Female Graduate Students’ Experiences and Career Orientations in Stem: A Comparative Case Study

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FEMALE GRADUATE STUDENTS’ EXPERIENCES AND CAREER ORIENTATIONS IN STEM: A COMPARATIVE CASE STUDY

by

Jasvir K. Pannu

A dissertation submitted to the Graduate College in partial fulfillment of the requirements for the degree of Doctor of Philosophy
The Mallinson Institute for Science Education
Western Michigan University
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Regardless of implementation of government policies to promote STEM education and eradicate the underrepresentation of women and minorities, the number of women choosing STEM throughout their educational career remains low. In 2018 65% doctorate degrees were awarded to men and only 35% to women. Moreover, 40% of all students enrolled in doctorate programs drop out before completion. The process of socialization in graduate school and students’ non academic responsibilities play critical roles in graduate students’ success and future career orientations. Processes of socialization involve interactions with faculty, peers, and administration while taking courses and conducting dissertation research. Non academic engagements include family, part time jobs, and other out of school activities that may impact students’ experience in graduate school.

This research evaluates the experiences of doctoral students, in the context of the socialization process at graduate school. A comparative case study methodology was utilized to explore the experiences of twelve females and eight male doctoral students in STEM. Using focus group discussions, students’ perceptions of faculty, advisors, and peer interactions were captured. Additionally students’ experiences with curriculum, teaching assignments, future career intentions, and non academic engagements were also evaluated. A gender and discipline based comparison of students’ perceptions were derived.
Overall students considered course work to be marginally beneficial in research or future careers. Availability of courses was an issue for all departments except geosciences. Female students faced some gender bias in their course taking experience in physics, chemistry, math, and geosciences. Additionally, departments requiring comprehensive exams provided less positive experience compared to other departments. A majority of students had positive interactions with their research advisors. Female students perceived peer interactions to be beneficial at various stages of doctoral study including taking courses, research projects and collaborative writings. As TAs all students perceived teaching experience to be valuable in their future career in academia but had concerns about lack of training. Female students connected the experience gained from teaching assignments with future careers more strongly than male students. Females had more non academic engagements as compared to male students that impact success in the program and career intentions negatively.

Findings indicated the need of several intervention strategies to improve the process of socialization in each area of study. First, gender bias in different departments should be assessed and some forms of bias interrupters be implemented. Second, providing more training to TAs, in particular before the first assignments, should be considered. Third, the evaluation of curriculum design including the numbers and type of courses, availability of courses being offered is highly recommended to provide a maximum benefit to students. Additionally, an assessment of comprehensive exams’ objectives in the light of its advantages and disadvantages to students may help in overall success of all doctoral students. Finally, to promote gender diversity and overall success of all students a culture of school-family balance is highly recommended.
DEDICATION

I dedicate this dissertation to the memory of my father,

Mohinder Singh Gill,

who always inspired me to reach the highest potential possible,

and encouraged to pursue a doctoral degree.
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Jasvir K. Pannu
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CHAPTER I

INTRODUCTION

Problem Statement

The underrepresentation of women in some fields of science, technology, engineering, and math (STEM) exists as a national and global problem that contributes to the lack of diversity in these fields, particularly the field of physical science and engineering (Lippa et al., 2014; NSF, 2017; Cheryan et al., 2017). A report published by the National Science Foundation (NSF), indicates that only 18% of White women are represented in the science and engineering (S&E) workforce, even though they constitute 31% of the U.S. population (2017). By contrast, White men take 49% of the jobs in these fields, despite their proportion of the U.S. population being the same as White women (31%). Gender and racial inequality tend to occur concurrently. Overall total US workforce is represented by 11% Black and 9% Hispanic. However, STEM workforce with bachelor’s or higher degree is represented by 7% Black and 6% Hispanic (Funk & Parker, 2018).

