ability to compete in the global market.

Research Questions

This study explored the distinctive configuration of everyday problems and working solutions female STEM students create in order to understand institutional practices of their college, administration, and faculty organized by policy, administrative regulations and practices, professional philosophies, legislation, and so forth. This study was guided by the overarching research question: How do the STEM education institutional processes, policies, and structure organize and inform STEM teaching and learning at a MRU for female undergraduate students? Data collection and analysis were guided by the following supporting sub-research questions:

1. What STEM teaching and learning practices and processes characterize the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?

2. What STEM institutional cultural norms and standards organize and inform the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?
3. How is the relationship between STEM institutional practices related to the institutional practices of higher education as an institution? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?

Delimitations

This study explored the experiences of female undergraduate students at MRU, but it is not representative of the experiences of all women at all STEM institutions, all women at MRU, or female students at other institutional types, such as non-research institutions. Additionally, because demographics at MRU do not represent the ethnic diversity of the United States, this study was not able to deeply explore the intersectionality that is particularly important in understanding how minorities are marginalized in STEM education. Finally, this study focused on the mathematics and physics departments of the College of Arts and Science at MRU, which neglects the experiences of female undergraduate students in other STEM fields.

Definitions

Institution: “Clusters of text-mediated relations organized around specific ruling functions . . . a vast nexus of coordinated work processes and courses of action” (Smith, 2006, loc 309-325), which in this proposed study is STEM education.

Problematic: A noun rather than an adjective. Territory to be explored in the lived experiences of a group that is explored in an institutional ethnography (Campbell & Gregor, 2004; Smith, 2005). Problematic: used “to refer to these moments of disjuncture that arise when something which is happening locally is at odds with how it is known about officially or ideologically” (Waters, 2015, p. 135)

STEM fields: "Aligned with the NSF designations (2013), the academic majors identified as STEM included the general fields of agricultural science; computer and information science; engineering; consumer science; biological science; health, pre-health, and wellness; law, criminal justice or safety studies; mathematics and statistics; natural resources; and physical science." (Szelenyi et al., 2013, p. 858)

Text: “A document or representation that has a relatively fixed and replicable character . . . they can be stored, transferred, copied, produced in bulk, and distributed widely, allowing them to be activated by users at different times and in different places” (Smith, 2006, loc 663).

Work: People’s everyday “doings,” their daily activities (Smith, 2005, p. 36) and “‘what people do that requires some effort, that they mean to do, and that involves some acquired competence’” (Smith, 2006, loc 2155).

Conclusion

Using the framework of feminist standpoint theory, I explored the everyday “work” of female undergraduate STEM students to uncover and describe the institutional practices of STEM education at MRU from the standpoint of female undergraduate students. In Chapter II, I summarize the literature that informed and guided this study. In Chapter III, I describe the data collection procedures and analysis methods guided by

Smith (2005) and Carspecken (1996). In Chapters IV, V, and VI, I report key findings according to each of the research questions. Finally, in Chapter VII, I situate the findings within the literature in order to draw conclusions and make recommendations for the field of STEM in higher education research.

CHAPTER II

LITERATURE REVIEW

Through a framework of feminist standpoint theory informed by Acker's (2000) theory of gendered institutions, this study's goal was to uncover and describe the institutional practices of Science, Technology, Engineering, and Math (STEM) education at a Midwest Research University from the standpoint of female undergraduate students. Using the framework of feminist standpoint theory, the proposed study explored everyday "work" of female undergraduate STEM students to provide a unique perspective on the STEM education teaching and learning environment. This study is informed by prior research on STEM education, specifically on the institutional, societal, cultural, and pedagogical characteristics of STEM education that have maintained a gender gap, and interventions that have been found to reduce the STEM undergraduate gender gap. This study builds on and extends previous research with the goal of making recommendations to higher education that meet the needs of female STEM students.

This literature review will address the relevant body of research. First, I address how a neoliberal movement has shaped higher education policy and how neoliberalism interacts with a gendered STEM education institution, which informs understanding of the larger higher education institutional environment explored in Sub-Research Question 3. Second, I discuss the theory of gendered institutions and the STEM education institution as gendered, which informs understanding of the STEM education institution explored in Sub-Research Question 2. Additionally, I review research on the institutional and structural discrimination of women. Third, to inform my exploration of the STEM classroom environment guided by Sub-Research Question 1, I discuss the nature of female students in STEM education, reviewing different factors that often work to marginalize these women. Fourth, I discuss research on individual interventions that have improved the persistence, success, and graduation of female undergraduate STEM students, also informing my exploration of the STEM classroom environment in Sub-Research Question 1. Fifth, informing my exploration of each research question, I review the recent body of research: (a) addressing institutional interventions that improve female STEM experiences, and (b) call for institutional approaches to change and future research. Finally, I summarize the research as: (a) it specifically applies to the study in this report, and (b) informs the proposed exploration at an institutional level.

Neoliberal Policies in Higher Education

Exploring a STEM education institution requires understanding of the larger policy climate that guides STEM policies in that institution. In the United States, higher education management is organized in a capitalistic climate through a management culture that focuses on the consumer and accountability for results as well as competition with other service providers for customers and support (Tolofari, 2005). This capitalistic organization of higher education is defined as neoliberalism (Tolofari, 2005). These capitalistic policies are reflected in the public market through processes of New Public Management (NPM) which is organized around a neoconservative discourse that disconnects citizenship from universal social rights provided by the state (Griffith &

Smith, 2005). In a neoliberal state, an individual is responsible for him or herself. The key characteristics of NPM are:

- large scale privatization;
- marketization and managerialism;
- a shift to change management to maintenance management;
- cutting costs by maximizing resource use;
- a shift from input controls to output and outcome controls;
- the creation of quasi-markets and greater competition;
- devolution/decentralization (e.g. boards of governors);
- disconnection of policy creation, implementation, and enforcement processes; and,
- performance accountability such as employment contracts (Tolofari, 2005).

Proponents of NPM argue that these mechanisms are necessary to ensure efficiency and serve the needs of customers. Within NPM, accountability and progress are measured by a system of goals and targets (Riddell, Tinklin, & Wilson, 2005). This system is reflected in an audit culture, which mimics the organizational structure of market economy by emphasizing productivity, measures of performance output, and accountability (Giroux, 2014).

Neoliberalism in Higher Education

Applied to higher education, neoliberalism, “conceives of education as the faculty production of credit points (input) and the student consumption thereof (output), usually in the form of standardized units called courses or modules" (Lorenz, 2012, p. 612). This guides university policy as higher education institutions need to meet performance levels regarding research to attract high quality students and to maximize profit (Bessant, Robinson, & Ormerod, 2015). The market for funding responsibility has shifted to students, and higher education has seen fees and tuition continue to rise to cover teaching funding (Bessant et al., 2015). As a result, NPM manifests itself in a consistent increase in the cost of education, decreased faculty income, and increased student debt loads (Lorenz, 2012).

Neoliberal policies have a negative effect on students, even though neoliberal policies are ostensibly guided by empowering students as consumers. Neoliberal policies affect students by increasing class sizes, because larger classes per faculty member increases revenue; decreased student learning as class sizes increase; more online courses; pressure to meet the performance standards set by an audit culture; and pressure to graduate in 4 years (Giroux, 2014; Lorenz, 2012). Additionally, Giroux (2014) argued that in a neoliberal climate, higher education is accountable to the business world through private funding and by defining the student as a future valuable employee (Giroux, 2014). As a result, Giroux (2014) contended there has been shift in the focus on education, "Students in this corporate-driven world view are no longer educated for democratic citizenship. On the contrary, they are being trained to fulfill the need for human capital" (Giroux, 2014, p. 34). By focusing on employability, the value of a liberal arts education for students has been diminished (Giroux, 2014).

Neoliberalism and Gender

Finally, a neoliberal climate reinforces the masculine nature of higher education (Barry, Chandler, & Berg, 2007). The neoliberal focus on assessable outcomes marginalizes women by reinforcing the ideal academic image as one who is committed, competitive, single-focused, and individualistic (Thomas & Davies, 2002). This focus conflicts with feminine discourses; Thomas and Davies (2002) found that this led female faculty to feel marginalized because feminine discourses of empathy and support were silenced. Neoliberal policies also increase work of faculty, which puts additional pressure on anyone unable to devote all their time to work, such as those with greater family responsibilities (Thomas & Davies, 2002). Finally, efforts to reduce the marginalization of women in STEM are set within neoliberal policy. Neoliberalism can diminish those efforts because reform discourses such as accountability hide inequality of and challenges facing women in STEM (Barry et al., 2007). This study explores the institutional policies and procedures that coordinate work for female undergraduate students that are set within a neoliberal environment; it is important to understand neoliberal policies in order to explore how neoliberal policies interact with STEM in higher education for female students.

Gendered Organizations

A neoliberal policy environment complements the masculine nature of higher education; additional understanding of the nature of a masculine institutional environment is informed by the concept of gendered organizations (Acker, 2000). This concept (gendered organizations) informs this exploration of a STEM education institution to understand how institutional processes, procedures, and practices can be subtly discriminatory to female students within a neoliberal climate. Gender is present in an institution’s policies, distribution of power, practices, images, work ideologies, and processes (Acker, 2000, 2012; Britton, 2000; Britton & Logan, 2008). The theory of gendered organizations views gender as the foundation of organizational structure and work life, and understanding institutional processes as gendered helps to explain gender inequalities in organizations (Britton, 2000). Modern organizations are often gendered through a substructure:

> [It] consists of processes and practices of organizing that continually recreate gender inequalities. These processes and practices are supported by organizational cultures and reproduced in interactions on the job, shaped in part by the gendered self-images of participants. These gendering processes are, at a less visible level, supported by gender subtexts of organizing and a gendered logic of organization that link the persistence of gender divisions to the fundamental organization of capitalist societies (Acker, 2012, p. 218).

For example, Acker (2012) explored Oregon's state government systems and found that the Oregon state job classification system created a gendered division of labor, and with it, wage discrimination. Women's jobs were typically lower level, care-based with general descriptions, and placed in low wage ranges (Acker, 2012). In contrast, men's jobs had material or physical tasks, were described in more specific terms, and had higher wages (Acker, 2012). Acker (2012) found that gender directly affected this system by attributing more value to men's tasks. Likewise, in the gendered organization advantage, control, action, and identity are each patterned as male or female (Britton & Logan, 2008). Viewing an institution as gendered shifts the focus from the individual to the structure when exploring gender discrimination (Britton & Logan, 2008).

Within a masculine gendered organization, the ideal worker is often based on a masculine ideal (Acker, 2000, 2012; Britton & Logan, 2008). Embedded in job descriptions are expectations that appear to be gender neutral, such as, “arrive at work at a specified time; take breaks for lunch at certain times and for an agreed upon length of time; do the work assigned to you; the work has your undivided attention” (Acker, 2012, p. 218). However, these job requirements are not gender neutral, because they are built on the premise that the worker has no body or obligations outside of work, an ideal that men are more likely to fulfill (Acker, 2012). The definition of the ideal worker is part of the gendered subtext of organizations, which informs organizational logic that coordinates workers’ activities.

Higher Education Organizations as Gendered

According to the theory of gendered organizations (Acker, 2000), gender discrimination persists at all levels of higher education, because most institutions are structured according to white, heterosexual, middle-class male norms and standards:

> The segregation of academic disciplines and institutions, the construction of faculty and administrative roles in ways that are more consistent with men’s lives, and the maintenance of evaluation processes that disproportionately value the disciplines and activities that men dominate are all examples of how university structures and associated cultures and practices are gendered (Bird, 2011, p. 208).

Professional roles are segregated hierarchically just like traditional gender role categories, which perpetuates gender inequity in higher education (Šidlauskienė & Butašova, 2013). In higher education, male status is an administrative assumption: “administrative and social practices of the academic workplace thus tend to favour these men without question” (Šidlauskienė & Butašova, 2013, pp. 52-53). Additionally, higher education is uniquely gendered because power is diffuse and gendering occurs at departmental, college, and university levels (Morimoto et al., 2013). The diffuse nature of power in higher education institutions makes identifying and addressing male-based gender roles, policies, and standards difficult (Bird, 2011; Morimoto et al., 2013).

Within higher education, there is often a gendered division of work that is especially prevalent in STEM disciplines at doctoral/research universities. This division values male roles and work over female roles and work (Monroe et al., 2008). Service and teaching are thought of as female jobs and undervalued, while research is masculinized and more highly rewarded in the status hierarchy (Monroe et al., 2008). For example, female faculty members report doing more service than male faculty members, and their service work was often viewed as lower status when it came to tenure and promotion (Monroe et al., 2008). Similarly, women are often assigned undergraduate teaching tasks, while male faculty members spend more time on research (Carrigan, Quinn, & Riskin, 2011; Monroe et al., 2008). Men are frequently assigned or are allowed to choose tasks more valued for tenure and promotion such as research and teaching graduate students.

Moreover, devaluation of female roles is often an arbitrary judgment that is dependent on the gender of the individual making the judgment. Female faculty participants in Monroe et al.'s (2008) qualitative interviews identified a gender devaluation process, which subtly devalued women's work so that positions once deemed high-status became devalued when women assumed those roles. Participants reported that increasing the number of women in leadership roles (e.g., chair or dean) was a sign of genuine improvement, but in some cases, the role would be devalued or minimized by changing it from a power role to a service role when a woman held the position. When a man would hold these leadership roles, the position would convey power and status, but when a woman held these same roles, the service dimension was emphasized (Monroe et al., 2008). This shift was accomplished, in part, by attributions of female ascension to affirmative action efforts or central administration "power grabs," not accomplishments of women in these roles (Monroe et al., 2008, p. 220). Within the gendered higher education organization, the number of female faculty members and the number of women in leadership or administrative roles is often insufficient as a measure of gender equity because of gender devaluation (Monroe et al., 2008; Morimoto et al., 2013).

Finally, administrative and social practices favor men through formal policies and procedures such as work rules, labor contracts, management directives, job descriptions, and performance reviews (Šidlauskienė & Butašova, 2013). Men are also favored through informal practices such as rules of a work group, norms about how work is accomplished, work relationships, distribution of responsibilities, information about how to be promoted, and an organization's tacit criteria for commitment and ethics (Šidlauskienė & Butašova, 2013). One example of a gendered formal procedure is seen in job descriptions for academic authoritative positions, which seek masculine traits such as competitiveness, independence, aggressiveness, and neglects other traits that are equally applicable to job requirements such as collaboration and empathy (Šidlauskienė & Butašova, 2013). Within higher education, prestige and power are often assigned to men, ideals are male-normed, and women are frequently assigned positions with lower perceived status. This has consequences for men too, as men who take up roles considered to be "female" can be denigrated because they are doing women's work (Weaver-Hightower, 2011).

STEM Education

Gendered patterns in faculty and administrative roles are also seen, and often exacerbated, in STEM education including gender devaluation and formal administrative practices that favor men discussed previously. Additionally, existing research suggests that women in STEM education are more often assigned to less prestigious, less valued tasks—such as teaching undergraduates (Carrigan et al., 2011). For example, a study of full-time, instructional faculty with the rank of assistant, associate, or full professor in STEM disciplines at public and private doctoral/research universities found that women allocated a higher percentage of time than men to undergraduate instruction, and men allocated higher percentages of time than women to graduate instruction, research, and service/unspecified activities (Carrigan et al., 2011).

Research supports the theory that STEM education is a male-biased, gendered institution. The emergence of STEM education as gendered became more widely perceived following a report from a longitudinal study at the Massachusetts Institute of Technology (MIT), which found that women were systemically discriminated against in a pattern that had persisted for decades (MIT, 1999). Specifically, the MIT study found that many tenured women faculty felt marginalized and excluded from having a significant role in their departments, and this marginalization increased as they progressed through their careers (MIT, 1999). Additionally, this study found that marginalization was often accompanied by differences in salary, space, awards, and resources, with women receiving less than men despite equal professional accomplishments (MIT, 1999). This study spurred research analyzing STEM education institutions; resultant research reinforced the MIT committee's findings (Carrigan et al., 2011). As reported by Carrigan et al., numerous studies have identified a persistent gendered division of labor in academies, where research was considered men's work and valued and teaching and service were deemed women's work and devalued.

These gender inequalities have persisted into the 21st century. Despite widespread adoption of policies intended to create a more helpful and collegial environment, recent data indicates that discrimination persists in institutional discourses, policies, and practices (Allen, 2003; Yakaboski, 2011). First, discourse analysis of STEM education institutional texts have found that a hegemonic binary system persists in language use that reinforces a number of dualisms: men/women, lazy/hard worker, competition/collaboration, and active/passive (Allen, 2003; Yakaboski, 2011). These binaries place men at the center, with women and their actions continually referenced as off-center or as recognizable and definable by their difference from men (Yakaboski, 2011). The language used in STEM higher education reinforces and reproduces stereotypical gendered roles, while establishing lower expectations for men and installing higher, often unachievable ones, for women (Allen, 2003; Yakaboski, 2011). This happens because women are cited as having an advantage, because they enroll in higher numbers than men. As a result, women are treated as the majority, even though the institution often marginalizes them by expecting them to measure up to standards created by a male ideal. Second, Minerick, Washburn, and Young (2009) found that almost 40% of the female engineering and technology faculty they surveyed rated the institutional support they received as fair, poor, or very poor. Similarly, Monroe et al. (2008) found that faculty at University of California, Irvine (UCI) perceived that academia retained both overt discrimination (including sexual harassment) and subtle institutional and cultural forms of discrimination.

Finally, there is a perceived incompatibility between having a family and a career in science (Herzig, 2010; Moors, Malley, & Stewart, 2014; Stewart, 2014). A study that compared the job satisfaction and belonging for STEM and non-STEM postdocs found that low institutional support for family commitments was related to lower job satisfaction for both (Moors et al., 2014). The STEM female faculty studied also felt less belonging in their workplace than their male peers (Moors et al., 2014). At each level of STEM education institutions, gender discrimination persists and this discrimination affects experiences of female faculty and administrators. Understanding the gendered institutional environment informs understanding of the climate for female students. Gender discrimination that persists in STEM education creates an environment that is often discriminatory overtly and subtly for female students; exploring both aspects requires a focus on the institution.

Masculine epistemic privilege. Understanding the masculine nature of STEM education is informed by defining the masculine epistemology of scientific knowledge. Traditionally, epistemic privilege has been located in academic disciplines, such as physical sciences;

> The disciplinary training of many physical scientists eschews alternative paradigms of knowledge production and produces structural challenges to thinking and researching outside of these frames, thereby potentially limiting opportunity and ability to develop feminist ways of knowing in these disciplines (Hesse-Biber & Nagy, 2014, p. 23).

Scientific knowledge is based on notions of absolute truth and a single reality; it is presented as unbiased and factual, which prevents challenges to its validity and applicability (Hesse-Biber & Nagy, 2014). Scientific knowledge is examined through an empirical lens that provides a foundation for the scientific method where, “All knowledge derives from sensory experience, exists relatively uniformly outside of social contexts, and is validated as true by its replicability through objective measurements” (Hesse-Biber & Nagy, 2014, loc. 717). Empiricism informs the epistemic privilege of scientific knowledge because it is premised on experience as finite and replicable, on which its validity as knowledge rests (Hesse-Biber & Nagy, 2014). Critiques of positivist thought and challenges to traditional research critique two tenets of the scientific method: scientific objectivity and universality (Hesse-Biber & Nagy, 2014). These critiques focus on the myth of objectivity, the detachment of researcher and researched, and the existence of a truth that exists outside a researcher (Hesse-Biber & Nagy, 2014).

Scientific knowledge is framed within a masculine paradigm, and research and knowledge are framed to reinforce masculine stereotypes (Hesse-Biber & Nagy, 2014; Martin, 1991). For example, Martin explored gender stereotypes hidden in scientific language through her exploration of the human reproductive process. She found that textbooks described the reproductive process using gendered language that characterized female eggs as passive and male sperm as aggressive, despite research that indicated the process was more symbiotic (Martin, 1991). Similarly, theories about female organisms have traditionally reflected heterosexual and androcentric bias which privileges male sexual experiences and fails to acknowledge and adequately explain woman’s orgasm experiences (Hesse-Biber & Nagy, 2014). Through the presentation of scientific “fact,” women have been encouraged to think about gender in male-centric ways and prevented from challenging the characterization of knowledge, because it is framed as unbiased and objective. Through characterization of scientific knowledge as unchanging, and the language used to describe what is known, masculine privilege is epistemologically asserted in the sciences. Masculine epistemic privilege contributes to the gendered nature of STEM education and informs understanding of a masculine teaching and learning environment.

The STEM Education Gender Gap

STEM education is a gendered institution that systemically marginalizes women. Institutional, social, and cultural factors that negatively impact STEM female faculty, administrators, and staff may also lead to a teaching and learning climate that often marginalizes female undergraduate students. As a result, women are less likely to enter STEM majors, and those who do enter are more likely to change majors or leave college, a phenomenon defined as the "leaky pipeline" (Ceci et al., 2014; Gayles & Ampaw, 2014; Kreutzer & Boudreaux, 2012; London et al., 2011; Morgan, 2008). At each educational stage, such as the transition from elementary to middle school, fewer women indicate an interest in pursuing STEM fields. For example, in 2011-2012, 32% of female students switched from a STEM to a non-STEM major compared to 26% of their male peers (Chen & Soldner, 2014). This finding is especially true in undergraduate programs, when many women whose planned major was in a STEM field changed their majors to those in a non-STEM field (Griffith, 2010). Finally, graduation rates are lower for female science students. For example, in their study of postsecondary students enrolled in STEM fields in 1996, Gayles and Ampaw (2014) found that about 56% of male science majors completed a bachelor's degree in 6 years or less, while less than half of the women in the sample did.

Research does not support the conclusion that biological differences, namely female deficiencies, explain the STEM gender gap and leaky pipeline; rather, environmental factors contribute to STEM ability differences (Ceci et al., 2014; Riegle-Crumb et al., 2012). For example, in their life course analysis comparing women and men in math to men and women in non-math fields, Ceci et al. (2014) found that sex differences in spatial and mathematical reasoning did not stem from biological causes but that differences in math ability varied over different time periods and nationalities. Moreover, differences in college achievement tended to be unrelated to prior achievement. For example, in their analysis of transcript data of college students, Riegle-Crumb et al. (2012) found that prior achievement, as measured by grades, did not have a significant effect on the gender gap for physical science and engineering majors, whether or not researchers were focusing on high-achieving or average STEM male and female students. Prior academic achievement and biological factors do not explain the gender gap in achievement for STEM fields.

The STEM education environment has a significant impact, beyond biology and college behaviors, on the performance of women in STEM education. For example, London et al. (2011) found that among first-year undergraduate female students, perceived identity compatibility, perceived social support, and sense of belonging in a STEM major declined between the first and second semester. They also found that there was a significant increase in women's self-reported likelihood that they would consider dropping out of their STEM major before graduating (London et al., 2011). Societal and cultural factors, such as gender role socialization, and the STEM education environment have an effect on the leaky pipeline (Sax & Harper, 2007), increasing the likelihood women will leave STEM fields.

Intersectionality

Exploring intersectional factors such as race and class changes the picture of the gender gap even more. While research has found that women as a group are less successful than white male students as measured by grades and persistence, poor and non-white students have even lower success rates (Herzig, 2010; National Girls Collaborative Project, 2015). For example, only 11.2% of bachelor's degrees in science and engineering were awarded to minority women in 2012 (National Girls Collaborative Project, 2015). Intersectionality provides insight into how the interaction between different factors, socioeconomic status and ethnicity, might combine to change the gender gap in higher education: "Structural intersectionality refers to how multiple social systems intersect to shape the experiences of, and sometimes oppress, individuals" (Museus & Griffin, 2011, p. 7). Because an individual's sense of self is not solely defined by gender, and student identity is fluidly defined according to race, ethnicity, class, or other groups with whom she (or he) identifies (Armstrong & Jovanic, 2016; Museus & Griffin, 2011), gender, class, race, or age can each shape the experiences of female STEM students (Museus & Griffin, 2011).

Intersectionality creates a more nuanced view of marginalization of women in STEM and structures of power that influence epistemological privilege (Cho, Crenshaw, & McCall, 2013). For example, research has found that gender is related to the leaky pipeline and discomfort in STEM classrooms; class and race have also been related to those factors (Herzig, 2010). Similarly, women from lower income households score lower than their male and female peers in high school math and science courses ("State of Girls and Women in STEM," 2015). However, Litzler, Samuelson, and Lorah (2014) explored the intersectionality of gender, race, class, and academic background and found that White women had lower self-efficacy and self-confidence when compared to White men overall. Complicating this picture, other groups, specifically African American women, were similar to White men when student experience and GPA were similar. These findings suggest that the interaction between different aspects of student identity complicates the exploration of female STEM student success, specifically that previous academic experience can mediate other factors like race and class.

The intersectionality of social systems and their influence on experiences of women in STEM have only been briefly explored in the literature. Gender and identity are not fixed nor are they disconnected and unrelated to other aspects of an individual's identity, and that affects how individuals experience a STEM environment (Litzler et al., 2014). Understanding intersectionality "promotes greater understanding of how converging identities contribute to inequality" (Museus & Griffin, 2011, p. 10) and reinforces the need for qualitative research that explores how and why women experience challenges in STEM education. I focused on gender in this study, but my qualitative exploration of female undergraduate experiences in STEM allowed for the influence of intersectional factors to emerge and provide a more comprehensive picture of women's experiences.

Gender Socialization

While different aspects of student identity complicate understanding of the STEM gender gap, roots of the leaky pipeline have been related to gender stereotypes and role socialization that begins long before entering college and are often replicated and exacerbated in higher education (London et al., 2011). Gender role theory argues that men and women are socialized to assume gendered roles from birth and are rewarded for behaviors that align with those roles through socialization (Salee, 2011). For example, in family roles, boys learn to become providers for their family and girls learn to be caretakers (Sallee, 2011). Likewise, the gender socialization perspective indicates that women look to the example of their mothers and men to the example of their fathers in forming their educational expectations (Wells et al., 2011). Different treatment and social expectations are reinforced in educational settings, where girls are praised for being obedient, and boys, for their knowledge; girls are expected to be neat and tidy; boys are rewarded and girls punished for challenging the teacher; and boys are punished less often for breaking rules (Villalobos, 2009). Social role theory hypothesizes that women are trained to be "good" students who are quiet, responsible, and care about their grades, while boys are expected to be aggressive and outgoing (DuPre, 2010; Stoll, 2013). Additionally, children are socialized to believe girls are good at reading and writing, while boys are good at math and science (Kimmel, 2008; Villalobos, 2009).

As a result of different treatment and expectations, girls behave differently than boys in school. According to Villalobos (2009):

> Boys are also more likely than girls to challenge rules. For example, boys engage in more disruptive behavior in the classroom . . . Girls are three times more likely

> than boys to raise their hands in class, and they put more effort into neat handwriting, turning in complete homework, and eventually getting good grades – which they do consistently more than boys. (p. 33)

Different treatment has also been related to mathematic problem-solving strategies. Crombie and Gold (2001) found that compliance is negatively related to problem-solving competence; since girls are raised to be more compliant, they learn and demonstrate the algorithmic mathematic problem-solving strategies taught to them as children. However, adherence to those algorithmic strategies keep them from breaking algorithmic rules when approaching problems in advanced math courses, which negatively affects mathematic problem-solving abilities (Villalobos, 2009). Related to the reluctance to break rules, men have been found to be more likely than women to engage in risk-taking behavior; within families fathers monitor and protect their daughters from physical risk-taking more than their sons (Byrnes, Miller, & Schafer, 1999; Villalobos, 2009). However, because taking risks is often a part of advanced mathematic problem-solving, women's reluctance to take risks and their adherence to the algorithmic strategies they were taught as children has possible negative ramifications for creativity and risk-taking in mathematical problem solving (Villalobos, 2009).

Through school and society, socially constructed male and female identities affect what possible selves women imagine for themselves (Markus & Nurius, 1986). Possible selves are the possible future selves women and men imagine for themselves and inform understanding of personal motivation and goal setting (Markus & Nurius, 1986). Possible selves for women are often wives/mothers, careers in fields like teaching, administrative work, or nursing, or working mothers. Gender role theory restricts gendered outcomes to a binary, which has been criticized because gender is not static nor dualistic (Sallee, 2011). However, understanding role socialization in relationship to STEM education provides insight into the pressure female students often feel, because they feel like they are not inherently good at math and science, their career path should be in a humanities field, or their first priority should be starting a family (London et al., 2011).

In STEM education, gender role socialization is related to stereotype threat, where women feel that being a woman and being in a STEM field are incompatible (Deemer et al., 2014; Isaac et al., 2012; London et al., 2011; Yakaboski, 2011). For example, social role stereotypes such as “women have a natural ability with words” and “men have a natural aptitude for math” lead women to feel they are unable to be successful in STEM. Likewise, pressure to get married and start a family might be perceived as antagonistic towards a career in science, where it is perceived that academic work and research would come before or preclude having children. These social role stereotypes and pressures to meet them work against women in STEM fields and push them toward traditionally female-dominated fields such as education, nursing, the humanities, and soft sciences (London et al., 2011). Gender roles perpetuated in society are reflected in the major choices of women (Bobbitt-Zeher, 2007; Ceci et al., 2014; Morgan, 2008, Riegle-Crumb et al., 2012).

> There is a strong divide, particularly among university students, between two academic “futures”—one that emphasizes science, numbers, reasoning, and argument, and another that emphasizes culture, people, and self-expression—such that perceiving oneself as oriented toward one group is strongly and reliably negatively associated with perceiving oneself as oriented toward the other. This

> "divided future" appears to parallel gender stereotypes. The data are very consistent in revealing a "divide" between young women and men in the academic realms in which they rate themselves as strong. (Lips, 2004, p. 370)

The gender divide in choice of major exists across STEM majors; women are less likely to major in science, technology, engineering, or mathematics (STEM), with the exception of biology (Ceci et al., 2014; Zhang, 2008).

Stereotype threat is, "identifying one's self as a member of a subgroup such as black or white, male or female, and being aware of the existence of the negative stereotypes associated with that subgroup. The threat comes from the perceived risk of confirming those negative stereotypes by performing poorly" (Palumbo & Steele-Johnson, 2014, p. 2). Within higher education, stereotype threat (Carr & Steele, 2009) persists for female undergraduate students, and even if women do not endorse the stereotype, they may still feel at risk of confirming it (Isaac et al., 2012; Palumbo & Steele-Johnson, 2014). Stereotype threat has been found to decrease female performance in testing situations and in formulating problem-solving strategies (Quinn & Spencer, 2001). To have a negative effect on performance, the stereotypes do not have to be made explicit by men or other women nor must they be made explicit in a stereotype-related situation; just being in a male-dominated setting undermines women's performance and motivation in STEM fields (Deemer et al., 2014, p. 144).

Stereotype threat persists across STEM fields, such as physics (Kreutzer & Boudreaux, 2012) and computer science (Beyer, 2014), leading women who highly identify with the field to feel devalued and, more frequently, causing women to have academic self-concepts that are different than men's (Hazari, Sadler, & Sonnert, 2013;

Lips, 2004; Sander, 2012). For example, in their exploration of male and female college students enrolled in introductory English courses, Hazari et al. (2013) found that women, especially Hispanic women, had lower self-perceptions related to science. Similarly, Lips (2004) found that male college students rated themselves as stronger in the math/science/business domain than their female peers. For women, there is a limited realm of possible selves in math and science, which leads to difficulty in creating a science identity (Hazari et al., 2013; Lips, 2004). Gender socialization and stereotype threat result in a perceived incompatibility between their identities as women and the STEM fields, which results in fewer women pursuing STEM degrees. For women that enter a STEM field, they often feel that they do not belong and have lower confidence compared to their male peers. This study explores how the gendered patterns that begin before women enter higher education are reinforced and replicated in STEM education institutional practices.