STEM jobs tend to require relatively high levels of education compared to other jobs. Data on number and percentage distribution of STEM degrees conferred by post secondary institutions by race/ethnicity and gender indicate that men earned 64% of bachelor’s, 66% master’s, and 65% doctoral degrees in 2018. In contrast to men, women only earned 36% bachelor’s, 34% masters and 35% doctoral degrees indicating the underrepresentation of women. A racial comparison of percentage of STEM doctoral degree granted to White (79%), Black (4.5%), Hispanic (4.7%) and others (12.4%) showed racial inequality in higher education (NCES, 2019).

Furthermore, statistics show that 38% of females in doctoral programs drop out before
completion (Sowell et al., 2015). Different factors that impact students’ successes include psychological, motivational and social factors (Borrego et al., 2017; Sverdlik et al., 2018; Ward & Brennan, 2018). For example mental wellbeing of students caused by supportive relationships reduce their intentions to leave academia (Hunter & Devine, 2016). Formal and informal obstacles, called glass obstacles, exist for female PhD students in STEM (Welde & Laursen, 2011). These glass obstacles include exclusion from the “Old Boys’ Club,” outright sexism, a lack of women role models, and difficult work-life choices. These social barriers are named glass obstacles because they are often invisible but impenetrable like a glass (Welde & Laursen, 2011).

**Theoretical Framework**

This study explored the experiences of doctoral students through the lens of socialization theory, which involves many players. Socialization is defined as the process by which persons acquire the knowledge, skills, and dispositions that make them more or less effective members of their society” (Tinto, 1993; Weidman & Stein, 2003). In the context of this study, the graduate school is a community consisting of graduate students, peers, faculty advisors, mentors, and administration. In this community graduate students socialize with other members to gain membership and develop an identity of a novice scholar.

Gardner (2010) states, it takes a whole academic community to raise and develop a scholar. The avenues through which socialization occurs are: (a) the interaction of students with the structures of the educational setting, (b) the interaction among students in the same educational program and (c) the interaction between students and faculty members (Bagaka’s et al., 2015; Bragg, 1976). Socialization strategies as a graduate student include following the structure of the program, building collegial relationships with peers, early involvement in research, and scholarly writing to boost their success as a scholar. Faculty members play
numerous roles in the socialization of doctoral students, including instructors in the classroom, supervisors for students with assistantships, committee members for dissertation, advisors or chairs of the research process, and mentors. In this way, faculty members serve as gatekeepers into and out of doctoral programs.

Furthermore, group supervision, cohort-based pedagogy, peer learning, and a connectedness approach to supervision are structural factors that create a sustainable community in which students can develop into scholars and be successful in completing their PhD and continue with a relevant career. Additionally, it is assumed that some graduate students may have non academic or personal responsibilities such as having children or family. For these students, departmental culture supportive of work-life balance is likely to be important for their success in the program (Grunert & Bodner, 2011; Castelló et al., 2017). Moreover, the integration of doctoral degree programs and family is becoming a central focus for doctoral students and institutions of higher education (Rockinson-Szapkiw, 2019). Therefore construct of non academic engagements was included in the framework of socialization.

Based on the theoretical framework of socialization (figure 1), this study focused on the impact of the socialization process on the satisfaction or success of students in their graduate programs, and continued interest in the field.
The five main components of the framework that may impact success and career intentions include: (a) course taking experiences, (b) interactions with faculty and research advisors, (c) teaching assistantships (d) interactions with peers and (f) non-academic engagements. The last component ‘non- academic engagements’ was added to the original model of Bagaka’s et al. (2015) to assess a holistic experience of students. Each part of this model is described as follow.

Course taking experience: Course taking, experience involves availability of course, relevance of course content to their future career interest or research, and teaching style of teachers. Experience of students involves interactions with faculty teaching courses, and with their classmates who take the same courses at same time. Students’ reaction to course content and communication with teacher and fellow students are called interactions.

Interactions with faculty and research advisor: Interactions with faculty and research advisor include students’ interactions with faculty teaching graduate courses and supervising
their research projects or acting as mentors. According to Gildersleeve et al. (2011), faculty interactions occurs through the process of mentoring and advising relationships as well as by engaging in research, and teaching” (p. 94).

Teaching assistants: Teaching assistants (TA) are defined as graduate students who work on teaching assignments as part of their program of study. In return they get financial support and teaching experience, important for their future careers in academia. During the process of teaching, student TAs socialize with fellow TAs and faculty whose courses or labs they are assigned to teach. In this category, students’ interactions with the department and structural aspects such as schedule of teaching assignments’, content of the courses they teach is also part of socialization.

Interactions with peers: Peers are considered any other student at the university who the participant has regular contact with, and is also pursuing a higher degree, or works with them directly in their lab. Interactions with peers such as collaborations in research projects, writing or group projects play a significant role in students’ success and satisfaction with their program of study.

Non-academic engagements: Non-academic engagements are defined as activities related to students’ personal life such as their responsibilities toward family. In addition to being a part of graduate school community students do spend time out of the school setting as well. Therefore student’s non-academic engagements such as taking care of their family may impact their success and satisfaction in the program of study, and departmental support in the form of providing school/work-family balance is likely to be beneficial.

Graduate students’ success and continued interest in the field of study: Success for the purpose of this study is defined as students’ perceived satisfaction with the program of study and
intention to graduate. Continued interest in the field of study means, they maintain the same level of interest in pursuing a career in STEM field as it was at the time of entry into the program of study.

Considering the problem of gender and racial inequality in STEM education and the workforce, the purpose of this study was to explore the learning experiences of graduate students in different fields of study to pinpoint factors associated with students’ success and challenges. Understanding the factors associated with the success of women, and students of underrepresented races such as Black and Hispanic could have helped in the creation of interventional strategies to promote gender and racial diversity in higher education, and potentially in the future STEM workforce. However, to make a meaningful comparison among different fields of STEM, it would have been ideal to compare either master’s students with master’s students or doctoral students with doctoral students. Since doctoral students are at the highest end of educational pathway and at the proximity of future careers, this study was focused on doctoral students only. Furthermore, the severe underrepresentation of Black and Hispanic students in PhD programs created challenges to enroll enough participants of these groups. Therefore, only gender based and discipline based experiences of doctoral students were evaluated in this study.

Gender: Gender refers to the socially constructed characteristics of women and men, such as norms, roles, and relationships of and between groups of women and men. It varies from society to society and can be changed (World Health Organization, 2017). Sex and gender are not synonyms. Sex refers to the biological or genetic differences between males and females. Gender refers to the continuum of complex psychosocial self-perceptions, attitudes, and expectations people have about members of both sexes. Therefore, to understand the impact of
gender on students’ experiences in doctoral program and future career orientation, an ideal scenario would be to consider the continuum of gender identities. However, looking at a single institution of higher education, it was not possible to get enough non-binary participants of either sex or gender in each discipline of study. Therefore for the purpose of this study gender was considered on a binary basis only.
CHAPTER II

LITERATURE REVIEW

Overview

This chapter reviewed previous research related to students’ experiences with learning environment and how that learning environment impacted students’ success in program of study, and future career orientations in STEM. The literature review started with a broader lens to assess the role of gender in science. Then research on career orientations and graduated students’ experience in STEM were reviewed. Literature was selected based on following criteria.

Inclusion /Exclusion Criteria

The inclusion criteria and keywords used for this literature search were the names of the selected domains plus some variations thereof, such as: “experience of master’s students in science,” or “experience of doctoral students or female doctoral students in STEM,” or “career intentions of women in STEM.” A literature search was conducted using online databases, such as ERIC via the Western Michigan University library and Google scholar. It is important to note that the amount of literature available for each of the three topics was variable. A specific focus was given to research that used the theory of socialization. There is a lack of literature in some relevant areas, such as impacts of teaching assistantships or the type of courses taken by students. While the literature on the role of gender in science consists of thousands of articles, research on the experiences of female graduate students in science results in less than 100 articles. The literature and research review were narrowed down by primarily focusing on studies conducted in academic settings including grade school, post-secondary and graduate schools. Finally, an emphasis was placed upon research cited by recently published review articles,
number of times an article had been cited, and research published by top researchers in these fields.