Chilly Climate

The effects of stereotype threat and gender role socialization can be seen in the leaky pipeline, frequently preventing women from entering STEM fields or causing them to change majors, because female undergraduates feel their identities are incompatible with STEM education (Kreutzer & Boudreaux, 2012). Research suggests that one significant contributor to the leaky pipeline phenomenon is the male-normed and -dominated classroom environment, termed “chilly climate,” which are, “competitive, weed-out systems that are hierarchically structured with impersonal professors” (Vogt et al., 2007, p. 339). The STEM classroom is often male-dominated, highly impersonal and individualistic (Charleston et al., 2014; Herzig, 2010; Grossman & Porche, 2014;

Morganson et al., 2010; Vogt et al., 2007). While the competitive STEM academic environment is often accepted and even promoted at traditional research universities (Vogt et al., 2007), this chilly climate can also lead women to feel that they do not belong in STEM fields. For many female students, the competitive STEM environment is discouraging instead of motivating, female students do not have the social and emotional support they need to be successful, and they feel that they are not academically strong enough to be successful in the STEM industry (Sartorius, 2010; Shapiro & Sax, 2011). For example, Herzig's (2010) institutional ethnography found that graduate women in mathematics felt they did not belong in mathematics. Reinforcing these findings, Gayles and Ampaw (2014) found that campus climate and environmental factors negatively affected women's persistence in STEM majors. The chilly climate may prevent female students from feeling that they belong in STEM fields, which may have a negative effect on persistence and graduation (Sartorius, 2010).

Examples of STEM classroom practices that contribute to a chilly climate are weed-out courses, courses that grade on a curve, competitive environments, reliance on lecture as a teaching method, individualistic cultures, and comprehensive exams (Mervis, 2011; Morganson et al., 2010; Shapiro & Sax, 2011). Weed out courses are introductory STEM courses designed to be prohibitively difficult to push out students who are not ready for difficult upper division courses (Mervis, 2011). This practice can create a hostile environment that is negative for women and minorities because research has found that some "women do not find competition a meaningful way to receive feedback and may even find it to be offensive" (Shapiro & Sax, 2008, p. 8). The competitive nature of STEM courses are reinforced in a large, lecture-based classroom that reinforces the competition between students to be at the top of the class (Shapiro & Sax, 2008). Finally, competition in STEM classes is often reinforced through grading policies and a focus on individual achievement: “faculty in the sciences are more likely to grade on a curve, which promotes competition among students . . . [and] discourages collaborative work, instead reinforcing the notion that individuals should take responsibility only for their own learning” (Shapiro & Sax, 2011, p. 8). The chilly climate reinforces societal suggestions that women do not belong in STEM fields. The practices that characterize the chilly climate are symptomatic of the institutional discourses, practices, policies, and procedures that inform and guide those practices. This institutional ethnography explores the STEM climate through the experiences of female undergraduate students in order to connect the practices to the coordinating structures; once the factors are identified, recommendations can be provided to the institution for addressing them.

Interventions to Reverse the STEM Gender Gap

The chilly climate is seen throughout STEM education, and it has been the focus of interventions to improve the experiences of women in STEM education. Recent research suggests that that the gender gap in STEM education is deeply rooted in institutional factors. However, research on interventions to address the gender gap has largely focused on the individual female student, echoing a deficit model of female achievement that suggests that women need to adapt to fit into the current system of STEM education (Šidlauskienė & Butašova, 2013). The individual interventions that have been found to improve the experiences of women in higher education and contribute to their persistence in STEM fields include the presence of women as faculty and administrators, the inclusion of undergraduate research experience, social support systems, and inclusive and engaging classroom environments (Carrell et al., 2010; Charleston et al., 2014; Gorman et al., 2010; Tatum et al., 2013).

Female Presence

Research has consistently found that the increased presence of female faculty, graduate students, and administrators has a positive impact on the female student experience, performance, and persistence in traditionally male-dominated fields (Bird, 2011; Carrell et al., 2010; Charleston et al., 2014; Gorman et al., 2010; Griffith, 2010; Tatum et al., 2013). For example, Kreutzer and Boudreaux (2012) found that the presence of female faculty improved female GPA in STEM fields. In their case study at the School of Science at Stevenson University, Gorman et al. (2010) found that a high percentage of female members of faculty had a positive impact on student experience and retention. Additionally, Carrell et al. (2010) explored the experiences of United States Air Force Academy students and found that a female professor had a positive effect on female student performance and a negligible effect on male performance in STEM classes. The presence of female faculty increased the likelihood that high-performing female students would take future math and science courses and graduate with a STEM degree (Carrell et al., 2010).

Moreover, the presence of women has been linked to a positive impact on the learning of all students, because women were found to be more likely to use active learning and inclusive teaching methods (Tatum et al., 2013). Tatum et al. (2013) observed classes taught by male and female professors from the arts, humanities, social sciences, and natural sciences and found that male and female professors behave differently; female faculty followed up on comments, praised participation and provided more corrections to students than male faculty. In addition, students voluntarily called out answers or responded to questions almost four times more frequently in courses taught by female professors when compared to courses taught by male professors. Students in female-taught courses engage in more frequent participation.

Interventions that increase the number of female faculty and administrators and residence life communities that focus on providing female support have been implemented to improve female experiences in STEM education. The positive impact of female faculty is higher for women in single-sex classrooms, which maximize the experience and performance of female students (DuPre, 2010; Morganson et al., 2010; Tatum et al., 2013). In their quantitative analysis of women enrolled in a single-sex program at a co-educational university, Rosenthal et al. (2011) found that perceived social support from close others and people affiliated with a single-sex program predicted women's engagement in their first year of college. They concluded that single-sex programs might successfully focus on identity compatibility and social support, which increased engagement of college women in STEM majors (Rosenthal et al., 2011). Altogether, the presence of female faculty improves the experiences of female STEM students.

Related to research that found that single-sex classrooms have a positive impact on female student performance and persistence is research on living learning (L/L) communities (Szelenyi et al., 2013; Szelenyi & Inkelas, 2011). L/L communities are residence hall associations where students from the same program live in the same housing unit or cluster of units; often these clusters are single-sex (Szelenyi et al., 2013). Research has consistently found that participation in these communities has a positive impact on female student persistence and academic performance. For example, using data from the 2004–2007 National Study of Living Learning Programs (NSLLP), women's participation in women-only STEM-focused L/L programs was positively associated with plans to attend graduate school (Szelenyi & Inkelas, 2011). Szelenyi et al. (2013) compared students at 34 campuses who either participated in their institution's L/L programs or lived in a traditional residence hall. They found that participating in a coeducational STEM L/L program had a positive relationship with female student perceptions of their own employability and future success, and participation in a women's only L/L community had a positive impact on plans to attend graduate school (Szeleny et al., 2013). These findings suggest that participation in an L/L program has a positive impact on female undergraduates, but more research is needed on whether the L/L community needs to be single-sex to maximize benefits.

Undergraduate Research Experience

Another factor that has a positive impact on female performance and persistence in STEM fields is undergraduate research experience (Campbell & Skoog, 2004; Deemer et al., 2014; Yelamarthi & Mawasha, 2010). Undergraduate research experience (URE) is hands-on research conducted with faculty who provide undergraduate students the opportunity to apply what they are learning and build relationships with faculty. Undergraduate research experience for women is related to increased confidence in the scientific research process, development of basic laboratory skills, and maintenance of interest in science, all of which contribute positively to pursuing graduate study and STEM careers (Harsh, Maltese, & Tai, 2012). In a study of 439 female undergraduate students at universities in the northwest, southeast, and southwest United States, Deemer et al. (2014) found that extended exposure to scientific research was an important step in the decision-making process for women contemplating science careers. They found that women with undergraduate research experience were more likely to choose a STEM career. Supporting those findings, Harsh et al. (2012) conducted a longitudinal study of practicing scientists and graduate students; they found that women were more likely to participate in undergraduate research than their male counterparts, and that participation in undergraduate research had a positive impact on their self-efficacy, science interest, and plans to pursue graduate studies in STEM. Finally, research suggests that undergraduate research positively impacts the experiences of all minorities, including women. For example, Hernandez et al. (2013) found that research experience was positively correlated with motivation, academic success, and persistence in STEM fields among high-achieving African American and Latino undergraduates in STEM disciplines, from 38 institutions in the United States (Hernandez et al., 2013).

Support Systems

Support systems, such as those developed by women in single-sex classrooms and L/L communities, improve female persistence and feelings of inclusion in STEM fields (Borum & Walker, 2012; Keels, 2013; Morganson et al., 2010; London et al., 2011). Perceived support counteracts the chilly climate and is integral to female students' feelings of belonging, self-efficacy, self-confidence, and social coping (Borum & Walker, 2012; Morganson et al., 2010; Szelenyi et al., 2013). Strong support systems and networks positively impact female persistence, both inside and outside of the classroom (Gayles & Ampaw, 2014). Support systems promote persistence by focusing on social coping and feelings of inclusion (Keels, 2013; Morganson et al., 2010). For example, Morganson et al. (2010) suggests that women are often uncomfortable in higher education and especially the STEM classroom, because the coping strategies they are accustomed to are not supported by universities. Social coping, or seeking support from others, is more important for female students; social coping predicted persistence outcomes such as commitment and turnover intent for women more than for men (Morganson et al., 2010). The importance of support systems was reinforced and extended to all minorities in a study of students who attended coeducational predominantly white institutions (PWIs) (Keels, 2013). Keels (2013) found that the significance of gender depends on race and socioeconomic status. This finding suggests that improving minority success, including women, requires extending the analysis beyond prior academic preparation to creating more supportive college environments. Much of that support can come from faculty inside and outside of the classroom, but can also be found in support service programs and peer networks (Morganson et al., 2010; Szelenyi et al., 2013).

Mentoring, when a more experienced or knowledgeable person guides a less experienced or knowledgeable person, is one type of support system that has been found to enhance female undergraduate STEM success and persistence (Borum & Walker, 2012; Campbell & Skoog, 2004; Cantu, 2012; DuPre, 2010; Gorman et al., 2010; Griffin, Perez, Holmes, & Mayo, 2010; Morganson et al., 2010). Multiple studies reinforce the notion that support coming from one-on-one and group mentoring with female faculty has a positive relationship with female persistence, feelings of belonging, confidence, and pursuit of a STEM career or graduate degree. For example, in a study of 12 black women with doctoral degrees in mathematics, mentoring was an important component of student persistence in mathematics graduate programs because it minimized feelings of isolation (Borum & Walker, 2012). Graduates from STEM programs reinforce those results. In a study of black faculty members, they indicated that mentoring and advising during their education was critical to their success (Griffin et al., 2010). Support systems designed for women and minorities improve the experiences, academic success, and persistence of female undergraduate STEM students.

Teaching and Learning

Although the presence of female faculty has a positive impact on female performance, research suggests that all faculty can support gender equity in the classroom through interventions targeted at enhancing student self-efficacy for success (Vogt et al., 2007). Through inclusive pedagogy, male and female professors can encourage women to recognize their competence and men to be more realistic about their expectations for themselves (Hogue, Dubois, & Fox-Cardamone, 2010). Classroom environments that engage students through active learning and inclusive teaching are especially promising.

In a study of 2,873 students taking introductory STEM courses across 15 colleges and universities, Gasiewski et al. (2012) found that when professors utilized active learning by encouraging a collaborative learning environment, providing immediate feedback, and formative assessment, female and minority students became more engaged (p. 252). Active learning, a teaching strategy that focuses on learners actively engaging with content knowledge through reading, writing, or problem solving, is an important aspect of female student success in STEM settings (Gasiewski et al., 2012; Vogt et al., 2007). Additionally, in their exploration of engineering students at west coast universities, Vogt et al. (2007) found that classroom environment had a positive effect on female student GPAs and self-efficacy by promoting help-seeking behaviors, critical thinking, and effort. Kreutzer and Boudreaux (2012) explored the experiences of students in introductory physics courses and found that the gains of female students were equal to male students in courses that incorporated interactive engagement. Finally, the relationship between active learning and female student achievement was reinforced by the National Research Council who recommended that active learning be used in the STEM classroom to enhance learning for all students (Beach, Henderson, & Finklstein, 2012).

Equally important for female success is inclusive teaching, a teaching approach that focuses on engaging all students regardless of background, learning style, and ability (Grossman & Porche, 2014; Kreutzer & Boudreaux, 2012). For example, Grossman and Porche (2014) explain how messages from teachers, counselors, and families about STEM engagement and achievement can help counteract stereotypical gender and racial/ethnic expectations. Focusing on engagement and achievement, these messages focused on the student's STEM pursuits and helped them identify micro-aggressions, rather than internalize negative messages about their group (Grossman & Porche, 2014). Kreutzer and Boudreaux (2012) explored the experiences of students in introductory physics courses and found:

> To support gender equity in the classroom, instructors can cultivate optimistic student-teacher relationships, affirm domain belongingness in women, practice nonjudgmental responsiveness, value multiple perspectives, and emphasize the expandability of knowledge (p. 5).

Research has found that including a course just for STEM undergraduate female students with an explicit focus on gender bias has a positive impact on female students' self-efficacy and confidence (DuPre, 2010; Isaac et al., 2012). Self-efficacy is a "person's beliefs in his/her capacity to complete certain tasks required to reach specific attainments within a particular domain" (Litzler, Samuelson, & Lorah, 2014). For example, Isaac et al. (2012) found that a course focused on gender bias awareness and aimed at increasing leadership self-efficacy in women, taken at the beginning of their careers, resulted in an increase in female participants' self-efficacy. Inclusive teaching has a significant positive impact on female performance and promotes male recognition of their part in promoting the male-normed climate that is hostile to female students.

Increasing the number of female faculty, providing support systems for female students, single-sex classrooms, Living/Learning communities, and undergraduate research all have been implemented have resulted in improved performance, retention, and feelings of support for female STEM students. Research on and implementation of these interventions are positive signs. They signify a recognition that a chilly climate exists for some female students and that efforts are being made to improve the experiences and retention of women in STEM. In addition, these interventions are and will continue to be necessary to support female STEM students; research suggests that women often need more and different support to be successful in STEM. As a result, there is overlap between individual and institutional approaches. However, much of the existing research on interventions to improve the retention and performance of female STEM students has focused on the individual female student as in need of "fixing" (Sidlauskiene & Butasova, 2013). As a result, the external interventions proposed have focused on retention, female representation, graduation rates, and academic performance as outputs that measure female success in STEM. These interventions do not address the institutional factors that lead to these interventions being necessary. This institutional ethnography explores institutional factors to identify the institutionalized discourses, practices, policies, and procedures that make these interventions necessary.

Institutional Transformation

Aligned with calls for a focus on institutional factors, recent efforts on reversing the gender gap focus on the institution. The institution is considered by some to be the root of discrimination against women in higher education. An institutional focus on reversing the gender gap in STEM fields is an approach that goes beyond a traditional focus on the individual female undergraduate student. However,

> many STEM programs focus only on increasing representation and not on the institutional issues that are barriers for many students, such as racism and sexism . . . However, programs that overlook issues of systemic oppression can be problematic, as they fail to foster long-term and enduring equitable opportunities for traditionally underrepresented students to succeed in STEM. Approaching the issue of underrepresentation and inequity in STEM in such a manner that will render intervention programs unnecessary should be a goal of institutions of higher education. However, without systemic change where cultural differences are managed, such programs and services will always be needed (Linley & George-Jackson, 2013, p. 98).

Acker’s (1990) theory of the gendered organization informs the focus on the institution over the individual. Because gendering processes operate at the surface (e.g., individual needs, gender composition) and at deep levels (e.g. embedded ideals of the ideal student, faculty member, and higher education ideologies), transformational efforts and programs must address both levels to affect change (Morimoto et al., 2013, p. 410). These attempts focus on changing the institution itself into an institution that is not only inclusive for non-male and non-white students, but also supports women, validates their knowledge and experiences, and gives them an equal voice (Sidlauskiene & Butasova, 2013). Many of these efforts include individual interventions listed previously, but the motivation for implementing those interventions is changing the system instead of remaking the woman to fit the current institution (Bird, 2011).

Broadly, institutional transformation can be defined as,

> planned alterations in core elements of the institutions: authority, goals, decision-making practices, and policies. Transformational change addresses changes in daily operations, but also changes organizational culture, customs, norms, communication style, reward structures, and ways of thinking (Morimoto et al., 2013, p. 398).

Those transformations require transformation at three levels: student, faculty, and institution (Whittaker & Montgomery, 2013). For example, faculty transformation might include teaching and mentoring, different from the interventions listed previously because they are one part of larger institutional change (Whittaker & Montgomery, 2013). One such university, University of Maryland, Baltimore County (UMBC), is touted as an exemplary model of institutional change. UMBC's institutional change was guided by their goal to develop an environment that empowers students, which UMBC called “inclusive excellence” (Habrowski & Maton, 2009). Inclusive excellence focuses its mission, values, norms, policies, processes and traditions on students, faculty, and administrators to change the culture of the institution (Habrowski & Maton, 2009). Institutional change requires support from the entire department, school, and institution (Wieman et al., 2010). Effective methods of institutional change include the empowerment of STEM faculty and administrative decision makers, organizational structure changes, clear career progression paths, female faculty, policies that support work-life-family balance, consistent progress reports, and the establishment of clear indicators of success (Sidlauskiene & Butasova, 2013).

The need for an institutional focus on reducing the STEM gender gap is reinforced by the National Science Foundation's (NSF) conclusion that only institutional transformation will ensure equal opportunities for women and men in STEM academia (Carnes et al., 2012). One study funded by the NSF explored the Computer Science, Engineering, and Mathematics Scholarship (CSEMS) program at Wright State University (WSU) as a recruitment and retention model in the STEM disciplines (Yelamarthi & Mawasha, 2010). The program removes artificial barriers, rewards performance, and provides non-threatening environments for females and minorities through scholarship programs, career orientation workshops, participation in co-op and internship programs, and academic and social support (Yelamarthi & Mawasha, 2010). Through institutional changes the environment and culture has become increasingly inclusive for both women and minorities, which had a measurably positive impact on enrollment, retention, and performance (Yelamarthi & Mawasha, 2010). Wieman et al. (2010) reinforce the importance of institutional change for gender equality in STEM education and found that when gender equality is a priority for the entire department, teaching improvements were more successful. This reinforces the importance of an institutional focus on research and change, demonstrating that gender equality changes needed to both start at and focus on the institution. The institutional factors related to institutional change are an institutional focus on the undergraduate population, achieving a critical mass of female faculty, practices of HBCUs, and changes in institutional culture at the department level.

Institutional Characteristics

An institutional focus on the undergraduate population and teaching is related to improvements in female student academic performance and persistence (Griffith, 2010; Sonnert & Fox, 2012). Griffith (2010) found that students at selective institutions with a higher undergraduate to graduate student ratio are more likely to remain in a STEM major and female STEM undergraduates have higher GPAs (Sonnert & Fox, 2012). Undergraduate students attending colleges or universities with a focus on teaching and research are more likely to remain in a STEM major, while those attending institutions with more emphasis on graduate programs (as is the case in many of the selective institutions in the NLSF sample) are less likely to remain in a STEM field major (Griffith, 2010). Female STEM students are more likely to persist at institutions with a higher ratio of female to male STEM graduate students (Griffith, 2010). Altogether, research suggests that an institutional focus on undergraduate students, specifically women, has a positive effect on their success and persistence.

Critical Mass

A second institution-level factor that has a positive impact on women in STEM is the achievement of a critical mass of female faculty, administrators, and students (Carrigan et al., 2011; Charleson et al., 2014; Mervis, 2011). Critical mass is achieved when female faculty or students make up 15% or more of a population (Carrigan et al., 2011). Research has found that a critical mass of women in a discipline challenges traditional gender stereotypes and diminishes inequities between male and female faculty, which has the potential to result in cultural transformation of the gendered higher education institution (Carrigan et al., 2011). Calls for a critical mass of female faculty echo national calls for greater parity in representation among faculty and students of color within computing programs and the information technology industry in general (Charleston et al., 2014).

Historically Black Colleges and Universities

HBCUs have also been found to have a positive impact on black female STEM persistence and success (Borum & Walker, 2012; Jackson, 2013; Perna et al., 2009). For example, a case study analysis that explored the ways that Spelman College, a historically Black women's college, promoted the attainment of African American women in STEM fields found that institutional characteristics and practices supported female success (Perna et al., 2009). Their practices included a cooperative instead of competitive environment, faculty involvement and commitment to student success, student support services, and undergraduate research opportunities (Perna et al., 2009). As institutions, HBCUs have many of the individual interventions previously discussed that support female achievement, but have implemented them as a part of an institutional focus on female student success that includes structures, policies, and procedures. As a result, HBCUs have a strong record of female student persistence and academic success in STEM fields (Perna et al., 2009). Reinforcing those findings, Jackson's (2013) qualitative analysis of female STEM students found that HBCUs support the success of female STEM students by building career capital, supporting the development of a STEM identity, and keeping them informed about the field (Jackson, 2013). The inclusive and supportive environment at HBCUs is supported by smaller class sizes and nurturing environments, which have a positive impact on female STEM students pursuing graduate degrees (Borum & Walker, 2012).

Departmental Change

Along with institutional characteristics, institutional change at the departmental level has been found to positively impact a chilly climate. Changes in institutional culture require attention to the inclusion and support of diverse faculty, and faculty development that focuses on diversity (Thomas, Bystydzienski, & Desai, 2014). First, mentoring of historically marginalized faculty members is one way to include diverse faculty in the department culture and improve bias literacy among existing faculty (Monroe et al., 2008; Thomas et al., 2014). Second, faculty development should be implemented and assessed as part of an institutional agenda that focuses on equity and diversity with an emphasis on systemic change (Whittaker & Montgomery, 2013). One example of this change is bias literacy, or the ability to identify personal biases, and create a plan of action to reduce those biases for faculty and the institution (Carnes et al., 2012). Instituting bias literacy programs at the college level has a positive impact on departmental equity, leading to an increased involvement in activities that promote gender equity (Carnes et al., 2012; Charleston et al., 2014). Finally, it is important that higher education institutions have policies in place that support female faculty and administrators (Minerick et al., 2009; Monroe et al., 2008). For example, Monroe et al. (2008) calls for higher education institutions to create policies for maternity and family leave time with legal mechanisms in place that support those policies. It is important to have policies in place that support alternative tenure tracks for faculty members who take time off to have a family (Monroe et al., 2008). These efforts are important for the student environment as well; addressing the gendered institution at each level will reduce the effects of the gendered institution for female students.

These institutional changes seek not only to improve the experiences, retention, and performance of women in STEM but also institutional gender equity. As a result, reaching critical mass, changing discourses, and revising policy also results in improved retention, performance, and comfort for female students but does so by affecting change at the sources of inequity. Institutional changes within a gendered organization require that the gendered practices are identified; identification precedes any recommendations for change that can improve gender equity through institutional transformation. To extend the research on the institutional changes found to affect the gendered institutional STEM practices, this institutional ethnography seeks to identify the institutional roots of challenges for female students in order to make recommendations for institutional transformation.

Conclusion

As an institution, higher education and specifically STEM education is discriminatory towards women, both faculty and students. For female students, gender role socialization has resulted in fewer students pursuing STEM degrees, and stereotype threat (combined with the chilly climate in STEM classrooms) reinforces societal gender roles that tell women they do not belong in STEM fields. The chilly climate often has a negative effect on female student confidence and feelings of inclusion, which encourages them to change their majors. Addressing the gender gap and leaky pipeline in STEM fields has largely focused on individual interventions that encourage the woman to make changes, such as through social coping, to be able to thrive in the existing STEM environment. However, such remedies fail to see the institution itself as problematic and have not been largely successful in reversing the gender gap in STEM fields. While individual interventions are important, they precede necessary institutional changes that need to occur in order for a reversal of the gender gap. Institutionalized policies, processes, attitudes, environments and cultures contribute to a STEM education environment that is hostile for women. Institutional transformation is required to make STEM education an inclusive, safe and equitable environment for female students and faculty.

By identifying how and where work is coordinated, this study heeds the call for research on the experiences of female undergraduate students with a specific focus on the institution. In order to make recommendations for transformational efforts and programs, qualitative interviews, observations, and document analysis focused on identifying the gendering processes that operate at the surface (e.g., individual needs, gender composition) and at deep levels (e.g. embedded ideals of the ideal student, faculty member, and higher education ideologies). Institutional change must address both levels to affect change. This institutional ethnography expands the existing literature on female persistence and retention in STEM programs by exploring the institutional factors that coordinate the work of being a female STEM student. It is by identifying these institutional characteristics that recommendations can be made for institutional transformation to improve the experiences, success, persistence, and graduation rates of female STEM undergraduates.

CHAPTER III

METHODS

As a feminist research method, institutional ethnography is motivated by, “a deep commitment to understanding the issues and concerns for women from their perspective, and being especially attentive to the activities and the ‘goings on’ of women in the research setting” (Hesse-Biber & Nagy, 2014, p. 113). By combining a feminist standpoint lens and feminist ethnographic research practices, the data collection and analysis methods used in this study grounded knowledge in the experiences of female undergraduate Science, Technology, Engineering, and Math (STEM) study participants to provide a unique perspective on the STEM education teaching and learning environment (Nielsen, Marschke, Shelf, & Ranking, 2005). Through a focus on the STEM female undergraduate experience at a Midwest Research University (MRU), I explored participant experiences as an entry point to understand how their everyday activities or work, were shaped by, constituent of, and in some way embedded in the STEM institution (Smith, 2006). Using the work of undergraduate participants as the starting point, I gathered data that identified the institutional processes that shaped the experiences and work of female undergraduates (Smith, 2006). Through an iterative process, where the data gathered and analyzed informed each stage of collection, I revisited the field to conduct additional interviews, classroom observations, and identified texts that helped me clarify and understand the institutional practices and policies that coordinated female undergraduate experiences. In this chapter, I describe the research questions, data collection procedures, participants, and data analysis methods that led to my findings.

Research Questions

Overarching research question: How do the STEM education institutional processes, policies, and structure organize and inform STEM teaching and learning at MRU for female undergraduate students?

Sub-research questions:

1. What STEM teaching and learning practices and processes characterize the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?
2. What STEM institutional cultural norms and standards organize and inform the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?
3. How is the relationship between STEM institutional practices related to the institutional practices of higher education as an institution? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?

Research Purpose

The purpose of this study was to uncover and describe the institutional practices of STEM education at MRU from the standpoint of female undergraduate students. Research focused on how the interface between female undergraduate STEM students and STEM education was organized as a matter of the everyday encounters between students and faculty and administration inside and outside of the classroom (Smith, 2006). I explored the institutional practices of administration, faculty, staff and students:

- The creation of plans of study;
- Student advising;
- The selection of required courses, policies such as those found in student handbooks;
- Practices of student governance;
- The distribution of student work, and
- The teaching and learning environment (which included teaching methods, content selection, course documents such as syllabi, assessments, and grading).

Procedures

I used purposive and snowball sampling methods to identify study participants. Upon receipt of IRB approval in June 2015, I began reaching out to faculty in math and physics via email at MRU with a request to meet and discuss my research, the potential to observe their math or physics courses in the fall, to ask if they would be willing to be interviewed for the study, and to ask for help recruiting students. I sought faculty help in order to identify initial interview participants who were able to provide insight into their experiences as undergraduate students, which required attention to their ability to communicate as well as their role(s) as STEM undergraduate students (Creswell, 2013). Faculty participants were identified according to their ability to provide insight and information into the processes identified by undergraduate students, for example I identified faculty members teaching undergraduate courses through the department websites who could speak to the classroom environment described by participants.

In June and July, I met with three faculty members, one from math (Ronald; all participant names are pseudonyms) and two from physics (Myles and Karl) who agreed to allow me to observe a course they were teaching in the fall and also agreed to send the study information to math and physics majors, so that those interested could email me to learn more about participation. From those initial meetings, three of my physics undergraduate participants and two of my math undergraduate participants eventually reached out to me via email to indicate that they would be interested in participating in the study. Myles and Ronald also agreed to participate in interviews after the first stage of data collection was complete.

Throughout the summer, I continued reaching out to professors, and met with a math professor in August 2015. While she felt her classes were too small for me to observe as a representation of math courses at MRU, she recommended that I reach out to Calculus I and Sets instructors. She felt observations of those courses would be valuable for this study because those courses represented the two key points in the socialization process for math majors. Math majors often struggled in these courses because they required new ways of thinking about math. From those recommendations, I reached out to the Calculus I and Sets professors and two calculus professors agreed to participate in the classroom observations (Jonathan and Thomas). Upon receiving consent from each professor who agreed to participate in the observations, I observed each of them the first week of class fall 2015 and conducted subsequent observations over the course of the fall semester. Three of the four also sent me their course documents (and syllabus and handbook, if applicable), which I included in my document analysis. To identify professors to interview, I continued reaching out to math and physics professors during September 2015, and identified two additional physics professors and one math professor who agreed to be interviewed (Nigel, Wilson, and Gilbert).

To recruit additional undergraduate participants in September 2015, I sent two additional recruitment emails to freshman math and physics majors. One math and onephysics student emailed to indicate their interest in participating in the research. Finally, also in September, I reached out to an additional physics major and emailed her directly, asking her to participate in the research, and she agreed.

Participants

Undergraduate participants were undergraduate students from MRU majoring in math and physics. Undergraduate participants were four physics majors, three math majors, and one math/physics double major (not identified to protect participant confidentiality). They participated in one to three interviews beginning in August 2015 and concluding in December 2015 (fall semester). Faculty participants for interviews and classroom observations were faculty from MRU from the math and physics departments. Four faculty participants were from physics and four faculty participants were from math. See Tables 1 and 2 for participant descriptives.

Table 1. Undergraduate Student Participants.

Pseudonym	Major	Number of Interviews	Class Standing	Background
Emma	Math	3	Senior	Large town
Olivia	Physics	3	Junior	Small town
Madison	Math	3	Senior	Large town
Darcy	Math	3	Senior	Large town
Betsy	Math	1	Freshman	Large town
Julie	Physics	3	Junior	Small town
Michelle	Physics	3	Senior	Small town
Samantha	Physics	2	Freshman	Large town

Table 2. Faculty Participants.

Pseudonym	Department	Participation
Myles	Physics	Interview/Observation
Nigel	Physics	Interview
Gilbert	Mathematics	Interview
Karl	Physics	Interview
Ronald	Mathematics	Interview/Observation
Jonathan	Mathematics	Observation
Wilson	Physics	Observation
Thomas	Mathematics	Observation

Context

Field, or the setting where the research takes place, is an important consideration in an institutional ethnography, as it should represent a “natural setting of the people and processes the ethnography is interested in learning about” (Hesse-Biber & Nagy, 2014, p. 120). To explore the experiences of STEM female undergraduate students, I selected

MRU as the setting because it is a flagship research university with undergraduate programs in STEM fields (MRU website). According to the institution's website, MRU's Carnegie classification was large, 4-year, primarily residential public research institution.

According to MRU's website, in 2015, students represented all 50 states; of around 15,000 students, slightly less than half were female and around three-fourths were undergraduate students. The majority of students at MRU identified as white (around 80%). Non-white students identified with the following categories: 7% international students; around 2% American Indian/Alaskan Native, Asian, Black/Non-Hispanic American, multiracial; and less than 1% Hawaiian/Pacific Islander. The average age for female undergraduates was 22. MRU has six colleges, a medical school and a law school. Within the STEM fields, MRU offers undergraduate degrees in Computer Science, Atmospheric Sciences, Biology, Chemistry, Mathematics, Physics and Astrophysics, Geology, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Geology, and Petroleum Engineering.