**Domains of Literature**

Career orientations in science are shaped by learning experiences accumulated throughout an individual’s academic career. Gender plays a decisive part in the process of career selection (Barth et al., 2015; Bragg, 1976; Jaeger et al., 2017). Therefore, this literature review includes three general areas of focus: (a) the role of gender in science, (b) career orientations of women in science and (c) graduate students’ learning experiences in a graduate school community. In addition to role of gender, a special attention was given to the role of race when reviewing the literature in all 3 categories mentioned above. The literature reveals common social cognitive themes such as the impact of self-efficacy, motivation, self-perception, stereotypes, self-identity, and lack of socialization on women’s career choices leading to their lack of interest in STEM fields.

**The Role of Gender in Science**

The role of gender in science is mainly based in social and psychological contexts. Gender roles are the set of behaviors, traits, and interests that are culturally defined as appropriate for one’s gender (Galambos, 2004). Socio cultural background and day to day interactions with people impact one’s personal psychological traits, such as self-efficacy, self-perception, and personal identity with science.

Gender socialization practices occur even in early childhood. Common examples are that boys are smart in math and girls are good in the kitchen, or that more boys are scientists and more girls are teachers (Gunderson et al., 2012; Régner et al., 2014). These socialization practices and conventions feed into the concept of stereotype threat, which can undermine girls’
performance in STEM fields (Shapiro & Williams, 2012). Furthermore, peers play an important role in the formation of gender stereotypes and career orientations of students. To fit into peer groups students tend to engage in similar activities as their peers, and avoid activities that may not coincide with the “in group” perception (Crosnoe et al., 2008).

In addition to stereotypes of gender, researchers often focus on stereotypes of the professionals who work in STEM fields. Professional identity and characteristics that are stereotypical of certain professions of science such as social awkwardness, non-fashionable clothing and looks, or an introverted character, deter women from participating in STEM fields (Cheryan et al., 2015). The practical implication of the research on role of gender in science is the need to create gender-sensitive interventions, aimed to increase the self-efficacy and self-perception of women’s ability in science (Lane et al., 2004; Potgieter et al., 2010). Furthermore, deconstructing gender stereotypes and traditional gender roles may facilitate increased participation of students in gender non-stereotypical careers (Kerkhoven et al., 2016).

Overall, the role of gender in science appears to be grounded in a socio cultural context (Reinking & Martin, 2018), therefore a particular focus was given to the research that uses the theories of socialization, and social cognitive theories including the constructs of science identity and self-efficacy. Review of articles selected under the domain of “role of gender in science” revealed five themes including (a) self-efficacy (b) self-perception, (c) self-identity (d) stereotypes, and (e) role models.

**Self-Efficacy.**

Self-efficacy is defined as a person’s belief in their ability to succeed in specific situations or to complete a task (Bandura et al., 1999). In general, a person’s performance accomplishments, vicarious experiences, verbal persuasion, emotional arousal, and adaptive
coping efforts impact self-efficacy (Lane et al., 2004). A successful performance in a given task, such as obtaining good grades on an academic test may act as a booster to self-efficacy. While self-efficacy may predict a student’s success and interest in science, self-efficacy itself is impacted by other factors, such as self-esteem. Lane et al. (2004) determined the correlation between self-esteem, self-efficacy, and performance of undergraduate students in a research methods course. Using a quantitative study they investigated the impact of self-esteem on changes to self-efficacy, following the receipt of assignment grades. Ninety-seven undergraduate students taking a statistics course completed a pre survey to self-report self-esteem and self-efficacy in an assignment related to completion of a statistical difference test or a correlation. Additional self-efficacy measures were taken at one-week time before and one week after the submission of assignment. Findings of the study indicated that students with high self-esteem scores did not show any change in their self-efficacy, while students with low self-esteem had a significant reduction in their self-efficacy if they performed poorly on the assignment. In another study, Lane et al. (2003) found that self-efficacy significantly correlates with dissertation performance by correctly identifying 80% of students who failed their dissertation. Furthermore, Devonport and Lane (2006) revealed that higher self-efficacy scores impact adaptive-coping efforts required to perform better in the research and dissertation process.