Math and physics are both located in the same college, Arts and Sciences. I chose those departments for this study because they are both located in the same college and I anticipated that they would experience similar institutional processes and procedures at the collegiate and institutional level. Additionally, prior research has been conducted on the chilly climate and leaky pipeline in math and physics, which informed my analysis and conclusions. Nationally, in math and physics in 2011-12, of the 18,842 bachelor's degree in math awarded, 8,119 (43.09%), were awarded to women; of the 5,265 bachelor's degrees in physics awarded, 1,002 (19.03%) were awarded to women (National Center for Education Statistics, 2013). Also in 2011-2012, of the 6,245 master’s degrees in math awarded, 2,551 (40.85%) were awarded to women; of the 1,681 Master’s degrees in physics awarded, 358 (21.30%) were awarded to women; (National Center for Education Statistics, 2013). In 2011-2012, 471 (28.22%) of the 1,669 PhDs in math were awarded to women; 316 (19.49%) of the 1,621 PhDs in physics were awarded to women (National Center for Education Statistics, 2013).

Department of Physics

According to the department website, the Department of Physics and Astrophysics has seven faculty members and ten adjunct faculty. All faculty members are male. According to the department website, on average, 49 undergraduate students are enrolled as physics majors every year. Undergraduate students majoring in physics can specialize in applied physics, astrophysics, computers in physics, or materials science. According to the institutional research page on the university website, for the 2012-2013 academic year, the ratio of male to female enrollment was around eight to one in the fall and six to one in the spring.

Department of Mathematics

According to the department website, the mathematics department has 19 faculty members, eight lecturers, and 80 to 100 undergraduate math majors. Four of the 19 faculty members are female. According to the department website, the math department is also a service department in that it has courses for non-majors that are designed to meet the needs of students from other majors such as education, business and the sciences. According to the institutional research page on the university website, for the 2012-2013 academic year, the male to female ratio was around 13 to 11 in the fall and 11 to nine in the spring, which was a significant increase in female enrollment for previous years (two to one in spring 2012 and 2011).

Data Collection

This study followed institutional ethnographic data collection procedures outlined by Smith (2005). I collected two levels of data, "entry-level data, which is data about the local setting, the individuals that interact there and their experiences, and level two data, which is an investigation into the missing organizational details of the how the setting works" (Campbell & Gregor, 2004, p. 85). To collect entry-level data, I conducted interviews with female undergraduate students to understand what characterized their day-to-day work. To collect level two data, I used four sources: interviews with female undergraduate students, classroom observations, faculty interviews, and institutional texts. Level two data helped me to understand how the work that female undergraduate students did was coordinated. While entry-level data helped to identify the unique challenges of female undergraduate STEM students, level two data helped me to understand how and why those challenges were coordinated and perpetuated by institutional structures. Level two data helped me develop a comprehensive understanding of the factors shaping the experiences in female undergraduate students in math and physics.

Interviews

In an institutional ethnography, the goal of interviews is not just to reveal subjective states, but to identify how individuals from different parts of an institution are connected and guide the next steps of an investigation into local processes that similar because they are coordinated by institutional practices (Smith, 2006, loc 327). Upon receiving informed consent from participants, I began the first of a series of interviews that focused on the core question of an institutional ethnography: How do you do what you do? (Campbell & Gregor, 2004). Campbell and Gregor (2004) recommend that interview questions in an institutional ethnography not be standardized, because the purpose is to build understanding of the coordination of activity in multiple sites; yet, I utilized an interview protocol to guide each interview. Guiding questions for the interviews asked participants to describe the everyday work they did as a student, which might include attending class, completing homework, studying with peers, and attending advising sessions (see Appendix A).

Multiple interviews are key in a feminist investigation because they provide rich details about participant lives and a comprehensive understanding of the different factors that impact their lives at different times. Multiple interviews over the duration of a semester were particularly important for this study, because the work done at the beginning of a semester of classes may be very different then the work done at the end of a semester (Pasque, 2013). With six of the eight participants, I conducted three interviews: at the beginning, middle, and end of the Fall 2015 semester. I conducted a total of 21 undergraduate participant interviews. Two participants only had one and two interviews. One participant left the university midway through the first semester for health reasons; one participant did not schedule the first interview until midway through the first semester, so the second interview at the end of the semester was the final interview.

In each interview, I asked students to provide rich detail describing their everyday activities, including in-depth descriptions of the different settings as well as of their work and the work of other students (Campbell & Gregor, 2004). The interviews were formal and in-depth and lasted between 30-90 minutes. During each interview, I recorded the audio for later transcription and took notes on salient events, my perceptions, and other observations that may not translate through the audio recording. Interviews were conducted where the participant was comfortable, either in a private room in a university building or at a coffee shop.

I also conducted shorter formal interviews with math and physics faculty after the first undergraduate interviews were conducted. Those interviews asked about the processes and policies that were identified in the undergraduate interviews and/or observations and provided information about how student work is coordinated at the department, college, and institutional level. See Appendix A for the faculty interview protocol. I conducted a total of five interviews; three with physics faculty and two with mathematics faculty. The interviews lasted between 30-60 minutes and occurred in October 2015.

Observations

Important to an institutional ethnography are participant and setting observations. I conducted 14 classroom observations over the course of Fall 2015. I observed five classes each in the math and physics departments and conducted between one and four observations of each class, related to the willingness of the faculty member to be observed (See Table 3). I conducted observations as an observer without participating, with the exception of introducing myself and my research in a required senior math course and a Physics 1 course (Hesse-Biber & Nagy, 2014) and observed social dynamics and patterns while looking for the steps in institutional processes and discourses

(Campbell & Gregor, 2004). Observations were also important, because they helped me identify texts that coordinated undergraduate female work such as syllabi and assignment descriptions (Campbell & Gregor, 2004). I documented my observations through detailed field notes, which I recorded during the observations, and elaborated soon after with vivid and detailed descriptions. Those field notes were descriptive and analytical. See Appendix B for the observation protocol.

Table 3. Courses Observed.

Course Title	Department	Number of Observations
Physics 1	Physics	3
Calculus Ia	Mathematics	2
Calculus Ib	Mathematics	1
Introduction to Astronomy	Physics	4
Senior Math	Mathematics	4
	Total:	14

Texts

Critical to an institutional ethnography is the analysis of texts, which, “appear in people’s talk, because they are an integral part of what people do and know” (Campbell & Gregor, 2004, p. 79). Through observations and interviews, I identified texts that coordinated the work of female undergraduate students such as four-year enrollment plans, course documents, and MRU policy (See Appendix C). I analyzed them with the goal of exposing the links between different types of data and gendered language (Campbell & Gregor, 2004; Gee, 2014). This analysis allowed the research to transition from the day-to-day activities of undergraduate participants to institutionalized practices, policies, and procedures that organized their work (Campbell & Gregor, 2004). Document collection and analysis began in June 2015 (simultaneous with participant recruitment), with receipt of IRB approval. As processes and procedures emerged through interviews and observation, I continually identified and analyzed new institutional documents that coordinated female undergraduate student work. The documents collected included all physics and math web material; math placement policies and procedures; state policies regarding admission; the student handbook and code of life (university policy); the College of Arts and Sciences policies (such as the Academic Grievance policy), assessment plan, and strategic plan; course lists and descriptions (university); essential studies documents; four-year graduation plans; scholarship information and application procedures; math and physics syllabi; and accreditation documentation.

Ethics

I selected my study, data collection, research paradigm, and data analysis methods with the goal of achieving an ethical study that gave participants a unique opportunity to be empowered by being heard and validated as an authority. I paid close attention to ethics by obtaining informed consent, ensuring privacy and confidentiality, and receiving ethical approval from the MRU IRB board (Rossman & Rallis, 2003). An important consideration was access, especially for feminist research:

> ‘Access’ related to the ‘social scientific goals of ethnography,’ and specifically meant gaining access to information, while entry commonly referred to the ‘initial act of entering the field or gaining permission from participants to start a study.’ (Hesse-Biber & Nagy, 2014, p. 123).

Before beginning the interview process, I gained the informed consent from each participant: through the consent form and verbal explanation prior to beginning the first interview, I explained the study, its goals, and how I would collect data (Creswell, 2013; Rossman & Rallis, 2003).

Throughout participant recruitment, data collection and data analysis, I protected the identity of each study participant as well as referential sources, guaranteeing confidentiality to all individuals who provided data and by using pseudonyms throughout data collection, analysis and within the researcher's journal (Creswell, 2013; Rossman & Rallis, 2003). Because the departments explored were small, excerpts from interviews quoted in the findings will not contain any information that could potentially identify participants. The interviews may have brought up sensitive topics for participants, especially for faculty who may not want to be critical of their department for fear of recrimination; therefore, I allowed the participants to participate in the interviews from the privacy of the location that they chose and was careful to reassure participants that the data collected would be confidential and that any data included in the report would remove any identifying information. Most faculty were not concerned and chose to meet in their offices, although one chose a neutral location on campus to meet. Most students chose to meet at a local coffee shop, in seating where we could not be overheard or in private conference rooms in the education building. I also reinforced the confidentiality and security of the data collection, storage, and reporting measures (Adler & Adler, 2003). I kept the audio recordings of the interviews in a password-protected file to which only I had access. Finally, to keep the insitution and participants confidential, I refererd to the institution by the pseudonym MRU and removed any identifying links to the institution and the state governing board in references cited in text. Additionally, I specified the source of the document when referencing information gained directly from the institution’s website and, therefore, publicly available. To reference institutional and state documents analyzed in Chapter VI, I reference the document when reporting findings. Appendix C includes a list of documents analyzed with pseudonyms for state and university names. Readers can contact me for redacted source materials.

Additionally, the selection of an unstructured format allowed the participants to “shape the contours of the interview” (Adler & Adler, 2003, p. 167). Although my questions guided the content, participants were free to respond however they pleased and ask me questions about the nature of the interview, research, and my experiences, which I did to reduce the hierarchical gap between researcher and respondent (Adler & Adler, 2003). Before beginning the interviews and observations, I informed participants of their right to discontinue the interviews and their participation at any point during data collection. I also ensured that participants knew their rights as study participants (Maxwell, 2013). I paid careful attention to their verbal and non-verbal responses throughout the interview process to assess their reactions to determine if they were uncomfortable at any stage in the interview process; if I had identified any concerns, I would have terminated the interview (Maxwell, 2013). These methods were selected to protect the rights of the study participants, ensure that undue emotional stress would not be inflicted during the research process and that participants were treated with respect.

Data Analysis

As an institutional ethnography, data analysis began immediately upon collection as an iterative process (Hesse-Biber & Nagy, 2014). I began analysis of participant accounts of their experiences as I collected them, because the focus of data analysis in an institutional ethnography is not only on collecting and describing participant experiences and perspectives but on the larger institutional processes that coordinate their work and that they may not be aware of (Campbell & Gregor, 2004). The overarching question that guided the data analysis process in this institutional ethnography was, "What does it tell me about how this setting or event happens as it does?" (Campbell & Gregor, 2004, p. 85). To answer that question, the data analysis process followed Carspecken's (1996) critical ethnography coding process and utilized discourse analysis of textual data (Creswell, 2013; Saldana, 2013).

The analysis of textual data provided insight into the rules, social organizations, hierarchies, and patterns of the STEM education process (Gee, 2014; Lazar, 2005). Throughout the data analysis process, I paid attention to the institutional practices that coordinated participants' work and the way gender related to the distribution of power and resources in social life (Hesse-Biber & Nagy, 2014). I also explored participant descriptives and the cultural and social nuances that informed each participant's responses including gender (Carspecken, 1996; Hesse-Biber & Nagy, 2014). Finally, this ethnographic analysis of the data through a feminist framework paid special attention to how gender mediates the female undergraduate experience in a STEM education setting.

Coding

Carspecken (1996) outlined a process of ethnographic data analysis that begins with low-level coding, followed by high-level coding, and then pulling codes together through the creation of themes. The first step is low-level coding: "coding that falls close to the primary record and requires little abstraction" (Carspecken, 1996, loc 3638), which includes descriptive and structural coding of interview and observation data and field notes (Saldana, 2013). The second step of data analysis is high-level coding, which is the intensive analysis of the data "needed to generalize findings that emerge from various forms of qualitative data analysis, particularly meaning and validity reconstruction, horizon analysis, and the analysis of interactive power" (Carspecken, 1996, loc 3673). I followed Carspecken's (1996) low-level data analysis process as I collected observation and interview data; transcription occured as soon as possible after the interviews, and analysis began during and after the transcription process.

Low-level coding. Low-level coding, especially of the initial interviews, was guided by the overarching research question, seeking to identify what work characterized the day-to-day activities of undergraduate participants. Initial analysis began immediately after the transcription of interviews with female participants and identified the work being done. Low-level coding included structural and descriptive coding (Saldana, 2013), but most importantly identified the work that was being done by female students. This analysis required very little abstraction (Carspecken, 1996) and attempted to describe what work was being done from the perspective of the female math and physics undergraduate participants. Low-level codes included descriptions of undergraduate female work, such as coursework and enrollment and also descriptions of what was going on during observations, such as how students participated during class. Second, low-level coding informed future data analysis to discover the policies, processes, texts, and cultural norms that characterize the organization of the relationship between female undergraduate students and their everyday work as STEM students. The initial interview data about student undergraduate work guided me as I searched for documents that coordinated student work and guided the questions I asked in faculty interviews and future student interviews. Low-level coding was used throughout data collection iteratively, to identify the policies and procedures that coordinated work. Of 217 codes, 174 were low-level codes (Appendix D).

High-level coding. After the first and second undergraduate interviews, faculty interviews and classroom observations were transcribed and analyzed for low-level codes. I began high-level coding of the data by identifying and explicating themes in institutional practices, policies, and procedures that coordinated female undergraduate student work. High-level coding, or coding that is "needed to generalize findings that emerge from various forms of qualitative data analysis" (Carspecken, 1996, p. 147), began with the first transcribed interview and continued for each piece of data. For high-level coding, I looked specifically for the discourses, power relationships, language, and practices that coordinated female student work and crafted practices that were either gendered or biased or neutral and normal. An example of high-level coding is Michelle’s description of how she did not look at her physics GRE scores. She described in her interview how she felt horrible about her performance on the exam, and then did not look at her scores when they arrived, because she had decided that she was not going to send them to schools when she applied for graduate admission. In initial analysis, I coded these details as “taking the GRE” and “pursuing graduate school.” In analysis after my three interviews with her were complete, and I had learned more about her, I hypothesized that she chose not to look at her scores because she feared seeing that she had received a low score. In high-level coding, I used the code “fear of failure” to describe this behavior on an abstract level. “Fear of failure” was a high-level code that explained many of the experiences and feelings expressed by undergraduate participants, and informed understanding of how pressure from a masculine STEM environment affected undergraduate participants.

Additional high-level codes included those that characterized STEM discourses, such as what characterized physics and math education discourses, the ideal STEM student discourse, and neoliberal policies. This thematic coding process continued until data collection was complete, and I was able to synthesize study findings. As data analysis in an ethnography occurs during the data collection process, collection and analysis is iterative. Therefore, gaps identified by the analysis informed additional data collection, which included asking participants clarifying questions after their interviews or identifying additional texts for analysis (Smith, 2005; see Figure 1). Of 217 codes, 47 were high-level codes. For a full list of high-level codes, see Appendix E.

Discourse Analysis. High-level coding involved discourse analysis, an integral part of an insitutional ethnography (Creswell, 2013; Gee, 2014; Saldana, 2013; Smith & Turner, 2014). Ethnographic analyses are also characterized by different ways to look at and analyze the data, "highlighting specific material introduced in the descriptive phase or displaying findings through tables, charts, diagrams, and figures . . . building taxonomies, generating comparison tables, and developing semantic tables" (Creswell, 2013, p. 198). To analyze the data collected through texts, I used critical discourse analysis to explore institutional texts by searching for the "coordination of subjectivities, consciousness, activies and relations among people" (Smith & Turner, 2014). To do that, I used document analysis to trace policy and institutional discourses to idenify and understand how and why participant's day-to-day work was coordinated. Additionally, I

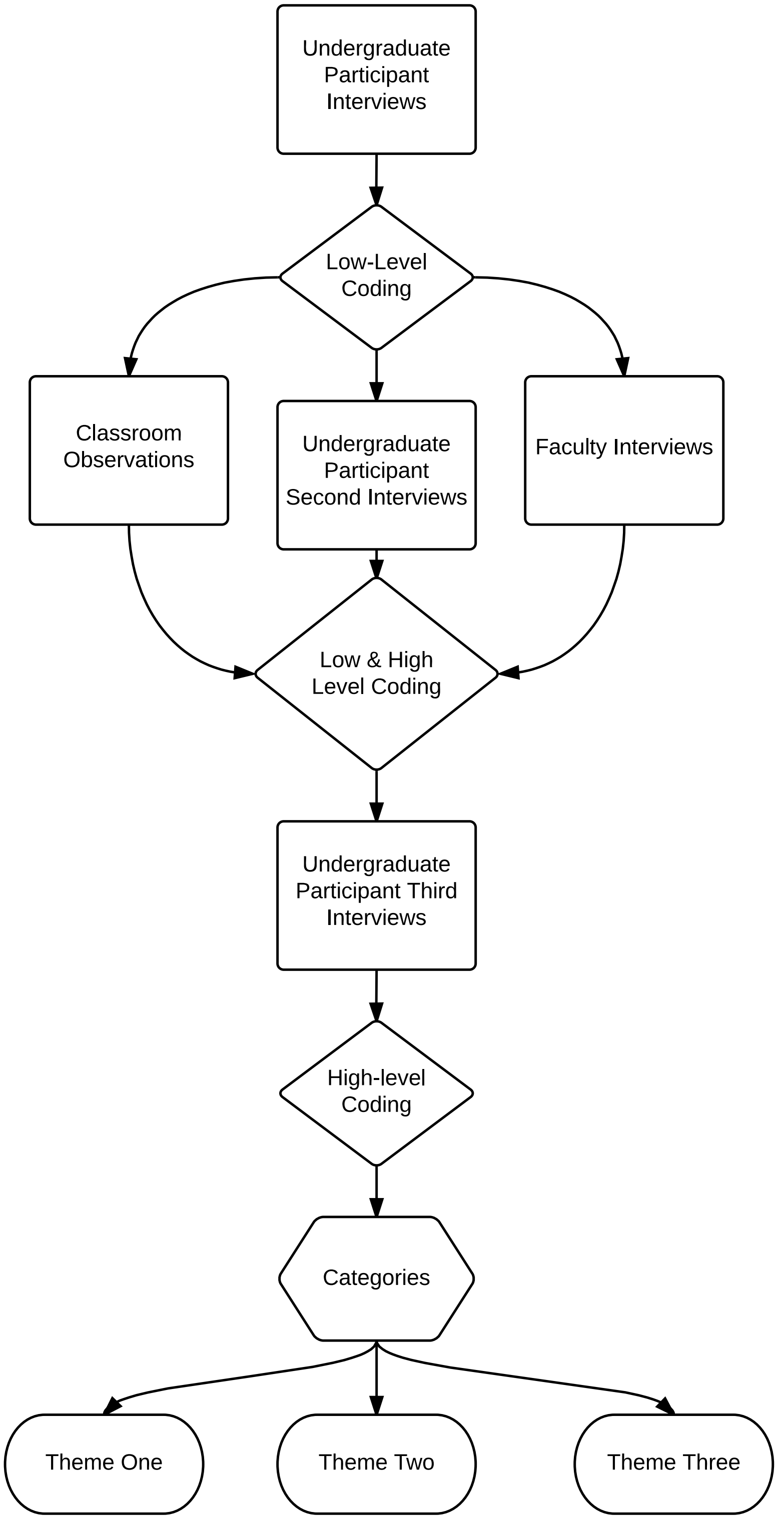

Figure 1. Data Analysis and Collection Procedures.

also utilized discourse analysis to inform the teaching & learning environment in the classroom by exploring instructional documents such as the syllabus. For this discourse analysis, I explored STEM documents for language and teaching practices that indicated or supported the teaching and learning environment.

Code reorganization. After low and high-level coding was complete (i.e., after all data had been collected and transcribed), I synthesized the analyzed codes into categories and themes through code reorganization. Code reoganization involved using code maps to diagram relationships between the codes, and was guided by memoing to organize codes into categories (see Appendix F). Memoing was the process of critically thinking about and reflecting through writing on connections within the data and to the literature that occurred throughout the research process (Creswell, 2013).

Categories were organized into themes responding to the three sub-research questions, and differentiated how student work was coordinated and the challenges that occurred for students by the insitutional level where the work was coordinated. Each theme represented how female undergraduate students were challenged as math and physics students, defined according to the organizational processes that created those challenges. Organizational processes were differentiated according to discourses and insitutional level. The three themes were, 1) STEM educational discourses at the classroom level; 2) The STEM institution and ideal student; and 3) The relationship between institutional and STEM policies and discourses. Within these three main themes there were several intermediate categories of codes that informed and described the larger themes (Carspecken, 1996).

Many low and high-level codes fell into more than one main theme. For example, the high level code "fear of failure" and low-level code "coordinates student work" informed understanding of how neoliberal policies affect STEM undergraduate students as well as how STEM education was gendered. The data collected in response to the research questions fell into the work that was coordinated from three sources: the state/institutional level; from the larger STEM discipline; and the STEM classroom level. Within those three themes, the categories grouped codes according to different ways that work was coordinated, what was coordinating the work, and discourses that coordinated work. In that way, the analytic angles were both close to the data and close to the institutional ethnographic purpose that guided this exploration. Data collection and analysis was completed when I had reached saturation through the high-level coding process and no new insights in respect to the research questions were forthcoming.

Credibility and Trustworthiness

To ensure the validity of data collection and analysis, I prioritized several strategies necessary to the integrity of qualitative research. First, I used triangulation, which required "using different methods as a check on one another, seeing if methods with different strengths and limitations will all support a single conclusion" (Maxwell, 2013, p. 102). According to Onwuegbuzie and Leech (2007), there are four different methods of triangulation: (a) Data triangulation, (b) investigator triangulation, (c) theory triangulation, and (d) methodological triangulation. In the proposed study, I utilized data triangulation, methodological triangulation, and theory triangulation. For data triangulation, I utilized a variety of sources: student participants from different fields of study (i.e., math and physics), different classes (e.g., freshman, sophomore, junior, and senior), and with different racial/ethnic and socioeconomic status (Onwuegbuzie & Leech, 2007). For methodological triangulation, I supported data collection by using multiple sources including interviews, observations, and texts (Onwuegbuzie & Leech, 2007). Finally, I used theory triangulation by revisiting the literature. Throughout the data collection and analysis process, I revisited the literature to see how my findings aligned with the literature and for additional insight and clarification (Creswell, 2013). Through triangulation with the literature, I expanded my literature review to include literature on neoliberalim in higher education to develop a deeper understanding of the higher education policy environment I was exploring. Through triangulation, I provided evidence that supported my findings, and reduced the risk of systemic bias (Maxwell, 2013).

In addition to triangulation, I utilized the methods of prolonged engagement, persistent engagement, peer debriefing, and audit trails to provide evidence of study validity. First, I collected rich data through interviews and observations (Creswell, 2013; Maxwell, 2013; Onwuegbuzie & Leech, 2007). The collection of rich data was supported by prolonged engagement and persistent observations that are typical of an ethnography (Carspecken, 1996; Onwuegbuzie & Leech, 2007). For example, I used repeated interviews of subjects to produce richer and more self-disclosing work (e.g., Samantha felt comfortable disclosing that she was bi-sexual in the second interview when explaining her understanding of how women were marginalized in STEM, but had been reluctant to share personal details of her life in the interview). Additionally, repeated interviews and classroom observations also allowed me to build a larger data set for consistency checks (Carspecken, 1996). Second, I used consistency checks (Carspecken,

1996) between what was said in interviews by participants and what I witnessed in classroom observations. Consistency checks illuminated misperceptions between what students thought about differences in their classroom behavior and what I observed. For example, some undergraduate and faculty participants stated that they did not observe differences in classroom behavior between men and women, yet differences in participation were observed in the classroom observations and noted by other student and faculty participants. Third, I relied on peer debriefing throughout the proposal, data collection, and analysis process to highlight any threats to validity through participation in a writing group with fellow doctoral students (Carspecken, 1996; Onwuegbuzie & Leech, 2007). Finally, I created an audit trail throughout each step of the research process, which included raw data, analysis, and a researcher journal (Creswell, 2013; Onwuegbuzie & Leech, 2007).

Limitations

This study was limited by time and space, which limits the applicability of findings on a larger scale. First, I limited the sample to students from the Math and Physics departments, because while a variety of participant perspectives is important, according to their backgrounds, the focus of the study was the institution. Because Math and Physics are both located in the same college, Arts and Sciences, I anticipated that students from those two disciplines would experience similar institutional factors. Second, data collection was limited by time and space because data collection and analysis needed to be completed within an academic year, and these limitations in participant sampling helped to narrow the focus of the study. Finally, much of the research on undergraduate gender gaps has focused on experiences of undergraduate female students in Math and Physics fields, and this study builds on that research. However, because this study only explored the experiences of female students in math and physics, it cannot be applied to students in other fields.

Third, the literature and a faculty participant suggested that discomfort expressed by women in STEM can be attributed to female experiences in education prior to entering higher education (Sax & Harper, 2007). As a qualitative exploration, this study did not control prior academic experiences when choosing participants in order to identify a causational relationship between experiences in higher education and causes for a chilly climate and leaky pipeline. That was not the intent of this research, and this study was not intended to communicate broad generalizability. However, it is possible that negative emotions experienced by undergraduate participants were related to their prior experiences in math and physics and not to the environment in higher education. However, through deep exploration provided by multiple interviews, participants described their perceptions of specific experiences in the math and physics environment, which suggests that at least some of their discomfort was related to the experience being described, not just background experiences and socialization.

Fourth, I was not able to observe or interview female faculty, who were only available in mathematics. Although I did reach out to them, I was not able to obtain their consent to participate. Research indicates that female participation is different in classes taught by female faculty. Not being able to observe that dynamic limited my understanding to the behavior of women in classes taught by male faculty members. Finally, this exploration only explored experiences of women in STEM. It is possible that male students experience many of the same emotions and perceptions as female students;

indeed, it is likely that many of them do. However, the purpose of this exploration through a framework of feminist standpoint theory focused on experiences of the marginalized group, because they were uniquely qualified to speak to their own marginalization, and also had a perspective on the entire system that marginalized them because of their position. Because of that, I focused on their experiences, although understanding may have been enriched by making comparisons.

Researcher Reflexivity

Throughout the data collection and analysis process, I paid careful attention to researcher bias (Onwuegbuzie & Leech, 2007). This strategy is especially important in feminist research to identify how power shapes analysis and findings (Hesse-Biber & Nagy, 2014). Acknowledging and taking into account these biases is the only way to produce “strong objectivity” (Hesse-Biber & Nagy, 2014, p. 26). Careful attention was made to identify my biases, while recognizing that they were not separate from my role as researcher. I utilized critical friends and the foregoing validation methods to ensure that my bias did not negatively affect the validity of the results.

My background and academic history provide insight into my rationale for conducting the proposed study. Because we did not have a television in our household, strong women in literature (e.g., my namesake, Laura Ingalls Wilder) were my first role models. They taught me that anything I wanted to do was possible; if you had asked if there was any disadvantage to being a woman, I would have said no. Yet my upbringing was atypical, and within my primary and secondary education, I saw girls being encouraged to pursue traditional female careers. I experienced that bias too, as I observed the shock others felt when I was chosen as the top scientific scholar in my high school. I entered college as a pre-medical student, but the chilly climate prevalent in STEM education was oppressive. Men dominated the classroom and were given more opportunities for leadership. I saw my fellow female students who had entered into a science field slowly start to change their majors to non-STEM fields. That included me. After a year of biology coursework, I changed my major to political science. It is not a decision I regret. Through my political science and philosophy courses, I developed as a critical thinker and learner and began to uncover and unpack much of what I had taken for granted as "the way things were" in my life. Well before I graduated, I became a feminist.

I continued as a feminist scholar throughout my Master's degree coursework where I had the opportunity to study the power/knowledge paradigm that persisted in higher education. This study focused my research interests to identify how higher education could challenge that paradigm to provide greater access for all women. This work culminated in my master's thesis, where I explored opportunities for higher education to meet the educational needs of former female members of polygamous societies. Through qualitative data collection and analysis, my findings suggested that higher education has the opportunity to support women in becoming successful within society by promoting the development of independent self-concepts, offering academic and social support, and providing opportunities for real-world experience and female role models.

Seeing the importance of education was critical to my philosophical development, and it reinforced my decision to pursue a Ph.D. in Teaching and Learning. Higher education is one opportunity for female empowerment and societal success and, from my experience, it can both be marginalizing (e.g., my experience in STEM fields as an undergraduate), but also be empowering (e.g., my experiences in graduate school and research). It is from that perspective that I approached this study, with a belief that while education may be one path to success for it to be empowering and emancipatory for all, it requires institutional change.

Finally, it was important that I was open to “being wounded” in the process of conducting this research (Campbell & Gregor, 2004). Throughout the interviews with undergraduate participants, I had to be open to letting myself be vulnerable as well, and to identifying how my ability to be vulnerable might enhance or bias my analysis. As a part of the dissertation process, I gained insight into why I left the STEM field as an undergraduate. As a part of that process, I gradually came to recognize that I felt shame for not being stronger when I was an undergraduate, for not recognizing the power relationships that were causing me to leave STEM, and for not persisting so I could be a strong role model in math and science. Every time I told a participant about my path out of science, I felt shame, because I was not strong enough to stay, to fight, and they were. Recognizing how my own experiences had the power to bias my interpretations helped me to ensure that they did not color my analysis, and also helped me to have a better understanding of the stress and anxiety that participants were feeling.

Conclusion

The purpose of this institutional ethnography was to explore the experiences of female undergraduate students in math and physics at MRU, to describe the work done by female undergraduate students, and to identify the institutional processes, procedures, processes, and discourses that coordinated their work. Exploring the institutional processes that coordinate student work allowed for a deeper understanding of the chilly climate in higher education and why female students choose not to major in STEM fields, or change majors before they graduate. In Chapters IV, V, and VI, I present the key findings in response to the research questions, organized according to research question, and differentiated according to the institutional level where challenges for female students emerged. In Chapter IV, I describe the processes, procedures, and policies that led to an uncomfortable, intimidating, and competitive classroom environment for the participants. In Chapter V, I describe the characteristics of the ideal STEM student and the challenges undergraduate participants reported with achieving that ideal. Finally, In Chapter VI, I present a policy map of the larger institutional environment and a description of the challenges participants reported between institutional and STEM discourses.

CHAPTER IV

A DIFFICULT, COMPETITIVE, AND INTIMIDATING ENVIRONMENT

In this chapter, I explore the Science, Technology, Engineering, and Math (STEM) teaching and learning practices and processes that characterized the organization of everyday work for female math and physics students in my study. This addresses Sub-Research Question 1: *What STEM teaching and learning practices and processes characterize the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?* Through descriptions of participants' day-to-day work as math and physics undergraduate students, I discovered key Finding 1: Participants described a teaching and learning environment that was competitive, individualistic, intimidating, and difficult. Their descriptions of the classroom environment were supported by interviews, instructional documents, and faculty participant interviews.

The lived experiences of undergraduate participants in this study, female math and physics majors, provided insight into procedures and pedagogical decisions that led to discomfort in the STEM classroom and program in this study. First, participant descriptions of coursework as difficult and time-consuming set up math and physics as difficult. Second, assessment and grading practices, such as comprehensive exams and grading on a curve, reinforced the discourse of difficulty in STEM for participants. Third, participant interactions with faculty and instructional language formed an intimidating classroom environment. Finally, discourses of individualism and competitiveness were seen throughout the teaching and learning environment and created discomfort for participants. For each aspect of the teaching and learning environment, I explain how these aspects of a chilly climate combine to create challenges for undergraduate participants.

"Physics is Hard": The Discourse of Difficulty

An overarching theme that repeated itself in every interview and from every participant was their perception that getting a math or physics degree was hard. Undergraduate participants explained that their coursework was hard because physics and math were, by nature, "really hard," and that courses were tough because the subjects students were learning, such as quantum mechanics, abstract algebra, and linear algebra, were complicated and complex. For example, physics major Michelle explained: "They all warned me that it was going to be hard, and it was hard . . . like [this] teacher‘s really hard, he pushes you hard. He used to teach at Princeton. So, he had a very set idea of what homework should be, and it's the most grueling thing ever." Participants' descriptions of demanding coursework and complex subject matter were supported by faculty. Karl, a faculty member in physics, explained how he created physics exams, "I cannot ask quantum physics questions that they would get 95%. Then, my quantum physics class is a joke. Or they are genius. Topic is too hard. Very elaborate thing."

Difficult Coursework

Participants described physics and math homework and exams as difficult, because they were time-consuming and challenging. Language used in instructional documents and in faculty interviews supported these descriptions.

Unclear expectations. First, math and physics coursework was difficult, because the language used in assignments was unclear, which made figuring out what students were expected to do the first homework hurdle. For example, physics major Michelle described the coursework in her toughest physics course, *Electricity and Magnetism*:

> One of the biggest problems of the class [was] what was my teacher asking me to actually do? He had a way of phrasing questions that didn’t make any sense to a lot of people. You had to stare at it for like 10 minutes just to know what he was asking you to do.

Participants described assignments that required participants to first understand what was being asked before they could work on the problem itself. Math major Emma reinforced the layers of difficulty in assignments in her description of math lectures:

> You go to class, and you’re sitting in your classroom, and your professor starts with his lecture, and you’re just like, “Okay, so I kinda understand some of the things that are going on,” and you just kinda nod your head, okay-oh, okay; and then you get to your assignment, and you’re just like, “I have no clue what’s going on. Nothing in the lecture has prepared me for this assignment. I don’t understand what’s going on.”

Participants perceived math and physics coursework to have instructional language that was unclear. Unclear language made it difficult for undergraduate participants to understand what a problem required of them. Additionally, homework and exam questions would often apply or extend the material covered in class, in ways that participants found difficult. As a result, participants described two challenges associated with coursework: figuring out what a question was requiring of them, and then solving the problem.

Second, in addition to confusing wording, course content and requisite coursework were often new and unfamiliar to students, further reinforcing a course's perceived difficulty. Emma described her toughest course, abstract algebra, as difficult, because it was "like a new universe." Similarly, Darcy described the math she was doing in an upper level physics class as hard, "because the math that we do is like something I've never seen before. It looks like gibberish." Participants were intimidated by work that did not resemble anything they had learned, which increased the perceived difficulty of their coursework.

Time consuming coursework. The difficulty of majoring in math and physics was reinforced by assignments that were hard. Coursework that required large amounts of time to complete added to the difficulty of the coursework. Physics major Julie described the work she and her physics peers put into completing one homework assignment for one class:

> We worked on it every night and all day Saturday until about 4 o'clock when we finally finished it. It's just that there are so many things, and when you go ask, a lot [of] times he [the professor] will say, "Well, it's obvious. Just think about it!" It's frustrating, and we ended up going back through and looking stuff up online

> and bringing out our partial differential equations books and other books, our linear algebra book, to try to figure out what some of the problems were.

Physics major Olivia reinforced the large of amount of time required for physics homework:

> With one class, we put in 30 hours a week, just for the one class. That's always fun. That's just on the homework. Cause it's usually like 6 hours a problem and like five questions. So, it's fun. I only have like three classes that I really have to work on, but they're all so time-consuming; mostly just E&M, that one's the worst. I mean a lot of people drop, or at least consider dropping [the class]; so it's kind of expected, I suppose.
>
> Laura: Why?
>
> Olivia: I think it's just how much time you have to put in just to get stuff done. And it's not like they [the assignments] are really worth a lot of points. So when you spend 30 hours, you're literally like an hour a point on a homework assignment . . . Our last test was the Monday after Halloween, and we studied all weekend. We studied all Friday, all of Saturday until probably like 10 o'clock, and then all day Sunday, just to get a 40% [on the exam]. You feel like you're putting in so much time, and it's not really worth it.

The coursework is time-consuming because of how hard the problems are and because of the resources students need to identify and search through relevant material that might help them determine how to complete their homework.

Because coursework requires so much work and time, math and physics majors perceived their work as different and harder than other majors. Darcy explained: "A lot of time you can run into the wee hours of the morning because like physics homework is really really different from any other major." Darcy explained how her roommate would get frustrated because of the amount of time she spent on homework, perceiving that Darcy was procrastinating. Her roommate's frustration prompted Darcy to explain that her math and physics coursework was difficult not just because the problems required more time to complete, but also because the relationship between time spent on an assignment and final grade were unrelated in physics. Darcy explained that a problem could take hours to complete; but, if she chose the wrong method to solve the problem, the work completed would be worthless. Like Darcy, participants described the time-consuming nature of math and physics coursework as a reason that their major was more difficult than other majors.

Participants also reinforced that time-consuming and difficult work required from them did not just occur during midterms or finals week, but that work required was constant throughout the semester. For example, Michelle explained why physics was harder than coursework in non-STEM majors when she explained how changing her major to physics changed her day-to-day activities:

> It takes a lot of time, and I find that I don't have a lot of time for anything. Like, I used to be super active my first 2 years here . . . But when I entered my junior physics classes, it was like nope, no time for anything. You just gotta work work work.

The difference in workload increased when she began upper level physics courses, which left her little time for any activities outside of academics.

Throughout the semester, coursework deadlines piled up and caused stress for participants, as Emma explained:

> You know, as soon as you finish one deadline of the week, you have another one due in a day or two. It's a lot. And the assignments are usually like weekly assignments. So yeah, when you have four classes, it's just one after another.

The constant workload and pressure to meet deadlines led to anxiety and stress for student participants.

Time consuming coursework became invisible work, required for students to be successful, but not formally recognized in course assessments. Completing homework and studying consumed every minute of available time for students, leaving very little time for anything outside of science and math coursework. However, student participants described the time spent completing assignments as often invisible to faculty because the only assessable work was the completed homework assignment or exam. As a result, the time and effort taken to complete an assignment and prepare for an exam became invisible work. In addition to the time-consuming nature of coursework, time spent learning software programs became invisible work because mastery of these programs was required to complete math and physics assignments. For example, mathematics students had to learn Mathmatica to add required mathematical notation to a required math paper and both mathematics and physics students spent time figuring out the correct way to enter correct answers into online learning management systems like WebAssign.

Instructional Language

Language used in instructional documents supported participant descriptions of the difficulty of math and physics work. For example, the syllabi explored in this study promoted a view of the classroom as academically challenging with high standards that were difficult to achieve. For example, the grading scale used to evaluate papers and presentations for an upper level mathematics course were ranked on a scale of 1 to 4:

4 = *Excellent* – the paper could be published in a journal suitable for work at this level.
3 = *Good* – the paper needs a few minor revisions in this area.
2 = *Poor* – the paper needs a number of minor revisions in this area.
1 = *Unsatisfactory* - paper needs major revisions in this area.

Criteria for the highest ranking described work that was suitable for publication, which is a difficult standard to achieve for all students, not just undergraduate students. Additionally, the difficulty of the grading scale was reinforced with the four-point scale where anything less than publishable could not receive a grade higher than a C (75%). The difficulty of achieving these standards was reinforced in this class during my observation of the syllabus review on the first day of class. The faculty member teaching the class emphasized that it would be incredibly difficult and require extensive work to receive a 4 on the final course project, and that not many students would do that. The instructional language promoted the idea that the high standards of the course were difficult to meet. The difficulty of coursework was reinforced in institutional language that emphasized how hard the project would be to complete and that standards would be hard for students to meet.

In interviews with faculty, they also reinforced their instructional goal of conveying how difficult work required for a math and/or physics major would be. Physics faculty member Karl described what he expected from students: “I also expect them to take this thing seriously, because I know it’s not easy; so at the beginning, I warn them, ‘Take it seriously, because it’s not that easy.’” The need to convey to students that the work would be hard in physics and math began in the lower level physics courses. A lower level physics syllabus read: “Deleterious effects of past experiences in courses where simply ‘trying hard’ received lots of points under the misguided philosophy that all answers have some validity. . . .” By stating that effort alone would not lead to academic success, this statement emphasized how difficult the subject matter was. As a result, this language reinforced the impression of difficulty for students.

Difficult Exams

Finally, in addition to difficult and time-consuming coursework, exams were designed by faculty to be difficult because the subject matter was hard, as Karl explained previously. Math and physics exams were usually comprehensive exams, as described in a STEM syllabus, “Each exam is semi-comprehensive. And the final exam is fully comprehensive. This means that tests may contain information from throughout the semester.” The comprehensive exams in math and physics were difficult because they often had material not covered in class or the homework, and in some cases, were designed to be so time-consuming that they had to be taken outside regular course hours. Physics professor Karl explained the rationale behind a test taken outside of class time:

> I let them stay in the exam for as long as they want. Like 2 or 3 hours or if they want the whole afternoon. And I ask [a] small amount of questions, like I ask four or five questions. And, what I try to do is show them or to see if they can stay focused on [a] limited number of questions for an extensive period of time. You

> see, everybody uses cell phones, computers or whatever, so what if you have nothing, a piece of paper and a pen and [you] go and do whatever you can do.

These tests are intimidating to students and difficult to complete. For example, physics student Julie, described her last physics exam:

> Um the last test was pretty rough. Well, you know you've got to be worried when they schedule the test outside of class. So it was for a 2-hour period, and that should give you pause in the first place, you know? It's like, okay this is going to be bad, isn't it? And you prepare as well as you can, but he [the professor] is of the opinion that nobody should ever get a 100% on a test.

The legend of these difficult tests is conveyed to undergraduate physics majors. Olivia expressed anxiety prior to the beginning of the semester about tests she would encounter in her first semester as an upper level physics student. In her second interview, she confirmed that her fears were justified and that the tests were as hard as she had expected.

Participants described how difficult upper level exams were by their receipt of low grades. Math major Emma explained:

> Our second test, so there was a couple grad students in there, and our second test it was, our teacher wrote down the class statistics, and I think everyone walked out of the room saying, "Well, I think I guaranteed a 30% on that test," and anyway, so we get our . . . he writes down the statistics on the board, and it's just like 100%-1. We're just like "who got that?" . . . and it was, uh, 90-99%-0; 80-89%-0; 70-79, there was like seven people; and the D, uh no, there must have been like five people, and the Ds there was probably like seven people, and then there were like 2 Fs.

Participants found exams to be difficult and receiving failing grades reinforced the difficulty of physics and math.

What is unique about the label of “difficulty” is how often it was repeated by participants using similar language. The difficult nature of the field served to guide faculty as they selected course content and to rationalize difficult and time-consuming coursework. Difficulty was also used to rationalize individualistic and competitive classroom practices, leading to intimidating environments. Physics professor, Myles, explained:

> If everyone got a 4.0 coming out of our department, people would laugh at us and you’d never get into grad school ’cause they know you’re just giving away the degrees, essentially. Right? You’re not learning anything. By its inherent nature, people find it very difficult when you need to learn. Not all of them, but most of them. The average is gonna be lower, right?

Math and physics must be difficult, faculty stated, because that was the very nature of the field. This was an illustration of how difficulty as a discourse is embedded into the institution of STEM in higher education.

Teaching Methods

Participants were additionally challenged by the teaching environment in math and physics courses. Undergraduate participants felt like they often left class without a clear understanding of what had been covered. First, participants described lecture as the most common teaching strategy used by math and physics faculty. While lecture was not universally disliked by undergraduate participants, the use of lecture allowed for very little student-instructor interaction. Physics major Michelle described how classes usually looked:

> Laura: When you get to class, lecture just starts?
>
> Michelle: Yeah. The hardest teacher that we have, he would always start out class by filling one-fourth of the chalkboard right away. Before you even got there, he'd get there like 5 minutes early and start writing. And we'd have a little chitchat right at the beginning, and then we'd all start taking notes, and he'd explain things, and he'd ask questions, and most of the time our pauses were for, "What was that subscript that you wrote on that letter?"
>
> Laura: What sort of questions does he ask?
>
> Michelle: Like, "Do you understand this?" Like, "Are we getting somewhere or are we just completely confused?"
>
> Laura: Are his questions hard?
>
> Michelle: Usually no one says anything. He goes really fast. Which sometimes just doesn't allow you time to think and keep up with him. And most of his questions will go unanswered just purely because of the fact that we didn't have time to think through what he just did. And he would skip steps regularly. He's been teaching this class for so many years, he knows the answer to an integral when you write that on the board. And there's like 15 steps to it. So he'd skip many steps, and we'd be just lost.

Michelle described a typical physics class as being lecture-based with very few student questions, which I also observed during classroom observations. Questions, when asked by faculty, were typically yes/no questions that received little or no response from students. Undergraduate participants explained that the use of lecture without student interaction required them to teach themselves, something they preferred not to do because they expressed a need to be taught because the material was so hard. Feeling like they had to teach themselves because they were not learning in class caused anxiety for students.

Grading and Assessment

In addition to difficult coursework, participants described an anxiety caused by grading and assessment practices. Their anxiety was caused by uncertainty about how their grade would be calculated, delayed or unclear feedback, and complicated grading processes.

“I Have No Idea How My Grade is Calculated”

First, in both math and physics, students expressed uncertainty about how their final grade would be calculated. In some cases, this uncertainty was because faculty members did not have a grading scale published for students to review in the syllabus, on the Learning Management System (Blackboard), or through in-class descriptions. Darcy explained her interaction with one of her physics professors about how grades would be determined, “He doesn’t know yet. I asked him that like a while ago. I was guessing he just hadn’t uploaded that to Blackboard, so I was like, ‘What’s the grading?’ And he’s like, ‘I need to figure that out!’” This uncertainty about what would comprise their final grade and how their performance would be measured was frustrating to students because getting good grades was important to them, and they wanted to know what they needed to do to get good grades.

Second, participants described being stressed because they were unsure of their grade because professors did not update cumulative grades to Blackboard or provide updates to students on their grades during the semester. Madison, a math senior, expressed frustration that none of her math courses had updated her grade throughout the semester. Because she was graduating at the end of the fall semester, knowing her grade for each course was important, so she needed to know if there was additional work that needed to be done to ensure that she would not fail a course or receive a grade that would have a significant negative effect on her GPA. This uncertainty increased her stress and anxiety.

Unclear Deadlines

Undergraduate participant uncertainty about their grades was reinforced by unclear course deadlines. For example, Olivia explained how she thought her grade would be calculated in a physics course:

> Laura: What else will your grade be based on?
>
> Olivia: We have tests. He didn't say how many tests.
>
> Laura: Is this the one that doesn't have a syllabus?
>
> Olivia: No, he didn't have one. He just told us like, just tests and homework. People have said that he doesn't actually grade things, or he doesn't actually keep your grades. They said like they never got their homework back, and essentially he just kind of picks how he thinks you're doing, and you get your grade based on that.

Lack of clarity about how grades were calculated led Olivia and other undergraduate participants to assume that the grading process was subjective. This assumption increased the pressure on them to perform because participants did not know how faculty wanted them to perform.

Complicated Grading

Complicated grading added to the uncertainty students felt about their performance. In both math and physics, but especially in physics, grading was very complicated, especially in classes with required labs. Physics professor Nigel explained the grading for a lower level physics class:

> [It] is very complicated, partly because the lab grades feed into the grades for the whole course. So even through the lab course isn't counted by [MRU], it's actually really complicated . . . the TAs grade the labs, and they give that information to us at the end of the semester, and we incorporate that into our [course] grade.

This grading process was confusing for students as well. Grades were important to participants because they were an indicator of comprehension and sometimes influenced whether or not a student would receive continued scholarship funding and post-graduation work. As a result, not knowing where they stood as indicated by their grade increased stress and anxiety for each participant in this study.

Delayed Feedback

In addition to not understanding their current grade, feedback from professors on assignments and tests was often delayed by weeks or even months. This interaction with Julie explained how not receiving feedback affected her:

> Laura: Has he given your grades back yet?
>
> Julie: No. He hasn't graded it yet. [redacted] And he's been like, pretty stressed.

> Laura: How does it feel that you haven't received your grade yet?
>
> Julie: It's really frustrating. It's frustrating because he did say that he would possibly give it [the test] out as homework, but we still haven't gotten anything back on it, so we don't know yet. We're wondering if he's still going to do that.

Like Julie, each senior or junior participant described a current math or physics course where performance on an exam was delayed by almost a month. Not knowing their grade caused participants stress because they wanted to know how they had performed on the test but also because exams were often comprehensive and informed by the content covered on prior exams. Without feedback, participants were anxious about their status in the class and future coursework.

Difference Between the Math and Physics Environment

While low grades were the norm for math and physics participants, grading practices in math and physics were different because math courses were less likely to grade on a curve. Darcy explained:

> Math is way more standardized. Like, if you get like, if you're doing well, you get a 90, where physics is a lot more like, they just really want to challenge you, so like they'll curve it, you know like they'll give a really hard test, and people get really bad grades, and then, you can curve it from there.

While physics was more likely to curve a grade, math was more likely to maintain the standard grading scale where 90 and above was an A and 50 and below was an F. While this adherence to the standardized math scale meant that math majors had a more clear understanding of the expectations regarding their grade, this also created additional pressure on participants to perform to a certain level. Additionally, participants reported that physics professors would tell students to expect low grades, setting an expectation for them that they would receive low grades. Where physics was more likely to make accommodations for a test that everyone failed; in math, that failing grade often directly reflected itself in a student's final grade even if the entire class failed the test. As a result, math participants often viewed low grades on a math exam as failure to understand the concepts presented in class. Physics students did not make that connection as frequently. This created challenges for math participants because while physics students reported understanding that low grades were expected and that their course grades would be curved to help their final course grades, math students perceived failing grades to be evidence they did not understand the content material and would fail the course. As a result, the very real feeling of failure further reduced the comfort level that math student participants felt with their ability to be successful in math.

Intimidating Environments

Intimidating environments created additional challenges for undergraduate participants. Participants perceived some interactions with faculty and fellow students to contribute to an intimidating environment.

Faculty

First, undergraduate participants described how they felt intimidated by faculty during class and from feedback received on assignments. For example, Olivia described her fear of interacting with one of her physics professors:

> He's very intimidating. We'll go to class, and we'll just like spend the whole time [thinking] please don't call on me or ask me something I don't know. 'Cause he's very mean to kids if they get it wrong, or they don't know it. We had a kid in my

> class. He asked, “When do you know if force is conservative?” He’s like, “When the [unintelligible] is zero.” He [the professor] is like, “Okay, go write that on the board.” So he [the student] wrote it, and he [the professor] is like, “So what does that mean?” He [the student] is like, “I don’t know.” And he [the professor] is like, “Exactly, you don’t know, sit down and pay attention.” Or, he’ll always call on you if you do something wrong. Suddenly, he’ll just call on you every time, no matter what. He gets very angry if you don’t do something right. He’ll put skull and crossbones on your homework if you do something wrong.

Fear of being called on in class and getting the answer wrong had Olivia so stressed that she spent extra time trying to anticipate what the professor might ask in class so that she could answer correctly. By her third interview, Olivia was less intimidated by the professor because she was doing well in the course, but still feared being called on in class.

Other professors were intimidating in a less aggressive way. Michelle explained how another physics professor would intimidate her during class lecture:

> Michelle: He will sit on a desk right next to you, and ask you, directly, a question. You’re in an entirely big class, and he’ll sit next to you, and be like what do you think? And he’ll like, sit there, and you will have to say the answer.
>
> Laura: Is that intimidating?
>
> Michelle: Yes, it is. It definitely is. So you’re sitting there; and he’s like, eye contact, like staring you down, like all your peers are next to you, and you’re like, if I answer this wrong, I’m going to look stupid.

While not every class or professor was described as intimidating, the few that were created a challenge for undergraduate participants. Participants reported dreading their interactions with those faculty members and feared what would happen if they gave incorrect answers in class.

Fellow Students

In addition to intimidating professors, interactions with other physics and math majors can be intimidating as well. Michelle, a physics major, explained: "Like, if there's a new physics major that comes in, and we don't think that they're going to make it, we more often than not, we'll not really be close with them." New students, male and female, are judged by their peers. If they are perceived to not be smart enough, they are made to feel unwelcome. This sentiment also explained why participants were so worried about appearing stupid to their peers.

The unwelcome and intimidating environment was exacerbated by sexist comments made by a few male students. Samantha described one time she felt uncomfortable in her math class:

> Samantha: I mean there's one dude there that has said some pretty sexist and racist things. I forget the joke he made, but I do know that once he made it, he looked at me and went, sorry. It was a joke about women being on their periods or something like that . . . And I guess we were on the topic of celebrities while we were on the way walking to calc. It was him and some other dude, and I think he said the words "Bruce Jenner." And then his friend was, "Don't you mean Caitlin Jenner?" And he's like no, no I don't . . .
>
> Laura: Does that make you feel welcome or unwelcome?

Samantha: Unwelcome.

Samantha felt like she needed to become inured to sexual language or comments that were derogatory to women in order to be successful in the male-dominated STEM environment.

Individualism

Like difficult coursework, the classroom environment in math and physics was characterized by individualism, as seen in instructional documents and interviews with faculty. First, the emphasis on the individual was seen in course documents, such as the syllabus. For example, a physics syllabus read: “Others may guide you in the acquisition of knowledge and skill, but in the end you teach yourself as a privilege and a responsibility.” The onus was placed on the individual for learning, and while group work is not prohibited, this language made it clear that the individual was solely accountable for learning. This focus on the individual in instructional documents was intentional, as Karl explained: “I want them to see a really difficult problem, and I want them to try that without anybody’s help. Alone. That is a good feeling because that’s everything that I feel. There’s a difficult problem. And, I deal with it.” Individualism was promoted in the math and physics classroom through an emphasis on the responsibility of learning on the individual.

Competitiveness

Similar to individualism, the competitive nature of math and physics syllabi was seen in instructional documents and expressed by faculty in interviews. First, the competitive environment was exemplified by grading methods. For example, in upper level physics and some math courses, a majority of the grading was based on a curve. Karl explained why he used a curve:

> But in quantum mechanics, which is a senior level class, I say, okay, it depends on the curve. So if everybody does well and you don't do well, you're not good. I also try to create some sort of competition between them, so they should get used to that feeling too . . . I mean they have to compete with everything. They have to compete for grants, you have to compete to be the favorite of your PhD advisor, that sort of thing, right? But it also shows them a little bit of how life is, right? You have to deal with the pressure.

Grading on a curve was used to create a competitive environment because competition was seen as a component of the physics professional environment. Likewise, the competitive environment was described on a physics syllabus:

> We give grades for a variety of reasons, two of which are:
>
> It allows you to judge your performance on national and international scales;
>
> It is a motivational tool that "encourages" you to further develop your potential.

Physics and math courses were designed to be competitive as an evaluative and motivational tool.

Faculty used competitive grading methods to help students understand that they would be measured against their peers, which undergraduate participants had internalized. Darcy explained why competition through grading on a curve was necessary: "If you've made it to quantum mechanics, you are good at physics, you're good at math, you're a smart person, so if it wasn't made extra hard, which I think quantum was already inherently hard, then everyone would be getting the same grade."

The importance of being able to compare themselves to their fellow students, both within MRU and nationally, was used as a rationale by faculty and students for difficult exams and for grading on a curve. Participants viewed competitive grading and classroom practices as necessary because students would be measured against their peers; and this would determine who received the best scholarships, who would be selected for competitive undergraduate research opportunities, and who would be accepted into graduate school.

Other Required STEM Courses

Although the focus of this exploration focused on the experiences of math and physics majors, and therefore math and physics courses, experiences in non-physics and math courses that were required for the major also contributed to the stress felt by math and physics students. For example, negative experiences in chemistry, a course required for physics majors and usually taken in their first or second semester, almost caused Olivia to change her major. Olivia described why she almost changed majors:

> I actually just panicked cause chemistry was awful, and I just dropped all of my classes for the next semester, and I was ready to drop my major and switch to something because it was very intimidating . . . I didn't do well, no matter how much I studied, I just felt like I didn't know any of it, and it was the first B I'd ever gotten in my entire life which is very negative for me.

She further explained why the course was so negative for her, "He [the professor] gave us a pop quiz once, and it [was] just like an A or B, directions said circle one, it was one question, and the answer ended up being neither, and he gave us all Fs on it." If Olivia had not received an email from a physics professor offering her an opportunity to do undergraduate research, she would have changed her major before she even began physics coursework. Similarly, Samantha found chemistry to be a frustrating requirement for a physics degree because she did not enjoy the class. Chemistry was such a negative experience for participants that it almost caused participants to change majors; it was not only the physics and math courses that contributed to perceptions of math and physics majors as difficult.

Also, not within the purview of the physics department, math coursework was another source of anxiety for physics majors. Professors and students cited math knowledge as one of the most important aspects for success in physics. Physics professor Karl explained:

> Karl: Mathematics classes. Taking significant amount of math classes. You see, coming from high school, they are not stupid, you see, but they have never been challenged . . . After three semesters upstairs [the math department], they understand what they are doing. Then my job is easy.
>
> Laura: What is it they are getting out of the math education?
>
> Karl: I think the most important thing is the math skills. Tools that they can pull out in the classroom . . . And also a way of thinking. Mathematics is a special way of thinking and physicists and mathematicians think quite alike.

The reliance on math was cited by all of the physics professors as an important aspect of success in physics.

Likewise, undergraduate participants expressed how important math was to understand physics coursework, and as a result, some physics majors expressed anxiety about the math needed to be successful. For example, freshman physics major Samantha, explained why she was questioning her decision to major in physics:

> There is a lot of calculus in astrophysics to begin with because you are doing a whole lot of calculations based on what you can't touch. The only way you can figure out what's in the sky is if you do a whole bunch of calculations that somehow match up and correlate to other calculations that you've done.

Samantha was sure of her interest in physics but questioned if she could be successful as a physics major because so much math was required. The necessity of math for success in physics was intimidating for Samantha and caused her to question her decision to major in physics.

The integral relationship between math and physics was reinforced in instructional and institutional documentation, which are often the first thing new students read when deciding what class to take and choosing a major. Physics course descriptions showed a clear difference between courses for non-physics majors (medical and engineering) and physics majors. Physics courses for non-physics majors specify that they were for non-majors and often specified the level of math required (usually college algebra). In contrast, the courses for physics majors required higher-level math and calculus as a prerequisite.

Conclusion

Through descriptions of their day-to-day work as math and physics undergraduate students, participants described a teaching and learning environment that was competitive, individualistic, intimidating, and difficult. As a result, undergraduate participants reported being challenged by the difficult and intimidating aspects of their teaching and learning environment, evidenced by stress and anxiety that resulted from these practices. The description of the day-to-day experience of math and physics students were the starting point from which I explored the STEM education institution to understand the institutional discourses that inform and guide the teaching and learning environment in math and physics.

CHAPTER V

THE STEM INSTITUTION AND IDEAL STUDENT

In this chapter, I explore the Science, Technology, Engineering, and Math (STEM) institutional cultural norms and standards that organized and informed the teaching and learning environment described by participants in response to Sub-Research Question 2: *What STEM institutional cultural norms and standards organize and inform the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?* Acker's (1990, 2000, 2012) theory of gendered organizations informed the exploration of this STEM institution. To understand institutional discourses that informed the teaching and learning environment in this study, I defined characteristics of an ideal student as described by faculty, students, and instructional documents and explored how seeking to meet standards of the STEM environment in this study created challenges for female undergraduate participants.

In this chapter, I report the second key finding (Finding 2) of this research study: Undergraduate faculty and instructional documents described the characteristics of a successful math and physics student as one who is motivated and persistent, is not afraid to ask questions, demonstrates the capacity for abstract and rational thought in order to identify and solve problems, is individualistic, is not afraid to fail, puts school first, and is respectful. Participants reported challenges in meeting standards created by participants' definition of an ideal student such as taking risks, asking questions, and putting school first. In this chapter, I describe characteristics of an ideal STEM student as defined by faculty and students. Second, I explore how expectations formed by this definition of an ideal student created challenges for female students.

The Ideal STEM Student

It is important to understand the standards that STEM students are expected to meet in order to identify how and why female students may experience challenges meeting those standards. I identified the characteristics of an ideal student by asking both faculty and students what was expected of a successful student in math and physics. Participant descriptions of these characteristics were supported and confirmed in instructional documents and classroom observations.

Adequate Academic Background

According to faculty participants, an ideal physics and math student comes to higher education with a strong academic background in math, which was defined as a student who has taken and done well in appropriate math courses (i.e., at least pre-calculus, ideally calculus) in high school to enable them to take Calculus I in their first semester at MRU. Evidence of this requirement is made clear to new freshman in the 4-year plans for math and physics majors that is made available to prospective students. These enrollment plans outline the courses a student needs to take and pass each semester to enable them to graduate in 4 years. In order for students to follow the plan, they must arrive at higher education ready to take Calculus I in their first semester of college.

Faculty participants reinforced the importance of coming to college with a high school background in calculus. For example, Karl described an ideal freshman physics major as a student who was able to take calculus in high school from a “good” teacher to provide students with a strong foundation in calculus. Similarly, instructional documents reinforced the need for a good high school mathematics background. For example, a lower level physics syllabus stated that students must overcome a “poor math background” to be successful in physics. Through instructional documents and interviews with faculty, an ideal math background was an important aspect of successful math and physics students.

Undergraduate participants were aware that arriving at MRU without adequate background to take calculus their freshman year was viewed as deficient, and this caused anxiety over their ability to be successful in physics. For example, physics major Olivia explained: “I come from a really small high school, so we didn’t really have anything, hardly. Kind of sad, ’cause I knew I wanted to, even my science teacher in high school was so bad, so . . . I didn’t have any preparation coming here, so it was kind of terrifying.” Olivia reinforced the expectation that good students came from a “good” high school or a school that provided an opportunity to take calculus. Because Olivia did not come from a “good” high school, information reinforced to her overtly in instructional documents like the syllabus and in her discussions with fellow students, she felt that she arrived at MRU deficient as a physics major.

School as First Priority

In addition to a strong high school background, math and physics students were expected to be able to dedicate 12 or more hours a day to school and be available for non-class academic activities outside of regular class hours. Physics major Julie described those extracurricular expectations:

> There's different things that they do in the department, like they have their astrophysics symposiums that they have once a month that they like the majors to go to. They have symposiums on Friday afternoons, I think it's from four to five, that they like the students to go to.

One participant, who had a son, explained that those requirements conflicted with her son's school schedule. She needed to be able to pick him up from school and wanted to spend time with him in the afternoon when these symposiums occurred. In addition to those symposiums, other required courses, like labs, often did not follow a set schedule. Some lab times changed weekly, and students were expected to be available throughout the week:

> There's this class I'm in right now that's called advanced physics lab, and it's not like a scheduled lab time because everyone has to use the same room to do it in. So, he makes a doodle [online scheduling program], and you have to pick a time. It just so happens that the way he picks the times, none of them worked for me except three to five because he picks like nine to 11, and I have class at 10, and 11 to 1, and I have class at 12. None of them work, so I go into the lab Monday Wednesday Friday, three to five. He had us do two labs so far but that doesn't mean that I just go in twice because sometimes it [the lab] just doesn't work. I think I probably went in like three times for one of them. And then the other one was really quick, for some reason, it worked the first time. So then I only had to go in once. (Darcy)

Scheduling labs can conflict with participants' lives outside of academics, but because labs were required, students had to rearrange their schedules.

Likewise, faculty and students expected successful math and physics students to dedicate most of their non-class hours to completing homework and preparing for exams. One participant explained:

> You learn to live your life around it. Before I worked like an eight to five job, and when I was done for the day, I was done for the day! You'd go home and relax, do whatever you want! And now you go home, and you still have stuff to do. You still have homework to do. You still have studying to do. You have a test to prepare for. You have reading to catch up on. While still living the rest of your life and helping, you know, your family do what they need to do, too, like my boy, making sure that he gets his stuff done. And helping him with that.

The time required to complete coursework made scheduling non-academic commitments, especially with family, challenging for participants.