Research shows gender, race, and personal identity also contributes to personal self-efficacy and career orientation in STEM. The role of gender in science has been explained using self-efficacy, which in turn is influenced by various other factors. Using social cognitive career theory (SCCT) described by Lent and Brown (1996), Wagstaff (2014) revealed both personal and school level factors’ influence on high school students’ self-efficacy and interest in science.
The findings of this study indicate that the personal inputs of being African American, female, and having a science identity predict both science self-efficacy and STEM career intent.

Furthermore, Wagstaff (2014) showed that participating in one extracurricular informal learning experience such as participation in a school club, predicts both science self-efficacy and STEM career intent. Mullikin et al. (2007) found significant gender differences in research efficacy in favor of men in a study conducted on medical researchers. Research findings showed that men have higher efficacy in various aspects of conducting research such as study conceptualization, study design, data analysis, reporting, and presentation of findings. Moreover, the impact of gender on self efficacy increased in a linear fashion in relation to participants’ professional ranks. For example, gender difference was higher among assistant professors than fellow researchers, and tenured faculty showed more pronounced gender difference than assistant professors. These findings explain the higher level of under representation of women at higher status positions.

In conclusion, self efficacy acts as a predictor of students’ success in courses, research and writing. Therefore, early detection of low efficacy may help in devising strategies to reduce failure rates by implementing learning environment to boosts self-efficacy (Lane et al., 2003). For example, providing extracurricular learning experiences, designing research environments and curriculum conducive to women’s interests may also increase women’s self-efficacy in science, and participation in STEM careers (Phillips & Russell, 1994).

**Self-perception.**

Kruger and Dunning (1999) define self perception as an ability to predict one’s own future performance in a given task. Similar to self-efficacy, self-perception tends to make a difference in students’ performance and interest in science. Research on self-perception has been
conducted to evaluate if students can predict their own future performance on exams. The phenomenon of a discrepancy between self-perception and actual performance has been named the Kruger-Dunning effect. Since 1999 various studies have been conducted in many science and non-science subject areas to come up with an optimum range of performance at which student’s self-perception would match with actual performance (Bowers et al., 2005; Jordan, 2007; Wirth & Perkins, 2005). These studies show that high performers (>50% to 90%) tend to be more accurate in their predictions; however, the top performers (>90%) usually end up underestimating their performance (Karatjas & Webb, 2015).

In the context of gender in science research has indicated that women are likely to have low levels of self perception as compared to their male counterparts. Karatjas and Webb (2015) explored the Kruger-Dunning effect in 1000-level chemistry courses, as it relates to gender. Results of the study showed higher self-perception of performance among male students in contrast to females. Data was collected using a pre-examination survey to evaluate the role of gender in self-perceived grades in chemistry courses over a period of two years. Then self-reported data was also collected on actual achieved grades and analyzed using a t-test to compare the difference between self-perception and actual performance. Investigations showed that high achiever male students predicted higher scores on their examinations, as compared to female students of the same high achiever group.

A study conducted by Jugović (2017) on senior high school students showed that girls had a lower self-concept of ability and lower expectancies of success in physics compared to boys. Expectancy of success for the purpose of this study was defined as the individual’s belief in how successful he/she will be in an activity in the future. By surveying a sample of 736 students, researchers studied the impact of variables such as expectancy of success, self-concept,
gender roles, and stereotypes on educational outcomes including academic achievement in
physics, and intention to choose a technical science major at university level. Results of this
study showed that self-concept of physics ability was the strongest predictor of physics school
grades, whereas the utility value of physics was the key predictor of educational intentions for
both genders. However, expectancy of future success in physics was crucial for girls’ intentions.
So, if girls are not sure about their future success in physics, they are not going to study that
subject at the post-secondary level. Findings also show that masculinity is positively related to
the choice of a technical science course and femininity is negatively related to the choice of a
physics class. Stereotypes were negatively related to some of the girls’ educational outcomes and
positively related to some of the boys’ educational outcomes. The findings help to differentiate
gender-based intentions of high school females to study technical courses in college. However,
the research did not evaluate actual educational choices, which tend to change with time. So,
early high levels of confidence in choosing a certain career may not be predictors of later career
indecision (Creed et al., 2006).