Likewise, participants viewed holding employment outside the department as impossible. Physics major Olivia explained: "I don't think a full-time job would be possible at all. I know some people do have jobs, but most of them just try and work in the department because it just gets to be too time consuming without it." Between homework and studying, Olivia felt that it would not be possible to do a good job at both school and work. Reinforcing participant perceptions that success in math and physics coursework was incompatible with outside employment were math majors Madison and Emma and physics major Michelle, three of four senior participants. Each of them had a part-time job off-campus at the time of their first interview. However, by our second interview, mid-way through the semester, they reported that they had quit their jobs because it was impossible to meet the academic requirements of their senior year with an off-campus job. For Madison and Emma, their parents were able to help them bridge the financial gap to pay rent, but this was an additional financial burden for Michelle, who had to find on-campus work to allow her to have the funds she needed.

These findings indicate that time required to be a successful math or physics student created challenges for students who wanted to meet academic standards of their department and the university, such as maintaining a high GPA. Participants reported that trying to balance the time required to be a successful student with outside commitments, whether family or participation in sports, required they either sacrifice their outside commitments, or accept that there would be academic standards they would not meet. Additionally, this may have created barriers for students who could not afford to participate in school without external employment.

Student Characteristics

In addition to having the time to dedicate to school and a strong high school math background, faculty described the personal characteristics of a successful math and physics student. As described by faculty participants and reinforced by student participants, an ideal math and physics student is motivated and persistent, asks good questions, demonstrates abstract and logical thought processes, is individualistic, and willing to take risks.

Motivation. First, an ideal STEM student is motivated and persistent, which means they work hard and are able to push past failure. Physics professor Karl explained why he thought some students fail where others succeed:

> I think ambition is an issue. Some students are really really – they want to be physicists. They are curious of something. For some of them, they are okay with

> it, they like it, but also . . . you see, sometimes you do well, and you are happy, and you fight for it; sometimes, you don't do well, and you give up.

For Madison, motivation was a key characteristic of a successful math major, which she described as a "nerd." She described a successful math student:

> [Someone who is] really dedicated to school and math in particular. Like for me, I have always kinda put school above a lot of things. You know, go home, get my homework done, and then if I get that done, then I can do other things. But if I don't get it done, keep doing it. That's dedication to schoolwork.

For Madison, putting school first was an indicator of motivation and dedication to math. This was a characteristic she identified in herself, and one she recognized in successful math students.

Finally, participants felt that motivation was indicated by attending class and participating in non-required academic activities. Olivia described the expectations faculty have for physics students:

> Definitely expected to put in the work and the time. If you skip class, they're not going to think you're taking this seriously. They want you to try. They want you to do research. They want you to make the university look good; you know, they want you to be putting yourself out there, and like trying and applying for things. If you're not really trying, they don't really take you seriously anyway.

Being motivated was described by students and faculty as "taking things seriously," which was measured by class attendance, perceived effort, persistence in the face of failure, and, for physics students, participation in research.

Asking good questions. Participants also described a successful math and physics major as a student who asked questions during and outside of class. The importance of questions is defined in a physics syllabus: "There is nothing wrong if you discover you're ignorant about something important, but there is something wrong if you remain ignorant." Recognizing incorrect comprehension and asking questions to remedy, that is the responsibility of the student. Reinforcing the expectation that students ask questions when they did not understand, Physics professor Karl explained his expectation that students communicate with him if they need help:

> I expect them to communicate with me in the class, meaning that they should raise hands, ask questions if they have a problem. So, what I do is, more or less, instead of like me teaching lecture, I mean I do that, but I want them to ask me questions, stop me anytime. If they don't do that, I get annoyed because it means that either they are sleeping, or they have no idea what they're doing. Because if they ask a question, from the way they formulate the question, I understand if they understand what I'm doing.

There was an expectation expressed by all faculty participants that students ask for help when they need it. However, there was an additional expectation tied to questions asked, because faculty have used the questions students ask to evaluate whether students understand course content. As a result, participants described an ideal student as one who asks questions in a way that indicates their understanding. A student was described as a good student when the student asked "good questions." This emphasis on the importance of asking "good" questions was reinforced by math professor, Gilbert, who emphasized that he knew a good student if they asked "good" questions. Finally, even students judged their fellow students by the questions they asked. Emma explained that she knew if her fellow students were “smart” and therefore worth working with by the kinds of questions they asked.

Capacity for abstract thought and rational thought processes. Similar to asking questions, math and physics faculty expected their students to demonstrate a capacity for abstract thought and prove they were capable of conducting rational thought processes through their coursework. Gilbert, a math professor, explained that successful math students, “need to know how to do this abstract thinking and reasoning,” and Karl elaborated that a successful physics student would need to be able to think in a rational way:

> You’ve got to have reason, right? Line-by-line reason for what you’re doing. You have to back up everything with another idea, with another thing that was already obvious or proven. There are theories, dilemmas, and that sort of thing in mathematics. And we have a similar thing, but instead of really going that formal, [we] usually use nature or experiment to study. The first idea when we said, if this is that, if we assume this is that, then what would you do? There is a line of reasoning, and it is absolute in the sense that there is no doubt about it. It is correct.

Faculty defined student ability to demonstrate a line of reasoning as evidence of abstract and rational thought; this capacity was necessary for students to be successful in math and physics.

Faculty expressed an expectation that math and physics students demonstrate they can think logically. Faculty expectations were internalized by undergraduate participants.

Each undergraduate participant expressed the logical nature of math and physics as a reason they chose to major in those fields. Physics major Michelle explained how she thought differently from students of other non-STEM majors:

> I don’t know how they think, but my English teacher would point it out about my writing, like she would tell me it’s very logical, step-by-step, like a mathematical approach to it, what you’re doing. And it’s kind of like the way a computer thinks. It’s just like, insert what you want to do, tell it what it what to do, do it.

Michelle compared her thought process to a computer, which she saw as purely logical and unemotional. In this comparison, we see the embodiment of conflict between emotions and rational thought. The math and physics student is expected to think and behave without emotion, and students feel they are expected to demonstrate unemotional rationality in their coursework, exam performance, and classroom behavior. When students felt emotions like stress, they described those emotions as abnormal or extreme. For example, Madison and Emma described themselves as easily anxious and stressed, which they viewed as a detriment to them being successful in math. Because they felt like math was an unemotional field, they perceived that their stress and anxiety was different and abnormal when compared to their peers.

The importance of a universal, rational thought process to succeed in math and physics led to the stated goal of math and physics work, which is to solve problems. Participants viewed problem-solving as the key skill that successful math and physics majors would be able to demonstrate at the conclusion of their degree. Math professor, Gilbert, explained that he expected math students to learn “how to solve problems, break complicated things up into pieces, work on this little piece and then tomorrow, work on that little piece. Structure your thinking, learn how to think." Learning how to think logically and rationally in order to solve problems has guided Gilbert in his selection of course assignments and exam questions.

Additionally, participants reinforced the importance of identifying and solving problems as a key characteristic of successful students. Math major Emma explained: "So math majors, and to a certain extent physics majors, really value figuring out why something is the way it is. We have to investigate it to its extent." Faculty expected students to use prescribed processes and steps to solve problems designed by faculty and the larger math and physics community. They expected students would see these problems and the path to solving them as objective, logical, and clear.

Individualistic. Referenced in the teaching and learning environment described by participants, individualism was a characteristic of an ideal physics student. This ideal guided faculty expectation that students demonstrate they were independently responsible for their own work. The importance of the individual in physics was explained by Karl who described why his tests were so difficult: "The reason that I do it this way is I want them to see a really difficult problem, and I want them to try that without anybody's help. Alone. That is a good feeling, because that's everything that I feel. There's a difficult problem. And I deal with it." Similarly, he described an ideal physics student who was "independent, meaning that [he or she] can study by himself, by herself, learn by himself, herself, something that is mathematically hard to them." The importance of being able to work on their own to solve problems was reinforced in instructional documents, as a physics syllabus stated: "Others may guide you in the acquisition of knowledge and skill, but in the end you teach yourself as a privilege and a responsibility." Faculty and instructional documents reinforced the importance of students being able to work on their own; and, most importantly, that students need to recognize they are responsible for their own success or failure.

Undergraduate participants also emphasized the importance of individual responsibility to student success in math and physics. Madison expressed that her biggest concern in her final interview was that she was relying on her peers too much. Likewise, although students worked in groups to complete assignments, they expressed a need to be able to work individually, as Darcy stated: “If you’re one of those people where you have to work on it with someone, and you didn’t come up with everything on your own, then you need to study more and practice more.” Darcy and Madison expressed that they were individually accountable for their success or failure in math and physics. This recognition was in contrast to emphasis on the importance of being accepted in a physics or math community for academic success and feelings of inclusion in math and physics.

“They must be willing to fail.” Faculty participants also described successful math and physics students as being willing to take risks and fail. Most often, faculty identified characteristics of “a willingness to take risks” as students being willing to respond to questions in class and to pose hypotheses in large and small group discussions. Willingness to fail was mentioned as a key characteristic of successful STEM students that female students most often lacked. For example, Nigel described what he saw as something that female physics students lacked: “In this field, sometimes you need to be willing to throw yourself out there and make hypotheses and then challenge them yourself.” He noted that a key difference between male and female students in class was that male students were much more likely to respond to faculty questions without fearing that they were giving an incorrect answer and were more willing to respond to his probes for hypotheses to why something was happening. Likewise, Karl agreed with the importance of students being willing to take risks, defining a successful physics student as one who, in addition to individualism and communication skills, was “not afraid to fail.” Importantly, undergraduate participants did not identify willingness to fail and take risks as a characteristic of a successful math or physics students. This divide supported faculty perceptions that female math and physics students did not demonstrate this characteristic and may indicate a disconnect between faculty expectations and how that expectation is communicated to students (at least female students).

Similar to faculty observations, in my classroom observations of both math and physics classes, I found that men were more likely than women to respond to faculty questions and speak in class. Specifically, men were much more likely to respond to faculty questions that required a guess; whereas women, when they participated, would respond to questions that provided additional information about a concept. For example, in an upper level math class observation, students were asked questions about what mathematical principal or formula would solve a given problem. Only men provided guesses about what principle or formula was correct. In contrast, both men and women would respond to questions about how to write or describe the formula or principle, once the correct answer had been given. This pattern repeated itself in each classroom observation where faculty members posed questions to the class; men would guess in response to faculty questions, and women would respond to questions that asked for procedural knowledge about a mathematical or scientific concept.

However, in some cases, a female student's possible fear of failure was identified as a lack of ability. For example, Gilbert described a female student who had dropped out of his upper level math course:

> Gilbert: I had her in differential equations, and she was really good. And then I got her in geometry, and it was this abstract mathematical proof, and she just didn't do well at all. I remember handing back an exam, and after I'd handed back the exam, I was looking at the blackboard, and then I turned around and she was gone. She'd just quit the course after that. She was really good at differential equations, but then she was just very hard for her in geometry where you do the proofs and abstract thinking.
>
> Laura: Do you think women take failing harder?
>
> Gilbert: My gut impression was that it was just this abstract proof thinking type stuff that that was what was hard for her. I didn't really think that . . . I mean it never entered my mind. Maybe you're right; maybe she just wasn't able to cope with getting bad grades. But, I just thought the problem with her was that she just had a problem with abstract proof thinking-type stuff.

In retrospect, we cannot know exactly why this student chose to drop the course and change majors, but the possibility that it was not an inability for abstract thought, but instead a fear of failure that had caused her to drop the course did not occur to Gilbert. In later interview questions, Gilbert did not identify natural ability as a difference between male and female students; in contrast to that, his assumption about why a female dropped his course ascribed a lack of ability as the cause and did not recognize that other factors may have caused the student to drop his course.

Respecting professors. Finally, faculty participants described their ideal student as nice and respectful. Gilbert described his ideal math student: “Well, the first thing that comes to mind is I like students who are friendly and respectful and don’t give me a hard time about things. . . . Who pay attention in class.” Nigel and Ronald agreed, that they wanted students who were quiet and respectful. In addition to being a characteristic of an ideal student, faculty indicated that niceness and respectful behavior were characteristics that female participants were more likely to posses than their male peers. For example, math professor Ronald explained:

> I want to say, although I don’t feel any confidence in it, so well, somehow it seems like, again, on average, care more, like are more or less inclined to be casual about it, right? Sort of a, my teacher has asked me to do this thing and I take that seriously, or I want to be respectful of that.

He further explained:

> I think, in general, it has seemed to me that female students are more serious and therefore seem to do better and . . . my impression, you have those good student attributes, those good student attributes are more often present in female students than in male students. Total impression.

Being nice and respectful was viewed as a positive characteristic of the female student.

Likewise, undergraduate participants described that being respectful of professors was very important to them. Emma, in describing a typical day, and how hard it was to fit in eating lunch when classes were back to back, explained why she would not eat during class despite health concerns that required her to eat regularly. She explained:

> Emma: I consider it rude if I'm eating during class, so like, I just bring a sandwich, and then I eat something between.
>
> Laura: Why do you consider it rude? Did someone ever tell you that?
>
> Emma: No no. I don't know, I just, I think like a lot of the students have a lot of respect for the professors who work there, and I just feel like a professor shouldn't have to ask you to not eat during a class.

Respect for professors led Emma to not eat in class. Similarly, Darcy cited respect for her professor as the reason she would not ask questions during class to clarify something a professor had written on the board. She did not want her physics professor to think that she did not understand his poor handwriting.

Challenges Meeting Ideal Student Standards

While faculty and student participants had similar definitions of ideal math and physics students, undergraduate participants described challenges meeting those standards. Those challenges were represented in: the fears female participants expressed, how female undergraduate participants described what was important and valuable to them within the program, and the internal conflicts female students described in decisions and choices they had made that led them to this point in their academic careers.

Fear of Failure

Although faculty participants reinforced the importance of students being willing to take risks and fail, undergraduate participants expressed a fear of failure, which manifested itself in anxiety about the potential of failing. Failure was most often defined as not passing an exam or a test. One student explained how fear of failure had affected her in a physics course: "I'm taking a class that I dropped last year because I was, like, thinking I could fail it." Early in the semester her junior year, she had performed poorly on the first test of the semester and found that some of the math that was being covered was math she was not familiar with. Although, she later told me that she probably could have taught herself the material and made it through the course, the potential that she was going to fail the course led her to drop the course and to even consider dropping the physics major completely.

Anxiety about the potential of failure also affected other participants, which made them doubt whether or not they belonged in a math or physics major. Freshman physics major Samantha explained how fear she would fail affected her performance on a quiz:

> I went down to the math help center so I could review for a quiz that I knew would be the next day, and um, but the thing was that I was so tired that I was barely working through any of it, and it took me like 3 hours to get through one section of like grouping questions, and there weren't even that many. And so, by that part, I kind of fell apart, and then I went home, felt bad for myself, like felt so sapped of energy and motivation that when I was like, trying to talk to myself to get up and go get some food, like I kind of lifted my head, and then slammed it back on the desk. And then, I was really, like, afraid to go to bed that night, 'cause I know it'd be closer to the next morning of feeling just as horrible as I did. And I took the quiz, and the thing is I panicked so hard, that I'm pretty sure I bombed it.

While it is likely that both men and women fear failing, participants perceived that women were more likely to feel like they were failing. Fear of failing lead them to drop a course or even change a major. Physics major Michelle confirmed that women were more likely than men, in her experience, to drop a class because they were afraid they would not be able to pass it. She explained:

> Michelle: I feel like it intimidated them so much that they ended up dropping it. Like they're doing good now, but-
>
> Laura: Do you feel like women are more likely than men to say, I'm going to fail, I'm dropping this class?
>
> Michelle: Yeah . . . like, I definitely feel like personally, the guys, when I do better than them, make excuses up for why I did better.

Michelle perceived that men responded to failure differently than women did because they made up excuses for why they had done poorly. In contrast, she observed that women viewed failure on an exam as evidence that they would not be successful in the course.

Importance of High Grades

Participants reported that they were taught from a young age that grades were important as an indicator of learning, but also as an indication of success or failure. Each participant indicated that they believed receiving high grades was important; they entered higher education, in some cases, having never received a grade lower than an A. Math major Madison stated: "I had straight As all through high school. I never had a B in my life." Similarly, physics major Olivia summarized how she felt about receiving less than an A: "I just like having a high GPA. For me like B is for bad." While faculty had an array of other indicators they referred to, to understand a student's success or failure in their classes and programs, for undergraduate participants, the ultimate and final measure of whether or not they were successful were grades they received on assignments, exams, and their final course grade. Cumulative GPA was the final word, students perceived, of their success or failure. Women in this study were, without exception, high-achieving students. This is important to understand because along with being high-achieving and focusing on grades, they also feared that they would fail, did not want to appear to not understand a concept, and feared confirming the stereotypical perceptions of women in STEM. This, in part, helps to explain why female participants were reluctant to speak up and ask questions, one of the characteristics of an ideal student that faculty participants described female participants struggled to meet.

Not wanting to appear to fail directly contrasts with characteristics of an ideal physics and math student--one must be willing to fail and take risks. It is a core requirement, at least according to faculty members, that students are able to experience and face failure and then keep on going. While this might be difficult for any student to do, high-achieving undergraduate participants reported that this was difficult for them. They described how they were expected to lower their expectations regarding failure and grades. Michelle explained:

> It's difficult to take a class, and like, have your teacher give you a 50% and be like, you actually did really well! Like it's hard, 'cause you're always taught that like, 90, 80, 70, 60, like that's the grading scale. And like A is the top and you should get like As. And it's just like - it's not like that in Physics.

Similarly, Madison described how her perception of grades had changed:

> Laura: Do you feel like not getting an A in a class means that you failed the class in some way?

> Madison: I think not getting a B in the class. In high school, I would have said yes. But college has made me realize that A is not everything. So, I have softened that.
>
> Laura: Tell me about that process.
>
> Madison: My freshman year, I got straight As the first semester. But then the second semester, I was doing a lot of traveling with curling, and [a] lot of the grades were based on participation, and there was nothing I could do to not get a B in the class because of that. So I was like, it's going to happen! And I mean getting past Calc III and Diff E Q, math classes get really really hard and you're kind of, you know, you've done all this work in the class, and you're like, you know, I've had a C all semester but you end up with a B, and it's really satisfying because you thought you weren't gonna get that.

Participants described the process of adjusting their expectations regarding grades as a necessary part of feeling comfortable and successful in math and physics. Physics faculty supported that process by setting an expectation for physics majors that they should expect to receive low grades on their coursework. However, without express and specific support from faculty and peers, participants dropped courses and considered changing majors when they felt they would fail.

Fear of Speaking in Class and Asking Questions

Related to a fear of failure, participants also expressed reluctance to speak in class and ask questions, behavior that I also observed in my classroom observations. When I asked undergraduate participants what differences they noticed between male and female students, each participant noticed a difference in how often women spoke up in class, even noting that they asked questions less often than their male peers. Julie stated: “When I think about it, I guess the females rarely ask any questions, or they’ll go and ask the professor like after, or um, if we’re doing homework, and we have questions.” This was reinforced by physics major Olivia:

> Laura: Do you see a difference in the way that boys and girls participate in class?
>
> Olivia: The boys definitely ask more questions.
>
> Laura: What kind of questions do they ask?
>
> Olivia: Pretty much anything that comes to mind. The girls in the class try to like, they only ask things if it’s like really relevant, I feel like they thought it out more, and they’re like what about this? And boys are like, well, how about this, and they’ll just throw out some random topic.

The reluctance to speak was not only in response to faculty questions posed to the class, but to speak in general, such as asking questions. Each of the participants expressed a reluctance to speak in class, in general, and especially in response to faculty questions. Undergraduate participants recognized that asking good questions was viewed as a characteristic of an ideal physics student and were afraid to ask questions that might reveal they did not understand a concept adequately.

The difference in classroom participation expressed by participants was confirmed through classroom observations of both math and physics classes. For example, in an upper level math observation, a female student brought up an example to contradict the answer a vocal male student had given. When the professor did not understand what she meant and asked probing questions to ascertain her meaning, instead of clarifying her answer, she apologized that her comment was unclear and said sorry several times. Finally, she retracted her example and refused to provide any additional clarifying information in response to the faculty member's question. In this example, the female student was trying to contradict an incorrect response a male student had given. However, she backed away from her statement in response to the faculty member asking her to expand on her response. I observed interactions like this in each classroom observation.

Fear of Providing a Wrong Answer

Related to a fear of failure, undergraduate participants also expressed a wish not to appear stupid in front of their peers. Michelle explained her fear of answering questions incorrectly: "If I answer this wrong, I'm going to look stupid. And a lot of physics majors won't speak up because they don't want to sound like an idiot." Likewise, directly in contrast to faculty wishes for students to take risks and be wrong, undergraduate participants expressed embarrassment when they did make mistakes and fears that faculty would view them differently. Darcy explained her embarrassment about a mistake she had made on an exam: "One of them was a really stupid mistake. I'm really embarrassed about it." Likewise, Emma explained one of her concerns about her low GRE score was that her poor performance would make her advisor think she was not smart. She described meeting with her advisor to tell him her score: "And then he asked me how my GRE went, and I'm just like, ah, okay, here's my score, has your opinion changed? Nah, you're still – you're fine. It's like, okay." Finally, Olivia also expressed a wish to ensure faculty kept her in high esteem: "Once you know your professors, I think it's so much worse to do bad on something, so then you're always like, please just don't think less of me now that I didn’t do well.” Female students did not want to appear stupid both to their peers, but more importantly, to their faculty, who they held in high esteem.

Overall, female students were less likely to respond to faculty questions; however, when they did respond, they responded to different questions than their male peers. As discussed previously, women were less likely to respond to questions where the answer they gave would be right or wrong and were more likely to respond to questions where they provided additional information. In addition, when women did ask questions, they were different than questions of their male peers. Female students were more likely to ask “can you help me” questions, and men were more likely to respond to questions with right or wrong responses in their interactions with the professor. For example, in a Physics 1 class, female students would ask a faculty member to verify if the steps they were taking to solve a problem were correct. In contrast, while male students might also ask the professor to confirm if the work they had done was correct, they would also respond when the professor would ask comprehension-checking questions during the lecture where their answer would be either right or wrong. Classroom observations confirmed participants’ expressed wish not to give incorrect responses at the risk of appearing stupid.

Confirming Biases

Some undergraduate participants feared failing and appearing stupid because they feared they would confirm the stereotype that women were not smart enough for math and physics, a stereotype threat referred to previously. Physics major Olivia explained her reluctance to speak in class: “Maybe ’cause you’re told you’re not as smart as the boys most of the time growing up, so you always feel like if you’re going to ask something, you don’t want to sound stupid.” This led her to try harder in classes as well, “I feel like, anytime you get something, people think it’s because you’re a girl, and not because you did well. I feel like you fight harder to show that you’re capable of doing things, whereas they just kinda do it.” Similarly, math major, Madison, confirmed that she felt a little more pressure to be successful in math to prove herself because she was a woman. Finally, Michelle and Olivia explained that their male peers would accuse them of getting high grades because professors were going easy on them because they were women. Michelle explained:

> Michelle: The guys, when I do better than them, make excuses up for why I did better. Like, it’s happened to everybody who had the same answer. The teacher has graded it, and one person ended up with a better grade on it than the other. Like, I’ve had it happen with me and another student. Like, we had the same thing, and I ended up with a worse grade on that part than he did. So, I asked the teacher about it, his explanation was bullshit. Like, I even brought the student in with me, and he was just like, well what, do you want me to take points away from this student? And I was just like, no. But it’s just like, I didn’t say that, it’s because [the professor] was in love with this student and was favoring him. But when I do it, like when it happened to me and another student, and I ended up with a better grade, it was, it’s because the teacher likes you. And I’m just like, fuck you, grading is a subjective thing, like it happens. But basing me doing well in this class purely because the teacher likes me or because I’m a girl . . . It makes me angry. I’m like, do not say that the reason I’m doing well in this class is just because I’m a girl.

Michelle's academic success has been minimized by her male peers when they attribute her success to being female instead of being smart. For Olivia and Michelle, this made them more reluctant to provide incorrect answers in class, and thereby confirm male peer perceptions that women were only successful in physics because faculty were giving them preferential treatment.

Very Easily Stressed

Undergraduate participants' fears of confirming biases and failure, and the pressure they felt to perform at a high level, led each participant to express how stressed they were, describing themselves prone to anxiety or easily stressed. Math major Madison described herself as "someone that's very easily stressed, I think. Like I just overthink things and worry about unnecessary things." Likewise, math major Emma saw herself as, "more prone to depression and anxiety." Madison and Emma, like other participants, described themselves as anxious or stressed. As a core descriptor of themselves, this suggests that they see their stress and anxiety as exceptional or different from their peers.

Participants also described behaviors they undertook to counteract the extreme stress they felt. First, each participant would take time away from homework, like Darcy described when describing a typical day:

> Darcy: I typically don't start homework right away 'cause I just need to, like, take a break and, like, eat. I don't know, de-stress. I get stressed really easily, so I just try to take time to, like, cheer up; and then, I'll just, like, do homework or whatever I have to do for the next day.

> Laura: When you say you get stressed really easily, what sort of things stress you out?
>
> Darcy: Um, just, like, even things that I have to do in the future, I, like, think about it. Which is probably good because it makes me want to do it, so that I like – I don't want to have stuff on my to-do list because then, when it's done, then I don't have to think about it anymore, like okay, it's done.

Darcy described her stress as higher than her roommates who were male math or physics majors. Additionally, like other undergraduate participants, Darcy engaged in behaviors to help her be less stressed, such as spending time with her roommates. Likewise, Olivia relied on swimming and Netflix to help her deal with stress. Madison spent time golfing.

Creating a Student Community

In contrast to the negative motivation of fear of failure, one of the most positive motivators for female participants who had been in the program for longer than a few months (Michelle, Julie, Emma, Madison, Darcy, and Olivia) was the importance of the community of students in math and physics. Each participant explained how important the community of students was to their success in their physics or math programs. When asked what advice math major Madison would give to students about how to be successful in math, she explained:

> I think you just need to make friends with the people; and then, you know, work with other people because math isn't just like – like one person can't possibly know everything. And, I mean some people may, maybe they do, or [they know] enough. But, I don't. And, so it's really nice to be able to work with people, and

> you know, get through everything together. Moral support a little bit, too, especially this semester.

Physics major Julie also valued the help of her fellow physics majors:

> So you kinda get to know them; and since you do that, and you work together, it gives you insight into other ways to work on some of your homework problems. You can help somebody, or they can help you with doing different types of problems. It's actually kind of really nice getting to know everybody in the department, so you can actually help each other.

Female participants strongly ascribed their success in math and physics to working with fellow students. This is clearly different from attributing success to ability or hard work.

In addition to academic support, female participants also described the community as important because they provided support when the program was hard. Olivia explained:

> I know it's nice that we have all of the physics majors, 'cause we all feel it at some point. We've had a lot of them drop their major, you know, like right at the end, 'cause they're like, "I'm burnt out, I can't do this anymore," so, usually we try to talk each other out of it. It helps having all of us. 'Cause we've all gotten really close – 'cause there aren't a lot of us.

The other students, especially other female students, were important to participants because they were going through similar struggles and could support each other when someone was struggling. This commonality of experience was a positive experience for participants, and it helped them to develop relationships because of the mutual need for support.

The community built for math and physics majors extended beyond academic support, which helped one student feel like she was a part of the community despite being much older and having a child that was close in age to other students. She explained:

> One of the nice things is that, the department being as small as it is, . . . you pretty much know everybody in your classes. You get along with them. You spend a large amount of time with them. And, we actually do things together. You know, go out to supper or something once or twice a semester just to chill and relax.

This community was one of the reasons that Michelle was reluctant to graduate. She said the most negative thing about the semester was "probably like leaving like all my friends and, like, even some of my teachers. This department is just, like, really close. And it's going to be hard to just pick up and like never see most of them again." The importance of the community for undergraduate participants goes beyond academic help they get by completing homework with their peers and being able to ask peers questions they are reluctant to ask professors. Relationships built with fellow students were one of the first things undergraduate participants cited when asked about what they enjoyed and what they would miss when they left. Participants' emphasis on community demonstrated how important relationships with their peers and fellow faculty members were to female students, despite the discourse of individualism that pervaded their STEM instructional environment.

Conclusion

Undergraduate faculty and instructional documents described characteristics of successful math and physics students as those who are motivated to push past obstacles, which requires persistence; students who are not afraid to ask questions; students who demonstrate the capacity for abstract and rational thought, in order to identify and solve problems; students who are individualistic; students who are not afraid to fail; and students who put school first. Participants reported challenges such as taking risks, asking questions, and putting school first. Finally, they preferred a collectivistic environment. They expressed challenges meeting the standards required to be ideal students because their focus on high grades, fear of failing, fear of appearing stupid, and attempts not to confirm biases conflicted with characteristics of ideal STEM students. Instead, participants either measured themselves against standards of an ideal student and found themselves lacking or made accommodations to the ideal according to feminine discourses through the creation of a student community.

CHAPTER VI

INSTITUTIONAL AND STEM EDUCATION POLICIES AND DISCOURSES

In this chapter, I explore the relationship between MRU’s institutional policies and Science, Technology, Engineering, and Math (STEM) policies, procedures, and practices to identify if and how they create challenges for female undergraduate students. This addresses Sub-Research Question 3: *How is the relationship between STEM institutional practices related to the institutional practices of higher education as an institution? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?* Through analysis of documents describing policies, procedures, and practices being used in STEM classrooms, I discovered key Finding 3: Document analysis revealed that the discourses, goals, and assessments of external organizations including the state governing body, ranking organizations, and MRU’s accrediting organization were reflected in MRU's institutional policies. By unpacking the roots of MRU’s institutional policies, procedures, practices, and norms that affect day-to-day work of undergraduate female students in math and physics, I have illustrated how institutional policies at the collegiate and departmental level conflict with the discourses of STEM in higher education. These conflicts create challenges for female undergraduates, because they are expected to meet expectations of both their institution and their STEM departments in order to be considered a successful graduate.

I begin this chapter by tracing MRU policies identified in undergraduate interviews as challenging for initial math placement, 4-year graduation, enrollment requirements, and GPA requirements. I begin by exploring the goals and assessments conducted by the state governing board, ranking organizations, and MRU's accrediting body to identify similar discourses and policies in institutional policy. Second, I explore how those goals and policies are assessed at the institutional level by creating accountability measures that set requirements for students. Finally, I describe how those institutional policies interact with the STEM teaching and learning culture at MRU to create challenges for STEM students.

External Organization Discourses and Goals

MRU policy and procedures reflect discourses or goals set by the state governing board, external ranking organizations, and accrediting organizations. Exploring those discourses and goals provides insight into the roots of institutional policies that interact with STEM discourses and negatively affected undergraduate participants.

State Governing Body

First, institutional policies, procedures, and goals at MRU reflected requirements set by the state governing board. MRU's state governing board oversees all public institutions of higher education in the state. The state board is guided by a vision that focuses on leading the nation in educational attainment. To achieve the mission and vision of the governing board, the governing board's 2015-2020 strategic plan is outlined in a document accessed from the governing board's website. The strategic plan outlined in this document includes goals that focus, in part, on improving admissions standards, improving attainment rates (i.e., participation, retention, and completion), affordability, and financial strength of the state system. These strategic goals, in addition to the state governing board's legal and financial oversight of the institution, are also seen in MRU's institutional policies, notably math placement policies, course enrollment requirements, and a stated focus on student performance measured by grades.

Rankings

Exploring the way rankings are calculated by ranking organizations provides insight into MRU's policies, because MRU wants to be ranked highly to attract students (Shear & Hyatt, 2015). MRU administrators may react to ranking of organizations through policy, in part because MRU's effectiveness as an institution is measured by its rank among similar organizations. I identified ranking organizations that had evaluated MRU through the MRU student recruitment webpage. At the time of this study, MRU was ranked within the top 100 public schools and top 200 national universities. Those rankings were conducted by U.S. News, an organization that ranks all educational institutions in the United States to provide a tool for potential students to make decisions about where they wish to attend college (Morse, Brooks, & Mason, 2015).

Rankings are made according to graduation rates, class sizes, faculty qualifications, student selectivity, student spending, alumni giving, and undergraduate reputation, which measure, among other factors, student performance evaluated by peers (Morse et al., 2015; "The 50 Best Online Colleges for 2016," 2015). For example, 22.5% of the ranking decision made by U.S. News is made according to first-year retention and student graduation rates (within 6 years; Morse et al., 2015). Institutions are categorized according to their Carnegie Classifications, a categorization that largely relies on research activity, school size, and makes a public/private distinction (Morse et al., 2015). MRU is ranked within the categories of national universities and public schools. The rank a university holds among similar institutions is used as a recruitment tool for future students. The success of a university is measured by student performance as measured by GPAs and graduation rates. High GPAs and graduation rates are two goals that are also seen in MRU institutional policy. As an indication of what measures institutions are evaluated by, rank of an organization is used, in part, to measure success and this is reflected in the goals and expectations MRU sets at the institutional level.

Accreditation

In addition to college rankings, exploring MRU's institutional policies revealed policies were informed by requirements set by its accrediting body, specifically those on the establishment and assessment of learning goals. Accreditation is the process by which an external body certifies that an institution has met a baseline level of quality (U.S. Department of Education, n.d). A higher education institution must gain admission to a select group of accredited institutions of higher learning, in order for graduates of that institution to achieve credentials for professional practice, and in order for students to receive federal funding such as federal student aid from the U.S. Department of Education (U.S. Department of Education, n.d; "Overview of Accreditation in the United States," 2016). Accreditation is conducted by federally approved organizations who conduct a multi-faceted assessment process to evaluate whether or a not an institution should receive and/or maintain accreditation.

As an institution of higher education located in the Midwest, MRU is accredited by the Higher Learning Commission (HLC). Five criteria guide the HLC's assessment of an institution; and, institutions must meet core components of each criterion to be accredited by the HLC (“The Criteria for Accreditation,” 2016). Criteria the HLC uses to evaluate an institution’s quality are:

- A clear and public mission statement;
- Ethical and responsible conduct;
- Quality teaching and learning measured by institutional and program learning goals;
- Continual evaluation and improvement of teaching and learning including program reviews, assessment of student learning, and attention to retention, persistence, and completion rates;
- Institutional effectiveness (“The Criteria for Accreditation,” 2016).

In a report published on MRU’s website, meeting accreditation requirements most recently was accomplished, in part, through evidence of an institutional focus on effective teaching, student learning, student support, and assessment of student learning. MRU was re-accredited in 2014-2015. Meeting the HLC’s criteria is required for MRU if it wishes to maintain its status as a reputable institution of higher education and be a destination for students nationally and internationally. As a result, these criteria also guide MRU’s institutional policies and goals, specifically: (a) requirements for assessment and proof of student learning as described in institutional accreditation documents linked to and accessed from MRU’s website, and (b) assessment processes required by the institution for each department. While some MRU programs have an additional field-specific accrediting body, the physics and math programs do not.

Goals and discourses seen in policies and measures set by MRU's rank among similar organizations, MRU's accrediting body, and the state governing board inform understanding of MRU policies reported as challenging by undergraduate participants. An accrediting body ranks institutions of higher education, in part, according to student performance and graduation rates. The state governing board guides institutional policy as it oversees MRU governance. The state governing board's emphasis on 4-year graduations, student performance, and adequate student placement are also seen in MRU institutional policy. Finally, the accrediting body's focus on student learning assessment is seen in MRU's assessment policy. In addition to focusing on student learning, assessment requirements also inform understanding of how institutional goals and policies are reflected at the college and department level. While MRU policy and procedures reflect the discourses of external ranking organizations, the state governing board, and accrediting organizations, I made the link between these policies and institutional policies because of the existence of similar discourses in external policies and MRU policies. However, the distance these discourses have to travel is significant. Causality, especially in the case of ranking organizations, cannot be ascribed, and discourses on how institutional performance is measured provided a link between these external organizations and institutional policy.

Institutional Policies

At the institutional level, discourses of ranking organizations, and goals and requirements set by the state governing board and accrediting organization are reflected in MRU's policies, procedures, and goals. This is seen, at the institutional level, in the mission and vision statement. First, MRU's mission statement emphasizes a strong relationship between the university and the state in regards to research and public well-being, which is similar to the state governing board's goals. Additionally, the mission statement reinforces teaching and service, which are also state governing board and HLC emphasis areas.

Second, MRU's vision statement has several initiatives that focus on teaching and learning, research, and service to link people of the state to the larger community. Each MRU institutional initiative is similar to one of more of the goals or requirements set by the governing body, the HLC, and ranking organizations. Specifically, the mission and vision, while focusing on student learning and performance, also refer to institutional goals that are geared towards increasing revenue, increasing enrollment, improving graduation rates and post-graduation outcomes, and improving the status of the university as a research institution. Of importance to this study, one vision initiative focuses on the student experience, which includes student learning and post-graduation success. This focus on student learning is similar to the accrediting body's criteria focusing on student learning. Specifically, this initiative includes goals for student performance and 4-year graduations, two institutional policies that created challenges for participants. Student performance, as measured by GPA, and graduation rates are also seen in ranking organization and state governing board discourses. Initiatives from MRU's vision statement provide an overarching framework that colleges and programs within the institution look to when creating their own goals. Using vision statement initiatives as a framework, the policies of colleges and individual departments create their own goals to help meet institutional goals.

College Goals and Policies

The departments of math and physics are located in the same college. Like the institutional mission and vision, college policies are directed by a mission statement that outlines the goals of the college. The vision aligns with MRU's mission and vision. Listed on the college's website, the college's mission is to provide students with knowledge and applied experiences; promote interdisciplinary programs and research; develop students who are problem solvers, communicators, ethical individuals, inclusive and analytical thinkers; and, to create a research environment where faculty research informs teaching and provides students with research experience that serves the state, country, and workforce.

The college's goals are accomplished through broad goals, as outlined in their strategic plan. Institutional policies identified as challenging by participants are similar to aspects of these college goals. First, college goals focus on, in part, the quality of undergraduate education, measured by grades. These goals are similar to the state governing board's emphasis on and the ranking organization's measurement of student performance. Second, a college goal that focuses on 4-year graduations relates to goals set by the governing board as well as ranking organizations. Finally, college goals focusing on student learning, student experience, and teaching quality relate to ranking variables and to accreditation requirements that student learning be defined and measurable. Each of these goals reflects or reacts to external organization discourses and goals. A college is several institutional levels away from the potential influence of these external organizations, but similar discourses and goals are seen at the college level, which may be because college goals are set within larger institutional policy.

Department Learning Goals

In addition to broader institutional goals set by MRU's vision, MRU's mission also sets learning goals that frame departmental learning goals as outlined in MRU's assessment plan (accessed from MRU's website) because program goals should fit within institutional goals (see Figure 2). Student learning goals listed in the mission direct general education learning goals, which include thinking and reasoning, communication skills, information literacy, and general education. MRU's mission goals focus learning goals at the department level. Program and general education learning goals and objectives directly relate to the HLC's requirements that institutions have clearly outlined student learning objectives, a general education program, and a plan to assess those learning goals.

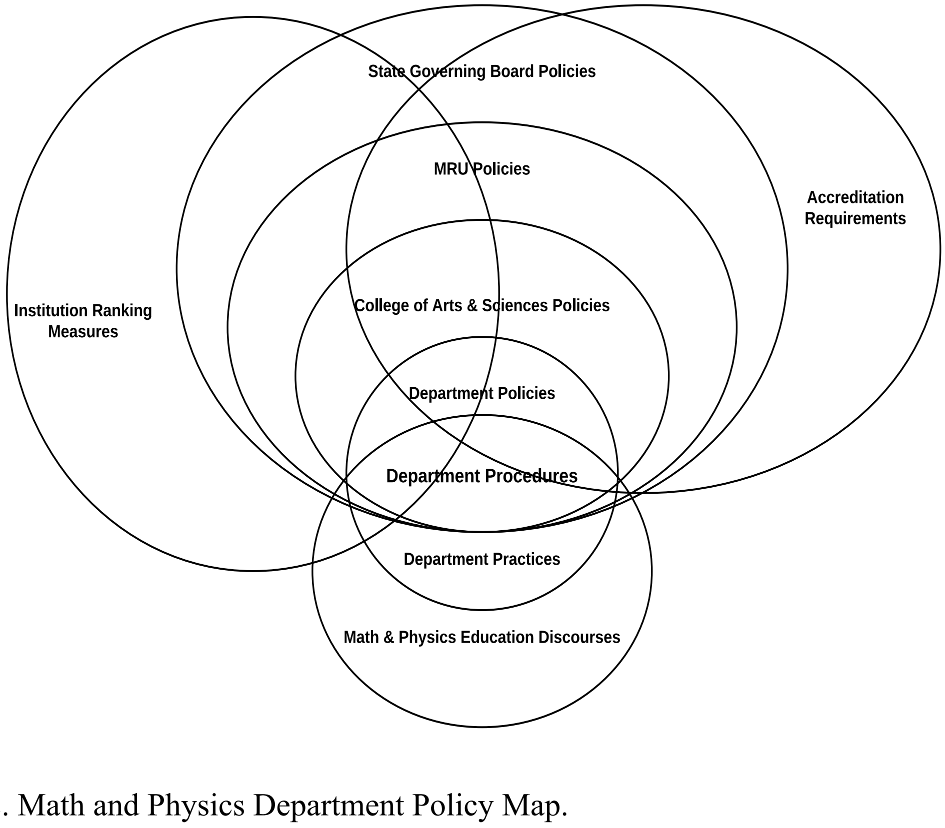

Figure 2. Math and Physics Department Policy Map.

Outlined by MRU's assessment plan, math and physics departmental learning goals are reviewed through a university-wide assessment process. These learning goals outline program-specific goals as well as broader student learning goals of communication, critical thinking, and analysis. For example, the physics assessment plan lists physics student learning goals as physics knowledge, physics skills, scientific communication, and critical thinking through research. Likewise, math student learning goals listed on the mathematics assessment plan focus on critical thinking skills through solving problems, quantitative reasoning skills, thinking and reasoning skills, communication skills, and math knowledge/skills. Content knowledge goals meet the departmental needs, while goals that focus on communication skills, critical thinking, and reasoning meet MRU's expectations that departmental learning goals align with institutional student learning and general education goals.

Assessment. Related to the HLC's requirement that student learning goals are clearly defined, the MRU institution and individual departments must be able to demonstrate that they are meeting their goals. Policies at the institutional level direct college and department policies and goals as described in MRU's assessment plan. The assessment plan describes the institutional policies and a series of accountability measures that should be created and implemented by colleges or departments to assess whether colleges or departments are meeting institutional goals. The assessment plan provides a chart for departments to fill in that requires a department to list learning goals and objectives, educational experiences that will lead to those goals being achieved by students, ways those learning goals will be assessed, a timeline for assessment, who will be doing the assessment, and how results of the assessment will be used, such as for program evaluation or department-level decision-making. Department learning goals, while determined by an individual department, are expected to fit into the framework set by the university. This requires department goal alignment with institutional goals and that goals are measureable, a requirement also set by the HLC.

Additionally, MRU's assessment plan directs math and physics department assessment plans. In addition to large scale surveys and campus-wide assessments that assess institutional data and report that data almost exclusively quantitatively, physics learning goals listed in the physics department assessment plan are assessed by exam scores, samples of student work (lab reports, student coursework, exam question responses), exit interviews, and informal reports. Similarly, math learning goals listed in a math department assessment plan are assessed by senior papers, student solutions to exam questions in a required senior course, student coursework, responses to exam problems, course success rates, and course evaluations, and may be assessed by informal interviews. For both departments, whether or not students are meeting learning goals is assessed largely through numerical representations of students work. The assessable work that evaluates student performance is their completed assignments, exam grades, solutions to math and physics example problems, and written papers, such as a required senior paper for math majors. For example, performance on a math paper is assessed using a rubric that breaks the score into a number between 1 and 4 before assigning a letter grade. The assessment process provides a tangible link between department, college, and institutional policies.

MRU's institutional policies reflect discourses, guidelines, or expectations set by external organizations. State governing board policy focuses on 4-year graduations. Graduation rate is also measured by ranking organizations. These discourses are seen at MRU in 4-year graduation and math placement policies. Ranking organizations, along with an accrediting body and state governing board, focus on measuring student performance, which is also seen at MRU in GPA requirements. Finally, accrediting organizations focus on student learning and require clearly defined ways to assess if learning goals are met. This focus on assessment informs, in part, how these discourse goals lead to expectations for female students set in institutional policy and procedure. Mapping those processes and relationships provides understanding of expectations set for math and physics students and how those expectations are influenced by or react to factors outside the department.

Conflict Between Institutional & STEM Education Discourses

Institutional policies created additional challenges for participants. Those challenges are seen in math placement, course enrollment, and grade requirements.

Math Placement

The conflict between institutional policies and the STEM teaching and learning environment begins after admission, when students are enrolling for courses the summer before their freshman year. For Emma and Madison, placement in math upon entering college was simple. During freshman orientation, Emma met with a math professor who helped her enroll:

> She wanted to make sure I was prepared for Calculus II to make sure that my education during high school was adequate so she was asking me, you know, have

> you done this yet, derivatives. Oh yeah. Have you done this? Oh yeah. Have you started to integrate? Oh, yeah, you know, used substitution and all that, and she's like, good, you're ready.

The process of enrolling in math as a freshman was similar for Madison. Because they had taken calculus in high school, they were able to take courses required for math and physics majors the first semester of their freshman year.

In contrast, Samantha, Michelle, and Olivia entered as freshman not having high school calculus and ran into roadblocks trying to take calculus in their first semester of college. Olivia explained why she had to re-take pre-calculus as a freshman:

> They didn't even tell me coming here that I needed pre-calculus. Because I took a high school pre-calculus, but I needed a college credit so that's actually why I'm here for 5 years, because when I came here and signed up for classes, they just told me, like, you can't take calculus, you don't have pre-calculus, and they didn't tell me I could test out of it or anything, so that wasn't very fun . . . I thought everything was still going to be okay, but then when you look at other classes, well this is your pre-req, but coming from high school, I have no idea about pre-reqs or classes you need and anything, so I didn't know one thing when I came here.

Michelle had a similar experience:

> Michelle: I told them that I wanted to do calculus and they signed me up for the algebra test. So I ended up having to take pre-calc again. That was fun.
>
> Laura: At orientation, it wasn't letting you register?

> Michelle: Yeah, it was the wrong test. Like, I didn't have the credit like for the test to take that class. And then I ended up just having to sign up for pre-calc but I'd also spent the last year in high school taking pre-calc.
>
> Laura: At that point, did you ask if there was a way you could take the calculus test?
>
> Michelle: Yeah. I would have to – no, they wouldn't waive it. I asked them to just do it. I'm like, "I can do this." They're like, "No, we can't do it. We won't. And I'm like – and they're like, "The only way to do it would be to retake the algebra test, it's like an hour-long test. And when we're signing up for classes, it was the very last hour of the last day, so I would have had to have taken another hour when it was 7 o'clock . . . And we had a 2 hour ride back. So, by the time, like, it was all, like, said and done, it was like 7:30, around the time we found out that I would have to take the next test; and she was, like, "We can't stay here another hour, and then sign up for more classes, and it's going to be like 9 before we leave," so I just was like, "Fine, I'll just take pre-calc. It'll be a fluff class. I'll do it again. It was a fluff class. I was very bored in it.

Both Michelle and Olivia were ready for Calculus I according to their own perceptions in their first semester at MRU but were prevented from doing that from institutional policies that required them to have a certain academic high school background.

Those requirements are outlined in math placement procedures. Under state system policy, an ACT Mathematics score of 21 or higher or an equivalent assessment is required for a student to enroll in College Algebra. Students without qualifying assessment scores must successfully complete a developmental mathematics course before enrolling in a non-developmental mathematics course. Placement in math courses is set by the state and would be difficult to change at the department level because it would require coordination not only within the department but also with all of the other universities and approval from the state level. Ronald clarified that even if the math department wanted to challenge placement requirements, challenging it just as one department would be political suicide.

While it would be political suicide, Ronald did not see a reason to change the standards, because he felt they were working, and he agreed with the state policy document that explained the rationale for math placement policies as a key factor for a student's math learning success. State universities utilized placement examinations and students who did not meet the minimum placement requirements would be placed in remedial and foundation level mathematics courses. Students who do not enter MRU have to at least have completed through high school pre-calculus or an ACT score of 26 to take Calculus I. These requirements are described on the math department web page. Math placement policies at MRU reflect policies enacted at the state level and instituted at the institutional level. Despite the perception that they were ready for Calculus I, Michelle and Olivia were not able to enroll in Calculus I in the first semester of their freshman year.

Freshman enrollment is completed at freshman orientation, and for participants, occurred with a counselor that was not working specifically through the math or physics departments. This meant that, unlike Emma, the individuals helping Samantha, Michelle, and Olivia enroll could not assess if the students had the academic knowledge appropriate for a math course and had to rely on policy to determine what course they were ready for.

In addition, sometimes those advising the initial enrollment made mistakes as Darcy explained:

> I guess he did kinda mess up, because he told me that my taking calc in high school didn't count. And so, yeah, he was like, "Yeah, AP doesn't count for this," and I was like, "What are you talking about? You know, you take the AP test when you're done, and they score you like 1 to 5, and I got a 5," and I was like, "Why doesn't this count? I already took this class."

As a result, Darcy was forced to register for the wrong course. It was not until the first week of the course, when Darcy attended the first few classes and went back to further protest her enrollment at the registrar's office, that her AP test score was recognized as equivalent for placement, and she was allowed to enroll in the appropriate math course.

Labeled as Behind

In addition, math placement policies lead to a negative label for students who were not able to enroll in Calculus I the first semester of their freshman year. From our first interview, Olivia and Michelle told me they were behind when they arrived at MRU because of their high school education. Olivia explained how she came to that perception:

> Laura: The last time we talked, you talked a lot about your high school and not getting a good education. Who told you that?
>
> Olivia: People after . . . would leave and go to college would come back and be like, this place does nothing to help you. And then, I got there, and after taking like science classes and math classes, I was like, "I was not prepared for in high school for this at all." Professors will all be like, "Okay, so you learned this in high school," and I'd be like, "No. No, we didn't."

Because Olivia and Michelle came from a high school in a small town, they believed that they arrived at MRU with an inadequate academic background. The behind label was reinforced in interactions with faculty. Samantha, who also had to begin in pre-calculus, was told in her first meeting with her physics advisor that she was already behind when he found out she was not enrolled in Calculus I. She explained:

> There's this introductory like physics major party . . . I met him there. And that was when he told me that I was behind. Like he didn't just straight up tell me like, "You're behind," or something like that. But he was just asking about like what I wanted to do, like, "Oh, astrophysics; that's cool." And he was like, where are you right now in your courses? And I told him, and he's like, "Oh, that's a little bit behind right now," and I was like, "Oh really?" And he's like, "Come talk to me, okay?"

When he found out Samantha was not in Calculus I, her advisor asked her to schedule a meeting where they could talk about her enrollment plan because she was already behind. Samantha, who was already struggling with fears that she was not smart enough to be successful in physics, perceived disappointment from her advisor which reinforced her fears and made her reconsider whether or not she should even major in physics.

The root of this label can be seen in state policy, beginning with the description of admission requirements for state institutions, such as an ACT score: "The purpose of a required ACT subtest score for placement into a college-level course is to provide students time to address any academic deficiencies at high school before entering college." Students who do not enter MRU having met the academic standards are labeled as having "academic deficiencies." "Academic deficiencies" becomes "behind" in the language used by faculty and students, but the negative label persisted and created doubt for Olivia and Samantha about their abilities to be successful.

Graduate in 4 Years

Math placement policies created challenges for students because not meeting the minimum requirements to take Calculus I meant that students could not take calculus in their first semester and therefore would be unable to graduate in four years. The math and physics four-year plan both require Calculus I to be taken the first semester of freshman year. This created problems for any students who could not take calculus upon entering MRU. Olivia explained why she was set back a year:

> Because I needed to take calculus that second semester and calculus is a pre-requisite for the Physics course, so normally you would come in and your would take calculus your first semester and physics your second and then you're on track, but with the way they worked the third, physics 3 is only offered every spring, so I did Physics 1 in the fall, Physics 2 in the spring and then had a break, and then took Physics 3 the next spring.

Not being able to take Calculus I in the first semester put math majors back a semester and physics majors back a year from a four-year graduation. This is why not being able to be placed in Calculus I in the first semester of the freshman year is viewed as so concerning to faculty and students. Additionally, graduating in four years puts pressure on students, as Myles observed: "you gotta be out in four years, pressure. So things are getting even worse. And you can't repeat any, cause you won't have time to do that in four years. So you got that big push."

To graduate in four years, each department created a four-year course enrollment plan published on MRU's website to guide student enrollment so that they will graduate in four years. Those plans specify degree requirements for each major and students are encouraged to plan their enrollment so they can graduate in four year. According to the four-year plan webpage, the four-year plans are a tool to help measure student progress toward graduation. The importance of graduating in four years is emphasized to incoming and current students and represented in the four-year plans created by the department for each MRU major.

Emphasis on the importance of four-year graduation reflected in course plans is seen in state policy. State documents outlining initiatives for student success direct institutions of higher education to focus on helping students graduate in four years: "in order to meet SBHE and Legislative leadership expectations, we must work in concert to make achieving students' educational goals in the most timely and effective manner our highest priority." Undergraduate participants had internalized this focus on the importance of graduating in four years, as Darcy explained:

> Laura: Is graduating in four years something that was like really important to you?
>
> Darcy: Yeah
>
> Laura: Why?
>
> Darcy: I don't know. I know that that it is, 'cause I was thinking about when I'm taking that year off, if I would take other classes, and I'm like, no because I want to graduate in four years. I've been working so hard to graduate in four years that I want to graduate when I wanted to.

Graduating quickly was important to Madison, so important that she was graduating a semester early. In her case, graduating even sooner than four years was equated with saving money. For Samantha, it was a goal that she felt she needed to have,

> All I can hope is that I do decent on that. At least on that, right now my goal is just to pass. Cause if I don't, then I'm going to be way too behind for me to be able to complete my major on time. Which I don't know if I even care about any more. But it seems like goal I should have.

Graduating in four years, which Samantha realized was impossible if she kept her physics major, was something she felt was important, even as she could not verbalize why.

Physics Track

The pressure to graduate in four years is additionally complicated for physics students, because the physics department only offered certain upper level courses every other year. Darcy explained how that made choosing what courses to register easy for her: "the physics major is really easy because a lot of the classes are only offered every two years so you have to take them in this sequence or else you can't take them at all." This differs from the math course plan because aside from not being able to take Calculus I or higher in the first semester, freshman year, required mathematics courses were generally offered every year, so not being able to take Calculus I on track would only push graduation back a semester. For physics major participants, not taking Calculus I in the fall of their freshman year pushed graduation back an entire year.

In addition, the physics course schedule also created difficulties for students who failed a course to graduate in four years. For example, one participant withdrew from a physics course her junior year and explained how this would had affected her had the course she withdrew from not been offered again:

> Typically, they only offer it every other year but for whatever reason they offered it again this year. I think they're trying to offer classes every year just because if something happens like what I did where I had to drop it, I would have had to wait two years to take it again and so it really like puts you behind. So luckily they are offering it again.

This additional pressure caused by the physics track caused stress for physics students not only because they put pressure on themselves to do well but they also know that failing will put them "off-track." The physics department started offering courses every year beginning the fall of 2015.

The physics course schedule resulted in addition problems for students who failed or dropped a course because of personal issues. One participant went through a divorce during her junior year and has been trying to get back on track. She explained:

> Obviously, I've been here more than 4 years now. I think the hardest part since I've been back is I'm redoing some of the classes that I'd taken before. I'm redoing them now because at the time I was taking them before – this is so bad – I ended up getting a divorce, so I got home, I had kinda figured out something was going and I went home and I was unfortunately right and it was - I'm not going to lie, it was a really really bad time. It was really really hard. I ended up taking a late drop for most of the classes that semester.

Withdrawing from courses in the spring semester meant that she had to retake those courses she withdrew from and retake the course that preceded it because they were two-semester courses. Because those courses were not offered for another year, this delayed graduation at least two years. The challenge for participants was between an emphasis on the importance of graduating in four years that led to course enrollment plans and math and physics coursework that is difficult and life circumstances that made it difficult for students to pass their courses. When participants did not start or stay on the enrollment plan, they were not able to graduate in four years. This created challenges for students because they felt like they were "behind" their peers, which put pressure on them to catch up or to consider another major where they could graduate in four years.

Heavy Course Enrollment Requirements

Along with course plans created to help students graduate in four years, institutional and state scholarship course enrollment requirements created additional challenges for students. Darcy explained: "I have to stay at 15 credits for my scholarship, which I hate because like 15 credits of physics is so not the same thing as 15 credits of some other like, I don't know, like sociology or something." Similarly, one student, who often could not enroll in 15 credit hours because that prevented her from taking care of her son, felt like the course load requirements were unfair:

> With the implementation of 15 or 16 hours per semester and graduating in four years, that's putting an undue burden on a lot of people in STEM cause a lot of the classes are a lot more intensive and they take a lot more and you spend a lot more in those particular classes than you would in um say some sort of liberal arts class. I mean, cause I can go write a paper and it takes me a night. But if I go and do a physics homework, that takes me several days. Just because you have to go in and figure out exactly how to do some of the stuff. And some of the stuff isn't

> always in your book. But, and I understand you have to do research to do other types of writing, however I think 3 or 4 classes in a STEM class . . . It's different than taking it in another field. So I think that doing, or requiring the 15 or 16 hours per semester can be detrimental to students.

Likewise, course enrollment requirements created challenges for students who could not meet them. She explained how she had to make adjustments to her mindset so she could do both:

> Well to me, I think that there is, I mean yes, I want to get into grad school, and I understand that yes, a large part of it is based on your grades and your GRE score, and different things like that. That being said, yes if I was 20 or 30 years younger, that wouldn't be a problem. But now, I have a family and to me, you have to have priorities, and my priority is and always will be my family first. If that's what I got to do - sacrifice some grades to be there for them or to help them, that's what I will have to do.

Participants agreed that these requirements affected math and physics students differently than students in non-STEM courses because the workload and difficultly was so high. These requirements increased the already difficult course load and increased stress for math and physics students.

Importance of GPA

Scholarship and institutional policy reinforce the importance of Grade Point Average (GPA) requirements, which created additional challenges for participants by increasing pressure to meet GPA requirements. For example, Olivia explained that state scholarships based on ACT scores required students to get at least a 3.0 to continue to receive the scholarship. The importance of maintaining a good GPA was also reinforced in policies that penalized students for dropping below a certain GPA, such as losing status with the university and being put on academic probation (MRU's student handbook). While scholarship requirements often were not often difficult for students to achieve, those requirements reinforced undergraduate student perceptions of the importance of grades as measures of student success as Michelle explained:

> Cause you're always taught that like, 90, 80, 70, 60, like that's the grading scale. And like A is the top and you should get like As. And it's just like, it's not like that in Physics . . . But in this country, it's like if you're not getting an A, you're not doing well enough. Whereas in high school, it was like the teachers and counselors always talk about your place in the class, and I feel like that puts a lot of unneeded pressure on us. I don't like it. I'd much rather be worried about what I'm learning in the class, then what my grade is in that class.

Michelle struggled to rectify wanting to get high grades and the reality of her physics coursework:

> It's hard, like I've tried to change it, like it's something that I feel like I'm going to always be working on, but like I've talked with professors and like, it's basically hearing that, once you're done with this those grades aren't going to matter. It's what you took away from that class that's going to matter. It's like, do you actually do know how to do that class? Or did you get an A and just forget it all? Or did you like learn how to do it.

Michelle shows insight, in her final semester at MRU, into the conflict between what she had been taught and the physics discourse where grades were not as important. But she, as well as the other participants, reinforced that while they may have lowered their standards a little upon entering math or physics, they still wanted an A and felt disappointed when they did not receive it.

Faculty also expressed that she saw the conflict between an emphasis on getting straight A's and the discourse about grading in STEM education. For example, grades are important to the university but often less emphasized by faculty (even the idea that failure is common in physics). Physics professor Myles explained:

> I mean yeah, when you come to me as a stranger and you have a friend with you, right, and I say oh, how did you do at university? And you say, oh I got a 4.0. And your friend beside you goes, I got a 3.6. And I don't say, oh, you're smarter than her, or whatever, or him, right? And the thing would be, well what did you take? Well, I took pottery making, what did you take? I took physics! Well okay. So it's weighted in that sense. Right, and that just make sense. I've had students that were concerned and professors in general would say look, you're taking physics, you're not going to get a 4.0, and even if you do, you're an elite part. If everyone got a 4.0 coming out of our department, people would laugh at us and you'd never get into grad school 'cause they know you're just giving away the degrees, essentially. Right? You're not learning anything. By it's inherent nature, people find it very difficult when you need to learn. Not all of them, but most of them.

Emphasis on the importance of grades puts additional pressure on students to receive high grades. This is perceived as challenging for math and physics courses because they believe it is harder to get high grades in math and physics than in non-STEM majors.

The challenge reported by participants was between an institutional and personal emphasis on the importance of grades and STEM discourses that led to lower grades through difficult coursework and grading policies.

Conclusion

Document analysis revealed how discourses and goals defined by external organizations were reflected in institutional policies and discourses mandating course enrollment, math placement, and GPA requirements. Specifically, the state governing board directed policies on four-year graduation, which were reflected in course enrollment requirements and math placement policies. Those discourses on graduation rates as well as an emphasis on student performance were also seen in ranking organization measures. Additionally, the importance of defining and assessing student learning goals was set by the accrediting body. These combined to create challenges for participants. Conflicting STEM academic expectations and institutional policies made it harder for undergraduate participants to meet STEM expectations.

CHAPTER VII

DISCUSSION

This institutional ethnography of Science, Technology, Engineering, and Math (STEM) in higher education focused on women's lives, activities, and experiences in the STEM setting and on the interplay of gender and power at the institutional level (Deem, 2002; Hesse-Biber & Nagy, 2014). The purpose of this institutional ethnography was to uncover and describe the institution of STEM education practices at MRU from the standpoint of female undergraduate students. A better understanding of the institutional processes, procedures, policies and discourses that coordinate and guide student work provided insight into how female students were marginalized in STEM education in order to make recommendations to improve the retention of female students in STEM.

I collected qualitative data by conducting interviews with female students and faculty, classroom observations, and document analysis. Participants in the study included eight undergraduate math and physics students and eight math and physics faculty members. Through a framework of feminist standpoint theory, data collection and analysis began with female undergraduate math and physics major participant descriptions of the day-to-day work of undergraduate female students in math and physics at MRU. Descriptions of their day-to-day work informed an iterative data collection and analysis process, where I searched for how their work was coordinated in subsequent interviews, observations, and institutional documents. Data was coded, analyzed and organized by the research questions into three themes; each theme represented a key finding of this study that identified challenges to female undergraduate students, according to the organizational processes where those challenges occurred.

The study was based on the following research question: How do the STEM education institutional processes, policies, and structure organize and inform STEM teaching and learning at MRU for female undergraduate students? Data collection and analysis was guided by three sub-questions:

1. What STEM teaching and learning practices and processes characterize the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?
2. What STEM institutional cultural norms and standards organize and inform the organization of everyday work for female math and physics students? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?
3. How is the relationship between STEM institutional practices related to the institutional practices of higher education as an institution? Do challenges emerge for female undergraduate students as a result of those organizational processes? If so, how and where do they emerge?