The problem of lower self-perception results from socio-cultural practices, such as
presence of stereotypes about science and women. In contrast some researchers indicate that self-
perception is more powerful than the negative impact of stereotypes, and people tend to apply
stereotypes differently to themselves than to others. Barth et al. (2015) proposed that career
orientations of adolescents are aligned with their self-perception about occupation-required
skills, and gender stereotypes may influence this process. However, application of stereotypes to
self and others varies, resulting in difference in one’s own self-perception and expectations for
others. In this study, 526 participants read vignettes that describe a hypothetical male or female
student who is talented in math/science or language arts/social studies. Then participants are
asked to rate that hypothetical student’s interest in occupations requiring some of those academic skills. Participants were also assessed for their own self-efficacy, interest, and stereotypes for STEM occupations. Results of this study showed that college students were more stereotypical in their ratings of others, as compared to their own. Because they did not manifest gender differences in their own STEM self-efficacy and occupational interests, suggesting that self-perception of one’s ability is stronger predictor of occupational interest as compared to impact of stereotypes. Therefore, gender stereotypes appear to play a secondary role. This study also showed that adolescents became more stereotypical in their career interests over time and more flexible in applying stereotypes to others instead of themselves. There is a need of research to find where graduate students stand on the spectrum of internalization and application of stereotypes to themselves and to others.

**Stereotypes.**

Stereotype is defined as a widely held but fixed and oversimplified image or idea of a particular type of person, thing, or profession. In general stereotypes cause an imbalanced gender participation in science (Cheryan et al., 2013). The role of society and practices of socialization are seen to be the main source of creating these negative stereotypes. For instance classroom or teaching practices may promote stereotypes rather than inhibiting them. Kerkhoven et al. (2016) investigated the total number of men and women depicted as science professionals in a school classroom. The analysis showed that there were more men than women depicted in science related fields and more women than men were presented as teachers. This study shows that there is a stereotypical representation of men and women in science education resources used in classrooms, highlighting the changes needed to create a balanced representation of men and women. Authors suggested that regardless the stereotypical representation of men and women in
science being a true reflection of the gender distribution in science, we should aim for a more balanced gender representation of science professionals. For instance, even if there are not as many female physicists or engineers as males in the field, and the reality is that women took 55 years to win a Nobel Prize in physics, still in a classroom of physics, teacher should utilize the visuals reflecting gender equality. Such a balance is an essential first step towards showing children that both men and women can do science and engineering, which will contribute to more gender-balanced science and technology fields and may enhance student’s self-perception and self-efficacy in science.

Another study evaluated the stereotypes of STEM fields (Stout et al., 2016). This study shows that stereotypes may also emerge from the perceived nature of science fields, for example fewer women participate in physical science as compared to biological or behavioral science. Stout et al. (2016) proposed the reason behind this to be that physical science is considered to be promoting self-agency goals as compared to communal goals of behavioral science. Since women’s preference in general aligns with communal goals they tend to gravitate toward behavioral and life sciences. The study measured the relationship between first-year college students’ stereotypes about science professions and course completion in science fields over a period of three years. Findings show that physical science related careers were more associated with self-direction and self-promotion (i.e., agency) than working with and for the betterment of others (i.e., communion). In contrast, behavioral science careers were associated with communion to a greater degree than with agency. Women completed a lower proportion of physical science courses compared to men. However, this gender disparity disappeared when women perceived physical science courses, and related professions, offered higher opportunities for communion. Similarly, behavior of men to pursue behavioral science courses shifted
positively when they perceived behavioral science providing opportunities related to agency. These results suggest highlighting the communal nature of physical science and the agentic nature of behavioral science in pre-college settings may promote women’s career orientations in physical science and men’s in behavioral science to promote gender diversity across STEM fields. Results of this study are consistent with other research showing women are inclined to identify themselves with jobs that are people oriented (Lippa et al., 2014). In order to identify with stereotypical or male dominated jobs women have to alter their self identity (Hughes, 2011).