I begin by synthesizing the findings in response to the research questions. Within that discussion, I connect findings to the existing research and identify similarities and differences between the literature and these findings. Second, I address the implications of this study for the field of STEM education, identifying study limitations that limit the applicability of findings. Third, I discuss specific recommendations for the field of STEM education suggested by findings. Finally, I discuss opportunities for future research to extend and clarify findings and recommendations from this research. This systematic exploration of the institutional policies, procedures, and practices that coordinate female undergraduate math and physics' student work revealed processes that were often invisible to undergraduate participants; provided insight into the female undergraduate STEM education experience; and identified potential opportunities to improve their experiences and increase their likelihood to persist. By understanding not only where female students were uncomfortable but also how and why those teaching and learning practices existed, I make recommendations for STEM programs in higher education as well as for higher education institutional practices to better meet the needs of female students and improve retention of female students in STEM programs. Additionally, I suggest future directions for research to clarify and extend understanding of the institutional factors that coordinate female undergraduate work.

In analysis of interview, observation and document data, I searched for the processes that coordinated student work and the discourses that guided those processes. The three key findings directly respond to the sub-research questions:

1. Through descriptions of their day-to-day work as a math and physics undergraduate students, participants described a teaching and learning environment that was competitive, individualistic, intimidating, and difficult. Undergraduate participants reported being challenged by the difficult and intimidating aspects of the teaching and learning environment.

2. Undergraduate faculty and instructional documents described the characteristics of successful math and physics students as students who are motivated and persistent, individualistic, not afraid to fail, not afraid to ask questions, put school first, and demonstrate the capacity for abstract and rational thought. Participants reported challenges taking risks, asking questions, putting school first, and preferred a collectivistic environment.
3. Document analysis revealed that the discourses, goals, and assessments of external organizations including the state governing body, ranking organizations, and MRU's accrediting organization were reflected in MRU's institutional policies. Participants described challenges from conflicting STEM academic expectations and institutional policies, which made it harder for them to meet STEM expectations.

The previous three chapters presented the findings by organizing data from various sources into categories to provide insight into the themes. In this chapter, I discuss the conclusions that follow from those findings, situated in the literature on STEM in higher education, gendered institutions, and the neoliberal higher education climate. The conclusions are intended to extend the research on the experiences of female students in STEM fields, and illustrate how the chilly climate and leaky pipeline persist.

The conclusions from this study follow the research questions and the findings and address three areas: (a) commonly accepted teaching and learning practices in the math and physics classroom that create the chilly climate; (b) the masculine nature of STEM education and male ideal that set standards for female students; and (c) the neoliberal environment that informs the institutional policies that reinforce the chilly climate and masculine STEM education institution.

Chilly Climate

The first major finding of this research is that the math and physics classroom environment is still a chilly climate because of the teaching and learning practices in STEM, which are directed by the institutionalized discourses of difficulty, competition, and individualism. These findings suggest that the chilly climate persists because the discourses that inform and guide the teaching and learning practices that create a chilly climate are institutionalized within STEM education. As a result, while the classroom practices that contribute to the chilly climate may have changed, because the discourses that informed those classroom practices have not, the chilly climate persists for female students. The discourses of difficulty, competition, and individualism informed the classroom practices described by participants in this study to make them feel uncomfortable, unsafe, intimidated, or caused them to consider changing majors.

Discourse of Difficulty

First, the discourse of difficulty created coursework expectations that defined the nature of learning for physics and math for students. Math and physics courses were designed to be tough, because faculty wanted to convey the difficulty of the subject matter they were learning. As a result, these courses “weeded out” (Gasiewski et al., 2012; Mervis, 2011) students, acting like gatekeepers for students who were intimidated by the difficult, confusing, and time-consuming work. These courses were so difficult that participants reported students changing majors because they were discouraged by the workload or low grades received on difficult work. Participants were similar to traditional female STEM students who are more likely to be high-achieving (Vogt et al., 2007), so the receipt of low grades was especially discouraging. These findings reinforce research that found that high grades are related to persistence in STEM for female students; difficult work caused self-doubt, which led to attrition (Vogt et al., 2007). The discourse of difficulty was a core aspect of math and physics coursework for student and faculty participants. It was used to rationalize every aspect that made coursework difficult, from the time-consuming nature of homework to exams that were so difficult they had to be taken outside of normal class hours, with everyone in the course receiving a failing exam grade.

Identifying difficulty as the discourse that informs and often motivates teaching and learning practices in the STEM classroom extends prior research and contributes understanding to why those practices persist. More than any other discourse, difficulty was used to rationalize the classroom practices that led participants to feel that success was impossible. There is a difference between challenging students and making them feel like success is impossible. The discourse of difficulty was used to rationalize an array of classroom practices that contributed to the chilly climate in ways that uniquely challenged high-achieving female participants because it made them feel like they could not maintain personal standards of achievement.

Individualism

Second, the discourse of individualism guided an institutional environment where the responsibility for learning was placed on the individual. Additionally, faculty promoted the discourse of individualism, which resulted in perceptions of lack of academic support. The emphasis on individualism created anxiety for participants who felt that they did not have the knowledge to teach themselves. However, participants were reluctant to go to faculty for help (e.g., asking questions in and outside of class), because they did not want to be perceived as struggling. This lack of support reinforces prior research on the individualistic climate in STEM education. Lack of support created the bind described by Morganson et al., (2010) where women in STEM struggled because the coping strategies they were accustomed to were not supported by the college and STEM faculty. Similarly, a lack of support is related to female perceptions of an incompatibility between STEM and being a woman (London et al., 2011; Sartorius, 2010). The discourse of individualism informs teaching and learning practices that places the onus on female students, reducing support, and possibly increasing feelings of incompatibility between themselves and their major.

The discourse of individualism informed a teaching and learning environment that focuses on individual success, “the view that people succeed because of superior abilities, dedication, and performance" (Acker, 2000, p. 630). As a result, changing practices such as adding new support mechanisms is insufficient to remedy the chilly climate without changing the discourse of individualism. For example, participants reported the availability of support mechanisms provided by the institution and the department, such as peer tutoring. Likewise, sometimes the instructional language used by faculty encouraged students to come to them with questions and collaboration between students. However, because the emphasis was still on the individual as solely responsible for her learning, students felt that their reliance on such mechanisms was to their own detriment. As a result, student perceptions of a lack of support from faculty and the department reinforced prior research and were indicative of the larger discourse of individualism and unlikely to change unless the discourse that motivated those practices is changed.

Competition

Third, reinforcing prior research on the competitive STEM classroom environment, the discourse of competition was promoted as a necessary part of STEM by faculty and student participants and led to teaching methods, grading practices and classroom environments that were discomfiting for undergraduate participants. Related to the discourse of individualism, a competitive climate contributes to the leaky pipeline, because women do not find competition a meaningful way to receive feedback (Shapiro & Sax, 2011). As an accepted pedagogy in STEM education, competitive practices such as grading on a curve, have been found to be contrary to the female student's need for collaboration and a collectivistic environment (Shapiro & Sax, 2011; Vogt et al., 2007). Reinforcing these findings, undergraduate participants in this study described how important the student community was to their success and expressed a dislike of competitive practices, even when they acknowledged they were necessary to differentiate students for undergraduate research and graduate school applications. For example, Julie mentioned that prior physics students had been competitive and expressed gratitude that the student environment was no longer competitive. However, because faculty sought to preserve the competitive environment by grading on a curve and the larger STEM environment maintained a competitive environment through the processes of applying to graduate school and undergraduate research, the competitive environment persisted. Despite changes in one aspect of the environment, the persistence of the discourse of competition manifested itself in other areas of the environment. In that way, competitive environments, especially without academic and social support from faculty, contribute to the chilly climate and leaky pipeline.

The discourses of difficulty, individualism, and competition inform understanding of an impersonal teaching and learning environment. Similar to research on the STEM teaching and learning environment (Morganson et al., 2010; Vogt et al., 2007), the classroom was described by participants as and observed to be impersonal, intimidating, and at times even hostile. Undergraduate participants reported more stress and lower confidence in courses where they were intimidated by the professor or the environment, such as when professors would respond angrily to incorrect responses in class and professors who would put students on the spot to answer difficult questions in front of their peers. These practices contributed to an environment that was chilly for female participants, because it created an uncomfortable or stressful environment. Research suggests that the impersonal and intimidating climate exacerbates the discomfort felt by female undergraduate students in the STEM classroom (Sander, 2012). This discomfort is crystalized for female students who are sensitive to biases about women being unsuccessful in STEM (Deemer et al., 2014) and seek not to confirm those biases in their response to faculty, even if they do not endorse the stereotype. Much of the research on the chilly climate has focused on the impersonal nature of the STEM classroom environment and its relationship to the chilly climate and leaking pipeline (Morganson et al., 2010; Vogt et al., 2007), and those practices persisted for participants in this study. While overtly discriminatory practices may not have occurred for participants in this study, the persistence of impersonal and intimidating practices suggests that they are motivated by these institutionalized discourses that characterize STEM education. As a result, the uncomfortable environment created by these discourses will continue to persist, even if the way they are manifested changes.

These findings reinforce and extend research on the chilly climate. The chilly climate still persists in the STEM environment despite the decades of research about the existence of and practices designed to reduce the chilly climate. The discourses of difficulty, competition, and individualism informed the classroom practices described by participants in this study to make them feel uncomfortable, unsafe, intimidated, or caused them to consider changing majors. Because the teaching and learning environment is motivated by these discourses, simply changing the behaviors that comprise the chilly climate will not address the discourses that motivate them (Carnes et al., 2012; Linley & George-Jackson, 2013; Morimoto et al., 2013; Sidlauskiene & Butasova, 2013) The chilly climate for female students will persist until those institutionalized discourses of individualism, difficulty, and competition are challenged and changed (Sidlauskiene & Butasova, 2013).

Gendered STEM Institution

The second major finding of this research is that female undergraduate students in math and physics are expected to meet expectations set according to a masculine definition of the ideal student. These findings extend the body of research on the gendered STEM institution and profile of the ideal STEM faculty member by identifying and describing the ideal STEM student. Faculty and student participants described the ideal math and physics student as being motivated to push past obstacles, which required persistence; a student who was not afraid to ask questions; a student who demonstrated the capacity for abstract and rational thought in order to identify and solve problems; a student who was individualistic; a student who was not afraid to fail; and, a student who put school before anything else. The STEM student standards created by this ideal were presented as unbiased; yet they are gendered in the abstract ideal they define (Sidlauskiene & Butasova, 2013).

Altogether, these ideal student characteristics create dualisms similar to those identified by Sidlauskiene and Butasova (2013) of motivated/lazy, aggressive/passive, risk-taking/safe, competitive/collaborative, emotional/unemotional, and quantitative reasoning/qualitative reasoning. These binaries place women and their actions and behaviors continually referenced as off center or as recognizable and definable because of their difference from men. For example, female participants described their emotional responses to the stress of the teaching and learning environment as excessive and abnormal, because it was different than the way their male peers dealt with or acknowledged stress. As a result, female participants experienced challenges measuring up to and against a male ideal.

The STEM student ideals are gendered because the gendered STEM institution evaluates women using measures and characteristics designed around a male worker (Acker, 2012). These measures and characteristics appear to be neutral; yet because they are built around an unemcumbered male worker, they are based on an ideal that is very difficult for female students to achieve (Acker, 2012). For example, while asking questions in class seems such as an objective and neutral way to measure the success and knowledge of students in math and physics, research has shown men are more likely to speak in the college classroom without fear of being wrong than female students (Kimmel, 2008; Tatum et al., 2013). Male students' willingness to speak in comparison to female students is even greater in settings where women are assumed to be less naturally skilled, such as math and physics (Tatum et al., 2013). Reinforcing prior research, findings from classroom observations and interviews indicated that men were more likely to speak in class, a characteristic of the successful STEM student. This requirement that the ideal student asks questions and speaks in class is based on the typical male student.

Likewise, while the ideal student was expected to be able to devote all of his or her time to coursework, undergraduate participants were either unable or unwilling to devote all of their time to schoolwork. The time-consuming nature of STEM coursework and the expectation that students will put in the time to be successful mirrors the masculine ideal job characteristic of being able to work an unlimited number of hours based on the unemcumbered male body (Acker, 2012; Britton & Logan, 2008). For example, one participant could not spend an unlimited amount of time on physics coursework, because she needed and wanted to spend time with her son. Likewise, Madison played many sports, which prohibited her from spending every moment on math and physics coursework. They each expressed that their participation with non-academic activities could affect their performance in math or physics, yet that they were unwilling to give them up. This aligns with research that found that reluctance to focus on math and physics to the exclusion of everything else (Herzig, 2010).

Finally, the expectation that successful students be willing to take risks and fail created challenges for female participants because of the importance to female students in STEM of receiving good grades. Similar to prior research (Kimmel, 2008), participants reported that they were taught that grades were important, as indicators of learning, and also as indications of success or failure. Reinforcing prior research as discussed by Kimmel (2008), traditional female students in STEM are high-achieving, which they measure by the grades they receive. This directly contrasted with the ideal STEM student characteristic of being willing to take risks and fail. Undergraduate participants still focused on grades as a measure of their success or failure and, additionally, feared confirming stereotypes of women in STEM. Therefore, they were unwilling to appear to fail, which prevented them from taking risks. Participant unwillingness to fail reinforces prior research on the effects of stereotypes on female students in STEM (Deemer et al., 2014), which puts additional pressure on women to perform and avoid confirming stereotypes with incorrect work.

However, the undergraduate participants in this study did not identify a willingness to fail as a characteristic of a successful math or physics student. These findings align with prior research (Byrnes et al., 1999; Villalobos, 2009) and are concerning because it is a characteristic that faculty are using to make judgments about students perceived success in math and physics. In addition, willingness to make incorrect guesses, to take risks, to be willing to fail, to even be willing to speak in class requires an environment that students feel is safe. Participant unwillingness to take those risks indicates that the classroom environment is one where they fear they will judged negatively if they are not correct. The perception that women are less likely to be willing to fail is also a sign that the environment is not as comfortable for women. Willingness to fail especially in the form of taking academic risks requires a safe learning environment (Sharma, 2015). Until women feel supported and comfortable in the STEM classroom, they will not be willing to take risks because they fear the reactions of their fellow students and faculty member. Unwillingness to fail is further confirmation of the chilly climate. On a deeper level, unwillingness to fail is also indicative of a masculine structural climate. Characteristics that are observed in male students throughout primary, secondary and post-secondary levels of education are speaking out in class and being willing to fail (Kimmel, 2008). Setting these behaviors as an ideal is one indicator of the masculine STEM education environment.

These findings create a definition of the ideal STEM student and extend research on the masculine STEM education environment. This ideal is difficult, if not impossible, for female students to achieve. Combined with social pressure and stereotypes of the incompatibility between women and STEM, pressure to meet almost impossible ideals puts more and more pressure on students, making them feel like they will fail, causing them to fail, and increasing the likelihood that they will change majors or drop out. Attempting to meet those standards is uniquely challenging for female students and exacerbates the discomfort that they feel in STEM, causing anxiety and stress. In order to feel comfortable in the STEM environment, the unwritten expectations need to be revised so that they are not based on a male ideal.

Intersectionality

While intersectionality was not the framework of this study, gender was not the only aspect of identity that affected participants' experiences in STEM. Intersectionality "promotes a greater understanding of how converging identities contribute to inequality" (Museus & Griffin, 2011, p. 10). For participants in this study, other aspects of their identity interacted to create different challenges in the STEM environment; for participants, "multiple social identities shape the lives of oppressed individuals" (Museus

& Griffin, 2011, p. 6). For example, class was a factor for participants, as Michelle, Betsy, and Samantha felt more pressure to earn money by working outside of the department in consideration of the loans they were taking out and the burden their attendance was putting on their parents not to mention being able to survive while in college. Outside employment conflicted with their abilities to dedicate the hours needed to be successful in math and physics. Finally, the rural/urban dimension meant that Olivia and Michelle, who were from small rural schools, did not have the opportunity to take the high school courses that would allow them to automatically be placed in Calculus I the first semester of their freshman year. Prior research has found that women, as a group, experience lower self-confidence and self-efficacy in STEM field, but that those factors are mediated by race and ethnicity (Litzler et al., 2014). Similarly, the different aspects of participant's backgrounds and identities affected their experiences in STEM education along with gender, combining to, in some cases, create new and different challenges.

Community

Contrary to the masculine STEM discourses of individualism and competition, undergraduate participants found community to be the most positive and valuable aspect of their STEM program. The feminine discourses of connectivity and relatedness emerged as they emphasized how important the community was to success in math and physics. The emphasis on the community is similar to prior research on the experiences on women in STEM, such as the study conducted by Thomas, Bystydzienski, and Desai (2014). They found that a strong community, built on a female mentoring program met the needs of female faculty members, and also improved retention and advancement. This mutual support was reinforced by each undergraduate participant in the study, who cited the community as the reason for persistence in math and physics, and for their success.

Second, connectedness with fellow female students was especially important for undergraduate participants. Participants each mentioned that while they included fellow male and female students in their supportive community, they found it to be positive to have fellow female students in the program with them. Likewise, the presence of social support (especially from other women) has been found to improve female student engagement, particularly in the first year of college (Rosenthal et al., 2011). The importance of a strong community with at least a few female members was reported to be important for female participants, which aligns with research that has found that the presence of women in STEM, whether fellow students, graduate students, faculty, or administration has a positive impact on female student engagement and feelings of belongingness for female students (Carrell et al., 2010; Carrigan et al., 2011).

Finally, undergraduate emphasis on the importance of community reinforces research that suggests that the communities formed by women are in direct opposition to the discourses that dominate STEM. Barry et al. (2007) reported research that found that collaboration amongst female STEM faculty was a form of resistance to the masculine STEM culture. Undergraduate participants recognized that their reliance on their peers, especially for academic support, was contrary to the values of math and physics, reinforcing that they should work more on their own. However, they felt that the community was important to them, and would add individual work on top of their group work, instead of spending less time with their peers. Madison even quit her job, because it was conflicting with the time she could spend with her fellow students; furthermore, physics students reported spending considerable time helping their fellow students. While faculty promoted individualism and competition, female undergraduates sought to achieve their academic and performance goals without leaving their fellow students to flounder. This focus on the collective and community is contrary to the STEM values of individualism and competitiveness, but critically important to STEM student success (Jackson, 2013).

Neoliberalism and the STEM Environment

Finally, exploration of MRU's institutional policies indicates an acceptance of neoliberal practices in higher education. Neoliberal institutional policies either conflated or conflicted with STEM policies and discourses and created challenges for female undergraduate students that made it hard to persist in STEM majors. First, the neoliberal environment complemented the masculine nature of STEM in higher education and increased pressure on women to perform according to masculine standards. Second, neoliberal policies conflicted with STEM discourses and policies, which created challenges for female students who wanted to meet the standards of both the institution as well as the academic requirements for their field. Prior research on the neoliberal climate in higher education has largely focused on the effects of neoliberal policies on faculty and staff (Shear & Hyatt, 2015; Shear & Zontine, 2015; Pucci, 2015), or the effects on students in general (Davis; 2015; Giroux, 2014). These findings extend those studies by exploring the interaction between neoliberal policies, STEM discourses, and female students.

Neoliberal Climate

The expectations and requirements that guide MRU policy are neoliberal in nature. A neoliberal higher education environment is characterized by a focus on measuring education quality by output measures, identifying research output as economic market value, and ranking the quality of higher education institution (Lorenz, 2012). Evidence of the neoliberal environment that motivates MRU institutional policy is seen by mapping the relationship between external organizations and institutional policy. The competitive higher education market is premised on the student as the consumer and guided by ranking organizations, the state governing board, and accrediting organizations. These organizations create requirements that, in part, help students decide which institution to attend, define institutional quality, and maximize institutional profit. Evaluating institutions according to neoliberal goals, such as the employability of graduates and other measurable student outcomes, rather than, say, appreciation of beauty in mathematics (Myles), these requirements are motivated by a neoliberal view of higher education (Lorenz, 2012; Marginson, 2008).

Characteristic of a neoliberal policy climate, findings revealed a policy map that reinforces prior research on the neoliberal environment in higher education by illustrating how neoliberal goals of increased profit, student performance, faculty research, and enrollment are overseen by lines of accountability (Marginson, 2008). MRU's institutional policies were reflected in the discourses, goals, and assessments of external organizations including the state governing body, ranking organizations, and MRU’s accrediting organization. The hierarchy created by neoliberal policies and assessment procedures at MRU leads to a multi-layered and often complicated policy map:

departments are accountable to the college and institution; the college is accountable to the institution; the institution is accountable to the governing board, and the accrediting body, and also expected to meet the student as consumer's needs, represented by the ranking organizations. At each level, assessment plans indicated how those goals were to be accomplished and evaluated. These layers of policy and accountability are indicative of a neoliberal environment. This focus on performance management shifts responsibility to colleges, departments and faculty members by dictating what they will do and how they will do it, as seen by MRU's assessment plan (Grace, Zurawski, Sinding, 2014; Shear & Zontine, 2015). Through those layers of policy and accountability, the neoliberal climate had an impact on female students, creating challenges as women sought to meet institutional, college, and department standards.

Neoliberalism Conflates the Masculine Climate

First, pressure on women to perform according to masculine standards became more intense under neoliberalism, where the focus on accountability measures reinforced the masculine standards that female students were expected to achieve. In this study, STEM ideal student expectations interacted with neoliberal institutional policies, complementing the masculine nature of STEM in higher education by creating policies and standards that increased pressure on women to perform according to gendered ideal STEM student standards (Thomas & Davies, 2002, p. 390). Reinforcing prior research, the masculine standards in STEM education are bolstered in a neoliberal climate that focuses on output measures such as attendance and homework grades. Pressure to meet those standards neglects to recognize invisible work and differences in student background. Additionally, affirming the importance of impartial standards contributes to the myth of an objective reality and ideal student characteristics that are in reality biased and more difficult for women to achieve because it is based on a masculine ideal.

These findings extend research on the interaction between neoliberalism and standards for higher education faculty. Barry et al. (2007) described how neoliberal policies also interact with academic requirements for research, leading to longer working days, because the ideal male faculty member is unemcumbered and can work an unlimited number of hours. Likewise, neoliberal policies reinforce masculine discourses in that: “'new forms of masculine subjectivities' diffuse through the new public management involving ruthlessness, single-mindedness, and a divisive atmosphere that valorizes 'competititiveness, instrumentality and individuality, which conflicts with feminine discourses of empathy, supportiveness and nurturing' (Barry et al., 2007, p. 106). Similar to the ideal academic worker, the ideal STEM student is based on a male ideal with an unlimited amount of time to focus on schoolwork. Values like individualism and competition were emphasized over collaboration. Reinforcing prior research, the neoliberal climate reinforced the masculine nature of higher education at MRU for participants.

Conflicts between Neoliberal Policies and STEM

Second, while neoliberal policies work in tandem with the masculine STEM environment, reinforcing the aspects of the chilly climate that make it harder for disadvantaged students to feel comfortable, neoliberal policies also conflict with aspects of the STEM environment. This conflict conflates the chilly climate to make it even more uncomfortable for women. For example, the initial math course placement process created challenges for female students. Institutional policy, guided by the state governing body and ranking organizations, focused on the importance of appropriate placement in mathematics courses upon entering MRU. Female participants who were not placed in Calculus I the first semester of their freshman year perceived that the process through which math placement was determined for students led to them being incorrectly placed in a lower math class. This placement resulted in frustration and boredom as “off-track” students were unable to begin program-specific coursework their freshman year. Darcy was able to switch to a higher math class, but for Olivia and Michelle, this placement made them re-evaluate whether they wanted to remain physics majors. These findings provide insight into Chen and Soldner’s (2014) findings that STEM persisters were more likely to have taken math credits in their first semester than STEM leavers. They found that among bachelor’s degree students, 30−40 percent of those who entered STEM fields in the first year (but subsequently left college or switched majors) took no mathematics at all in the first year, compared with 14 percent of those who persisted in STEM fields (Chen & Soldner, 2014). Similarly, the rigorous placement process created challenges for students who were not able to enroll in Calculus I when they entered MRU.

The math placement process indicates a challenge that is created by neoliberal policies because of institutional and state pressure to graduate in four years. In addition to frustration expressed by participants that they could not take coursework their freshman year, this process also resulted in them being “off-track” for a four-year graduation. The pressure to graduate in four-years conflicted with faculty and department goals that students be placed in courses that were appropriate for their skills and background knowledge and that students were able to demonstrate the knowledge needed to pass a course. Not being able to start math or physics coursework caused participants to re-evaluate their major and consider changing their majors to one where they could still graduate in four years. Taken independently, placement requirements, enrollment place and four-year graduation policies might not create significant challenges for students. However, when they interact with students and result in a delayed graduation or delayed entry into coursework, they create additional challenges for students by putting pressure on them to graduate in four years and because they dislike the stigma of being “off-track.”

Second, attention to the neoliberal discourses that frame students with less than an ideal academic background as behind calls attention to how institutional policies and procedures shape the 'problems', where the focus becomes the individual instead of institutional relations that create that problem by definition, shifting the focus and responsibility to the individual from the institution (Nichols, 2014). As a result, making the chilly climate chillier makes it more likely that those marginalized in STEM, such as female students, will either choose not to major in STEM or change their majors to a non-STEM field. For example, physics major Olivia internalized the belief that her academic background in high school was poor and that she was not prepared to be successful in Physics. She also reported being intimidated by faculty members and disliked the individualist and competitive teaching and learning environment. Finally, she received pressure from her boyfriend’s family who questioned whether she could be a wife and mother while pursuing a PhD in physics. Each of those factors caused her to question whether she should remain a physics major. Taken together these almost caused Olivia to change majors, despite her passion for astrophysics that began as a child.

By rewarding students who were able to attend a high school where advanced math and physics courses were offered, neoliberal discourses keep the same type of people in math and, more broadly, going to college, as it rewards those who already fit into the current system. This conflict occurs when neoliberal policies and discourses make it clear to students that it will be easier to maintain good standing at the university in a non-STEM degree program. These findings reinforce and extend prior research on the processes and policies that created challenges for female undergraduate students. Addressing the chilly climate also requires a change to neoliberal policies that reinforce the masculine STEM environment and make it even harder for female undergraduate students to persist.

Summary

As a result of the masculine STEM teaching and learning environment, efforts to reduce the chilly climate have been unsuccessful, largely because the discourses that motivate the chilly climate have not changed. Those discourses are evidence of the masculine STEM institution, which also creates a male ideal that female students are expected to meet, further exacerbating their discomfort in the STEM environment. The masculine nature of the STEM institution is reinforced by neoliberal policies that emphasize the importance of meeting the gendered STEM student characteristics, now reduced to quantitative measures of success that women try and fail to meet, without realizing that they are based on an impossible ideal. The result is that women feel uncomfortable in STEM, and persist, but not without serious stress, anxiety, and discomfort. Attempts to remedy the chilly climate without addressing the institutionalized causes have hidden them more, so it seems that the problem has been eliminated. Instead, the chilly climate and women's marginalization in STEM persists but have become more subversive and therefore harder to identify and address.

Recommendations

In the following section, I offer recommendations based on the findings and conclusions of this study. The recommendations are for STEM higher education departments and faculty, higher education institutions, and for future research to improve the experiences of women in STEM and improve retention.

Recommendations for STEM Departments and Faculty

First, it is clear that the first step to improve the chilly climate in STEM fields requires revising the STEM institution from one that is masculine to one that is inclusive for non-male students. The goal is to create a STEM education environment that supports, validates, and gives women an equal voice (Sidlauskiene & Butasova, 2013). Changes need to focus on remaking the institution instead of remaking the woman to fit the STEM institution (Sidlauskiene & Butasova, 2013). This process is daunting and lengthy and requires transformation at three levels: student, faculty, and institution. For example, some methods of institutional change found to be effective for reducing marginalization of female faculty and administrators include the empowerment of STEM faculty and administration as decision makers, organizational structure changes, clear career progression paths, female faculty, policies that support work-life-family balance, consistent progress reports, and the establishment of clear indicators of success (Sidlauskiene & Butasova, 2013). For female students, similar methods of institutional change could include empowering female students by giving them decision-making power, such as course enrollment choices, undergraduate research options, and in classroom projects. Similarly, the presence of female faculty can provide examples of a career progression path that demonstrates that women can be successful in STEM. Policies that focus on student-life-family balance might help female students and faculty balance their academic and non-academic lives.

Second, departments and colleges need to remove artificial barriers such as those created by placement requirements, reward performance, and provide non-threatening environments for females and minorities. Those can be accomplished through scholarship programs, career orientation workshops, participation in co-op and internship programs, and academic and social support (Yelamarthi & Mawasha, 2010). For example, scholarship programs can create opportunities for students who may not meet the placement course requirements by providing access to STEM programs for students who attended high schools where opportunities to take advanced science and math courses were not available. Additionally, social support from faculty can help to create a non-threatening environment for female and minority students and academic support can help all students to feel successful and competent with math and science coursework.

Institutional change begins with a process that is similar to an institutional ethnography. Departments can begin by identifying the processes that are marginalizing women and trace the policy, procedure, and process to its source. Identifying where and how marginalization exists is the first step; next, departments must ask why that policy exists and if it is necessary. Examining why a process is perceived to be necessary begins to unpack the discourses that are motivating the procedures and can lead to productive conversations about whether these discourses, and therefore the results, are truly necessary to the educate future STEM academics and professionals or if there is room for change. In this way, identifying processes to determine why something is happening to change that is more productive than just treating the symptoms. This is difficult and understandably STEM academia is reluctant to challenge the ideals and practices that have persisted for centuries. This requires a culture shift, from pushing students out of the major through failure to a focus on how to help students succeed. However, it is necessary to diversify and make the environment inclusive for all students, not just women. STEM departments can work to redefine what it means to be successful by changing expectations for students and clearly defining the expectations students are expected to meet. As discussed previously, this process may begin by clearly identifying what students are expected to do and how they are expected to behave and then exploring who is able to meet those standards. For example, this could include defining "taking a risk" and exploring who might not be willing to take a risk for fears of appearing stupid and confirming biases. While a neoliberal focus on outputs can reinforce the masculine nature of higher education, when ideal student standards must be achieved by women in order to be perceived as successful, clearly outlining the expectations in policy has shown to reduce the marginalization of women (Barry et al., 2007).

Critical mass. An important aspect of changing the masculine nature of STEM academia is diversifying the faces in STEM academia. It is critically important that women achieve at least critical mass in STEM faculties. Departments need to focus on hiring female faculty, promoting female faculty to positions of power, and recruiting female students. While recruiting and promoting female faculty may be difficult for smaller, rural institutions, recruiting women into the field will positively impact the pipeline for faculty positions in the future. Research and this study reinforced the importance of female faculty members (DuPre, 2010; Carrel et al., 2010; Charleston et al., 2014; Gorman et al., 2010; Rosenthal et al., 2011; Tatum et al., 2013). Female faculty members have been found to increase participation, feelings of inclusion and belonging, and female perceptions of identity compatibility (DuPre, 2010; Gorman et al., 2010; Rosenthal et al., 2011). Likewise, increasing critical mass also involves actively recruiting female students and supporting them throughout the enrollment process. Changing the face of STEM in higher education can also help to make the STEM environment less masculine and more inclusive; yet it is important to note that adding more women without changing the discourses will still perpetuate gendered climate.

Student support. Related to increasing the number of female faculty and students, departments need to improve support for female students from faculty. Special attention needs to be paid to the support of female students in STEM until those practices become the norm and widely accepted. For example, faculty should be trained to be able to coach female students in STEM contexts to be proactive in developing their own resources to draw on for social coping. Social coping was found to predict desirable outcomes such as commitment and turnover intent for women (Morganson et al., 2010). If faculty are trained to help female students develop those skills, they can help female students to persist and perhaps to feel more connected to their STEM major (Morganson et al, 2010). Social coping methods might include support from faculty for the female student's selection of a nontraditional field, such as supporting the student's self-efficacy in making those decisions (Brown, Garavalia, Fritts, & Olson, 2006). This includes reinforcement of the student's choice to major in math or physics and subsequent encouragement to continue in math and physics after graduation, such as through the pursuit of a doctorate degree (Morganson et al., 2010). Likewise, it is important that faculty acknowledge to female students that this is a nontraditional career choice and the chilly climate that women face (Morganson et al., 2010; Suresh, 2006). Faculty often need specific training to be able to provide this support, especially because the support preferred by women is often different from the support preferred by men.

Likewise, social coping can include mentoring for long-term success (Borum & Walker, 2012; Griffin et al., 2010; Whittaker & Montgomery, 2013), which has been found to promote the persistence and success of women in science (Campbell & Skoog, 2004). Successful organized mentoring programs in STEM provide opportunities for women to be involved in undergraduate research and alerting students to the obstacles they were likely to face as women in STEM (Griffin et al., 2010). Likewise, mentoring (and student support in general) should build student confidence in academic skills (Yelamarthi & Mawasha, 2010). Additionally, mentoring can help female students to learn how to develop their own resources to draw on for social coping, something that was seen in this study as female participants reinforced the importance of the community they developed with their peers for social and academic support (Morganson et al., 2010). In addition to support from peers, mentoring can help students to identify who to go to for support, such as the mentor, but also other resources, such as faculty familiar with the graduate or job application process (Morganson et al., 2010). This support needs to extend beyond the classroom and mentors and faculty need to interact with students outside of the classroom (Gayles & Ampaw, 2014).

While student support existed for some undergraduate participants in this study, it was on an individual basis. Olivia received support from a faculty member who provided an opportunity to participate in undergraduate research. This opportunity kept her from changing her major her freshman year. This faculty member also gave her advice about graduate school and the application process. Additionally, Madison and Emma reported that a faculty member provided support for them as they considered graduate school and guidance with their math senior projects. However, support was not organized by either department on a larger scale such as through a mentoring program. Reducing opportunities for direct support, the physics department had two advisors for the entire physics department, limiting non-classroom support to two faculty members. Students developed their own support communities that were reinforced in physics by the existence of a physics major room. Although the math department did not have a room dedicated to majors, students made space to collaborate in the mathematics tutoring center. Finally, student and faculty participants did not report any acknowledgement that the chilly climate that persists in the STEM environment might create challenges for female students. It is these aspects, in addition to the social coping and mentoring-specific recommendations that are needed in STEM programs. Social support is critical and related to persistence in STEM (Szelenyi & Inkelas, 2011) and careful attention needs to be provided to female students.

Recommendations for Higher Education Institutions and Administrators

At the institutional level, the neoliberal higher education climate provides an opportunity to create clearly measurable metrics related to diversity and other outcomes that suggest an improved condition for women, such as the ratio between female to male faculty members. In that way, neoliberal audit cultures can attempt to legislate diversity, such as by requiring a certain number of female hires or family leave policies that department culture prevents individuals from taking (Minerick et al., 2009). But when those practices do not lead to changes in the institutional culture, the marginalization of women persists. As such, the contradictions between these findings and the literature about research on neoliberal policies and their effect on marginalized individuals within the university are complex. Similarly, while the standards by which female students are measured based on the male ideal, research has found that, at least initially, neoliberal policies that require clearly defined performance measures to evaluate faculty reduce discrimination because the clear standards reduce the subjectivity of performance (Britton, 2000; Jones et al., 2014). However, because those standards are often gendered themselves, the existence of a clear standard may result in less bias in the evaluation of student success, but the standards used to measure them are still biased. As is seen by the masculine ideal student that creates the ideals female students measure themselves against, creating standards based on that ideal reinforce the power of the masculine standards. Additionally, the neoliberal standards are quantitative and presented as unbiased and objective. Pretending that differences do not exist can preserve and even promote institutionalized gendered practices (Acker, 2000). This suggests that institutions can promote diversity through accountability measures that indicate an improvement in diversity. However, the standards students are measured against need to be examined to ensure that they are not based on a masculine ideal.

Finally, careful attention should be paid to the language used to describe students. Labeling students as behind and off-track further reinforces the negative consequences of not measuring up to the ideal characteristics of the STEM student, increasing their likelihood to change majors to avoid those labels. To address that, language that ascribes an internalized disadvantage to students should be removed, such as removing the word deficient in instructional and policy documents. Likewise, administrators have the opportunity to be careful when using language like “remedial” to describe foundation courses and labeling students who will not graduate in four years as “off-track.” The label of “off-track” could confirm for students that they do not fit in a degree program and increase the likelihood that they will change their degrees to a major where their success, as measured by the time it takes to graduate, is in line with a four-year graduation and their fellow students. Changing how students are labeled institutionally has the potential to have a powerful effect on how students are treated throughout the institution. The transition from being treated as a challenge to an opportunity can have a powerful impact on how the student feels and their feelings on belongingness in STEM fields.

Future Research

Finally, future research is important to confirm and extend findings on a larger scale. First, it would be valuable for research to follow female students throughout their education, beginning before they enter college. Long-term, in-depth relationships with female students would provide insight into how they feel, and if they change majors, why they are changing. This research would help to supplement and extend findings on experiences of women in STEM from their perspective. Likewise, the second recommendation is for research that explores experiences of a larger group of women from varied institutions. This research would extend findings on a larger scale and increase understanding of institutional processes, policies, and procedures that marginalize women in STEM. Third, in light of the limitations of this study, it is important to extend this research to other STEM fields beyond math and physics.

Although conclusions of this study for math and physics were similar, it is clear that each discipline has significant differences, and understanding how each environment and chilly climate are different, and possibly better (or worse), can help to provide additional insight into marginalization of women in STEM and how to improve retention. Finally, future research should aid in increasing the number of students in STEM education so a more diverse group of students from varied backgrounds would make up a STEM student body. Additionally, in future qualitative studies, specific interview questions about background experiences would explore the effects of background on the experiences of female students in STEM.

Researcher Reflections

When I embarked on this study, I expected to find that women were marginalized, but did not know how the coordination of work could provide insight into the roots of that marginalization. As data analysis proceeded, however, I was surprised by how much was revealed simply by tracing the processes that coordinated the work described by female students. Despite participant assertions, both student and faculty, that the climate was not marginalizing, not gendered, understanding the institutional environment illuminated how it was gendered, albeit on a deeper, more subtle level. Findings suggest that significant change is necessary to truly re-make the environment comfortable and safe for women; while that requires difficult changes and critical self-examination, the potential for women in STEM is great.

Conclusion

Efforts to reduce the chilly climate have been unsuccessful largely because the discourses that motivate the chilly climate have not changed. Those discourses are evidence of the masculine STEM institution, which also creates a male ideal that female students are expected to meet, further exacerbating their discomfort in the STEM environment. The masculine nature of the STEM institution is reinforced by neoliberal policies that emphasize the importance of meeting the gendered STEM student characteristics, now reduced to quantitative measures of success that women try and fail to meet, without realizing that they are based on an impossible ideal. The result is that women feel uncomfortable in STEM and persist, but not without serious stress, anxiety, and discomfort. The first step to improve the chilly climate in STEM fields requires revising the STEM institution from one that is masculine to one that is inclusive for non-male, non-white students. This process involves a critical examination of the processes, policies, and procedures that marginalize women and institutional changes such as changing expectations for students away from a male definition or success and hiring more female faculty members. Additionally, female students need additional organized support from faculty members through mentoring programs and training on providing social support. Finally, future research should extend the findings of this study on a larger scale, exploring the experiences of female students at a wider array of institutions as well as a larger number of students from more diverse backgrounds. It is hoped that these recommendations can help to improve the experiences on women in STEM and, as a result, improve the recruiting and retention of women in STEM.

APPENDICES

Appendix A
Interview Protocol

Interview code: ___________

Consent form signed: yes/no (circle one)

Review purpose of the interview:

The purpose of this interview is to explore Physics/Mathematics undergraduate experiences and perceptions. It is estimated that interviews will last 45-60 minutes. If you are willing, this interview will be recorded using the AudioNote app on my iPad for the purpose of review and transcription. Your name and identifying information will not be recorded.

Do I have your permission to record our conversation? yes/no (circle one)

Date/Time of interview:

Location of interview:

Mathematics or Physics student (circle one)

Year in school (circle one): Freshman Sophomore Junior Senior

Other (Please specify):

Interview number (First, second, third):

First interview questions (asking additional questions to clarify unclear information or to re-focus responses to be pertinent to the study):

1. Why did you choose to pursue a degree in Math/Physics?
2. Did you enter college as a Math/Physics major? If not, what did you major in initially? Why did you change?
3. Starting when you began your Math/Physics coursework, tell me about how you have progressed through your program. Guiding questions (if necessary):
    a. What classes have you taken?
    b. What has been your hardest class? Why?
    c. What has been your easiest class? Why?
    d. Have you met with an advisor? If yes, what was that experience like?
    e. Are you a member of any communities on campus? If so, which ones? For each one, describe how you became involved and what involvement entails.
4. Overall, what have been your biggest challenges? (Tell me more…)
5. Tell me about a typical day when you have class. Guiding questions (if necessary):
    a. What do you do when you wake up?
    b. When do you get to class? How do you get to class and how long does it take?
    c. What do you do at class?
    d. What happens after class on a typical day?
    e. Describe the work for school you do on a typical day.
    f. How does that change during preparation for an exam?
    g. What else happens during the week?

6. Tell me about a Math/Physics class you are taking right now. Guiding questions (if necessary):
    a. What happens on the first day of class? What is on the syllabus?
    b. How do you find out about assignments?
    c. What does a typical class session look like?
    d. What do quizzes/exams look like? How do you prepare?
    e. Where would you go if you needed help?
    f. Tell me about the people in the class (leaving out names or other identifying information)
7. How do you find out the information you need to be successful in Math/Physics classes?
8. Who do you go to for support? Academic support?
9. What other information do I need to know to understand the steps/processes you take as a Math/Physics undergraduate student?

Close of first interview:

This is all of the questions I have for you today – thank you for your time. About halfway through the semester, I would like to meet with you for a follow-up interview, intended to last 45 minutes. Would you be willing to talk again? yes/no (circle one).

Additionally, if I have follow-up questions, can I call or email you for clarification?

Second interview questions (follow consent process above):

1. How is the semester going so far?
2. Remind me of what classes you are taking?
3. Tell me about ___________ (fill-in with current class).
    a. What assignments are you working on? How do you find out about them?
    b. How does the professor structure each class session?
    c. How does the professor structure the work required for the course?
    d. Where do you go if you need help?
    e. What does a typical class session look like?
4. Do you have academic support inside of the classroom? Outside of the classroom? Tell me about it.
    a. How often would you talk to your professor outside of class?
5. Thinking ahead to graduation:
    a. When do you anticipate you will graduate?
    b. What do you need to do to graduate with a degree in Math/Science? How do you know?
6. Are you still planning to graduate with a degree in Math/Physics? If not, tell me why.
7. How does a typical day look for you? Has that changed? Do you anticipate that it will change? Why or why not?
8. Thinking about your Math/Physics administration and faculty, tell me about your interactions with them.

    a. Who would you interact with the most? Why?

9. What is expected from you as a Math/Physics major? How do you know?
10. (If applicable) Tell me about your participation in undergraduate research and/or the Living/Learning community.

Close of second interview:

This is all of the questions I have for you today – thank you for your time. After the conclusion of the semester, I would like to meet with you for a follow-up interview, intended to last 30-45 minutes. Would you be willing to talk again? yes/no (circle one). Additionally, if I have follow-up questions, can I call or email you for clarification?

Third interview questions (follow consent process above):

1. How did the previous semester go?
2. Overall, what was your experience in each class (go class by class)?
3. Thinking back, what stands out to you positively about the last semester?
4. What stands out to you negatively about the last semester?
5. Tell me about Math/Physics finals.
    a. Were the tests comprehensive?
    b. How did you find out how to prepare for the tests?
    c. What would have helped you to prepare better?
    d. Do you feel like you were prepared? What could have helped you to prepare better?
6. Thinking specifically about Math/Physics classes:
    a. Tell me about the composition of your classes (male/female, year in school, etc).
    b. Who participated the most? Least?
    c. Was there support inside of the classroom? Outside of the classroom? Tell me about it.
    d. How often would you talk to your professor outside of class?
7. Thinking about your Math/Physics administration and faculty, tell me about your interactions with them.
    a. Who would you interact with the most? Why?
8. What is expected from you as a Math/Physics major? How do you know?

    a. Where do you find the information you need to be a Math/Physics major?

9. Do you think your experience as a female has influenced your experience as a Math/Physics major? If so, how?
10. Thinking about your experience this past semester, what additional information/experiences would you like to tell me about to understand your experiences?

Conclusion of interview:

Thank you for your participation in these interviews with me. As you know, these interviews are confidential and no identifying information was recorded. Over the next few months, I will be continuing to gather and record information. As a part of that process, I would like to confirm that the information I have gathered from you is in accordance with your perceptions and intentions. Would it be okay if I emailed you portions of our transcribed interviews for you to read through and clarify any information as you see necessary? yes/no (circle one).

Faculty interview questions:

Obtain consent and review purpose of the interview (above).

I have some specific questions for you about how the day-to-day activities of undergraduate students are coordinated as well as about specific documents used in the classroom to coordinate those activities.

1. Tell me about your course syllabus. How do you decide what information should go into the syllabus? How does the syllabus function in your classroom?
2. How do you structure assignments? Is there a guideline for what should be assigned in each course? How do you know?
3. How do you structure course assessments? Is there a guideline for what should be included in an exam? How do you know?
4. What else do you expect from undergraduate students in your classes? How do you communicate those expectations to students?
5. Do you see differences in the work and/or effort from different students? What are those differences? What motivates those differences?

6-?. Additional questions about specific texts that have emerged in the interview/observation process?

Final question: What additional information do I need to know to understand how the day-to-day activities of undergraduate students are coordinated?

Conclusion of interview:

Thank you for your participation in these interviews with me. As you know, these interviews are confidential, and no identifying information was recorded. Over the next few months, I will be continuing to gather and record information. As a part of that process, I would like to confirm that the information I have gathered from you is in accordance with your perceptions and intentions. Would it be okay if I emailed you portions of our transcribed interviews for you to read through and clarify any information as you see necessary? yes/no (circle one).

Appendix B
Observation Protocol

Date/Time:_________

Location:

Description of the setting:

Who is present?

What does the setting look like (diagram)?

Guiding questions:

1. What is happening? Are there any patterns in who is participating?
2. How do students interact with peers? With the instructor?
3. How are the activities being coordinated?
4. What texts may coordinate the activities being observed?

Observations:	**Commentary:**

Appendix C
List of Documents Analyzed

State documents:

Report to the State Board of Education: MWSUS Strategic Plan 2015-2020

MWSUS Policies

Daring to be great MWSUS publication

Pathways to Student Success proposal

MWSUS Policy 402.1.2

MWSUS Policy 403.9

Recommendations of [MWSUS]' Best Practices in Remedial/ Developmental Education

Task Force: Mathematics

Institutional documents:

MRU Mission Statement

MRU Vision

MRU Plan for Assessment of Student Learning and Assessment

Student Handbook

Code of Student Life

Academic Catalog

HLC Report: Executive Summary

College of Arts & Sciences:

College of Arts & Sciences Strategic Plan

Academic Grievance Policy

Departmental documents:

Physics Assessment Plan

Mathematics Assessment Plan

Math Placement at MRU

Math Four Year Plan

Physics Four Year Plan

Math website

Physics website

Course documents:

Math required senior course syllabus

Calculus syllabi (2)

Physics 1 syllabus

Introductory Astronomy syllabus

Physics lab handbook

Numerical analysis syllabus

Precalculus syllabus

Quantum Mechanics syllabus

Survey of Physics syllabus

Computers in Physics syllabus

Physics lab descriptions/instructions (5)

Appendix D
Low-Level Codes

Coordinates student work

Intertextuality

Coordinates faculty work

Enrollment

"Requires approval"

Explicit mention of women in mathematics

Meaning unclear

Does not count towards degree

Math placement

Coordinates new/transfer student work

Physics academic support

Scholarship requirements

Math academic support

Coordinates international student work

Textual representation of student work

coordinates students with disabilities/special needs

Admission requirements

Refers to Blackboard

Coordinates student coursework

Essential Studies

Refers to Campus Connection

Learning objectives

Use of Clickers

Refers to WebAssign

STEM Course Grading/Assessment Methods

High school courses for college credit

Special Examinations

Declaring a major

Graduation requirements

Essential Studies requirements

Double majoring

Federal/National text

Institutional penalty

University Procedure/Policy

Refers to Code of Student Life

Arts & Sciences policy

First advising experience

Determining math placement entering UND

Self-advocate/self-confidence

"toughest math class"

No multiple choice tests

Math coursework

Math Community

Negative perceptions of grades received

Coordinates student work through advising

coordinates student enrollment

Typical day

Differences between math and physics majors

Anxiety/stress

"Feeling constantly behind"

"Putting in the time"

Changing major to STEM

Applying to UND

Math as a foreign language/different world

Not wanting to ask for help from professors

Difference between high school and college math

Outside employment

Conscious of money

Physics track

Undergraduate research

Changing major (to non-STEM)

Coordinates lab work

"toughest physics class"

Physics community

Pursuing graduate school/post-graduation plans

Making connections between content and the real world

Non-class school work

Program-specific employment

Time-consuming

Deciding to major in physics

Student support services

Difference between first and second college experiences

Registering for classes for the first time

Importance of math to physics

Not having pre-requisite knowledge

Physics capstone

Importance of ACT/Standardized testing scores

Importance of grades (undergraduate student)

Reluctance to speak in class

Upper level courses much more difficult than lower level classes

Physics coursework

Unclear deadlines

Descriptions of professors by students

Collaborative/Active learning

Reviewing prior content

Extra/unnecessary student work

Physics advising

Syllabus content

Grading on a curve

Lack of Importance of grades (to faculty member)

"not afraid to fail"/take risks

differences between students

Differences between male and female students

Financial support needed

First college math experience

Bored in class

Graduating early

Math advising

Course content set by others or other departments

Coordinating teaching with other faculty members

Coordinating course content with lab

"complicated" grading

Selecting course content

Lecturing

a "recruitment" problem

Refers to Physics Procedure/Policy

Off-track

Freshman orientation

Difficulty in chemistry

Disadvantaged student challenges

First day of class

Perceived connections between genetics and ability

"perfectionist"

Schedule of classes during the day

Multiple tests at the same time

"wired" for math/physics

Experiences/perceptions with exams

Preparing for exam

Delayed feedback from professors

Needs a break

Comprehensive final exam

Instructor student hierarchy

Taking the GRE

Grading unclear

Perceptions that female students get special treatment

NDUS policy

Quitting outside employment

Re-taking classes

Prefers grades weighted towards homework

Dislikes grades weighted towards tests

Lowering expectations regarding grades

Professor descriptions of student performance on exams

Changing policy

Accreditation

Selecting exam content/questions

4-year graduation

Differences between male and female classroom behavior

Success because it's easy

Failure attributed to "I just can't"

More men than women

Inappropriate jokes/comments

Peer-grading

Perceptions of the causes of difficulty

Failure attributed to external causes

Successful because of support from peers/faculty

Not able to prepare/study for exams

Success because of effort

Perceptions of the causes of success

Being socialized into STEM

Asking good questions

Exceptionally low grades on exams as the norm

Low grades as the norm

Heavy courseloads

Expected effort/workload to be high

Difficult exams

Fast-paced coursework

Availability for day and evening academic commitments

Professor is hard to understand/follow

Teaching self

Negative response to receiving bad grades

Respect for professors

Using TAs

Excluding people who don't "fit"

Shame because of stupid mistake

"I take away their self-esteem a little bit"

Motivated/Persistent

Logical/Rational way of thinking

"Solving the problem"

"Nice and respectful"

Understands abstract concepts

Needs to know content knowledge

Only the best women persist

"Women are more serious"

High-quality work

Appendix E
High-Level Codes

Coordinates student work

Meaning unclear

Coordinates student coursework

Control of the student body

invisible work

Ideal STEM student discourse

Physics discourse

"Objective" knowledge

Individualism

Audit/Assessment Culture

Social pressure not to like math

STEM discourse

"adequate" high school education

Math placement gatekeeping

Math discourse

Differences between procedure and practice

Ideal student discourse

Conflict between school and non-school life

Inadequate high school preparation

ideal STEM education discourse

"physics is hard" discourse

Competition

Fear of failure

Insider knowledge

Unclear expectations

Students as commodities

Chilly climate

Gender "naturalization"

College teaching discourse

"diversity is good" discourse

Hierarchy within STEM

Disconnect between STEM education and College Teaching discourses

Perceived connections between genetics and ability

Knowledge as subjective

Gendered treatment

Gender "blindness"

Neoliberal Discourses

Lack of effort

Socialization

Intimidating behavior from professors

Employability

Unsure of choice to major in STEM field

Disconnect between STEM education and Neoliberal discourses

Understanding vs "right answer"

Perceived incompatibility between self and math/physics

Imposter syndrome

Alternative Feminine Discourse

Appendix F
Code Reorganization Maps

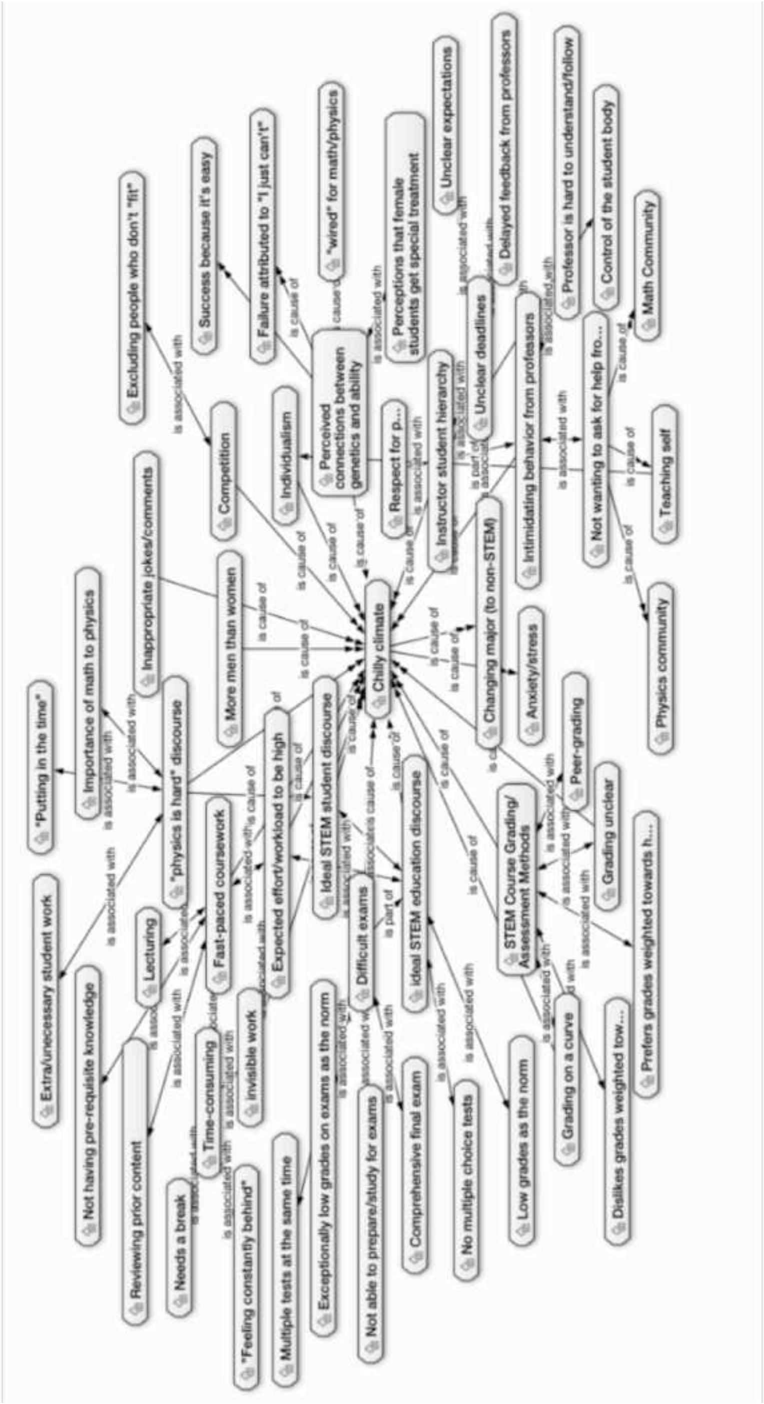

Figure 3. Chilly Climate Code Map.

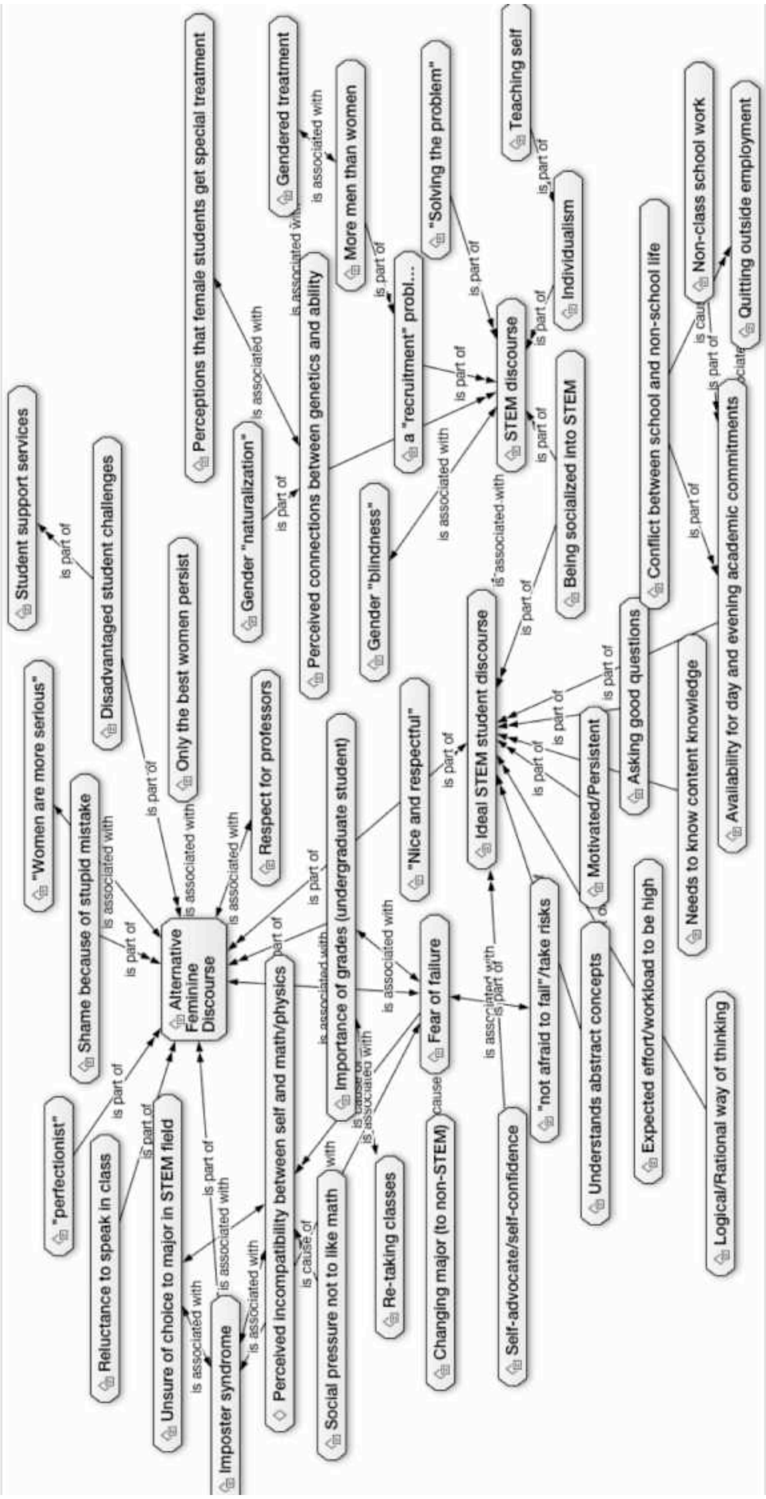

Figure 4. Gendered Institution Code Map.

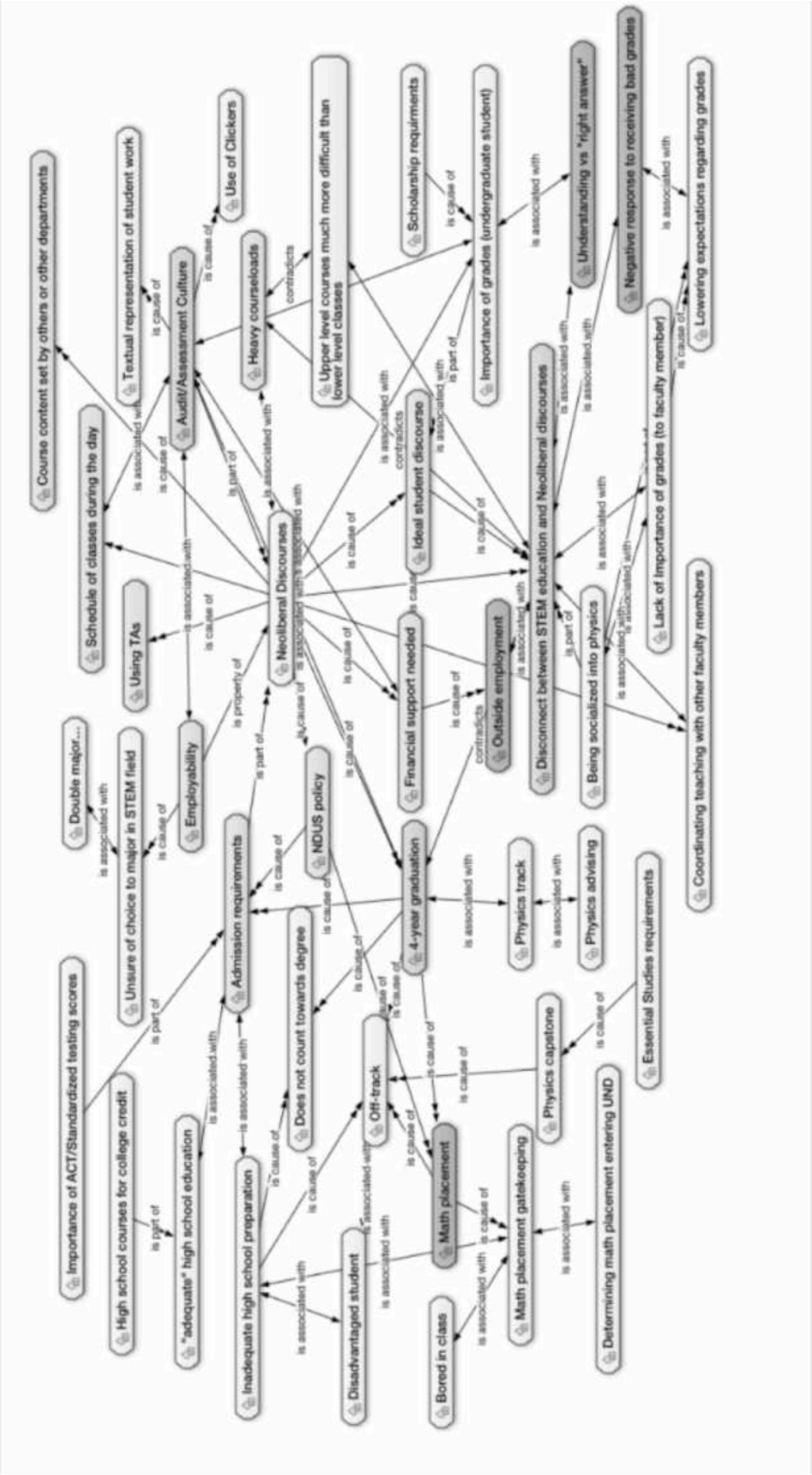

Figure 5. Institutional Policies Code Map.

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