**Scientific Identity.**

A person’s identity is the way an individual defines oneself as a kind of person (Sparks & Shepherd, 1992). Development of self-identity is a complex process; a person may feel self-efficacious but may still lack identity of the field because of lack of recognition by others, or negative stereotypes of the field. Women in general do not identify themselves with the male dominated fields of STEM. Theorists agree that women’s lack of identity with STEM is a result of cultural and social attitudes. Social interaction and the mechanisms by which gender roles are viewed in social and cultural structures form personal identities and career orientations. For example, Archer et al. (2014) emphasized how identity and gender identity stems from gender roles that can contribute to shaping children’s attitudes toward science and science aspirations. Hughes (2011) and Cheryan, et al. (2013) found that unless women altered their perceived identity to fit in with the stereotypical field, they would not pursue or persist in STEM. For instance, Hughes (2011) wrote a case study of a female undergraduate student who perceived engineering students to be “geek of geek”, and she did not want to be identified as a geek. In other words, the student did not want to alter her identity, so she ended up quitting her major in chemical engineering. In contrast, female students who altered their perception of identity and
focused on the similarities between themselves and their male peers ended up staying in the field of engineering. Furthermore, the male dominated image of science and scientists prevent many women from having a sense of belonging in STEM fields (Hughes, 2011). For example, a study on the impact of stereotypical role model revealed the long-lasting impact of stereotypes on women’s interest and lack of identity with the field (Cheryan et al., 2013). Researchers showed that even a brief interaction with a stereotypical computer science role model exerted a long-lasting negative influence on women’s interest in the field. In this study 100 undergraduate women who were not computer science majors had a two minute interaction with a female or male peer role model who either had a computer science stereotypical appearance or not. These role models stated their interests in the field. Participants’ interest in majoring in the field was assessed immediately, and at two weeks after the interaction. Results presented a negative impact at both time points on women’s interest in computer science, regardless of the gender of the role model, showing an immediate and an enduring negative effect of stereotype on gender based scientific identity. Therefore, conveying to women a sense of belonging in the field may matter more in orienting them to male dominated fields than the gender of a role model.

**Role Models.**

A role model is defined as a person whose behavior, example, or success is or can be emulated by others, especially by younger people. In general, positive role models such as teachers, parents, or peers have been established in literature (Ost, 2010). In the context of role of gender, research has shown that women are more likely to leave STEM as compared to men, partly because of lack of female role models such as peers, teaching assistants, and instructors. Furthermore, exposure to similar role models may help in eradicating stereotype threat, increasing personal identity, and career motivation in science.
Herrmann et al. (2016) showed that utilization of a role model increased the performance and retention of female students in an introductory undergraduate chemistry class. This study investigated the impact of sharing the academic experience of a female role model on course grades and withdrawal rate of study participants. Academic experience of the role model included the benefits of a college degree, her feelings of not belonging to the field, and challenges of poor performance on the course grades. Sixty eight female undergraduate students read a letter after their first exam in the course that was presented to them by a male teacher, along with a demographic survey during the fifth week of the semester. In the letter a female graduate student normalized undergraduate students’ concerns about not belonging, spending significant time preparing for exams, and having challenges with academic performance and persistence. In the letter the role model explains how she worked hard in her first undergraduate exam in chemistry and thought she did well, but her grades prove otherwise. She also shared her experience on not belonging when she asked herself “why am I spending tons of money and time when I can’t even get good grades?” Similarly to emphasize the value of a degree in STEM she suggested that it was good to spend time and money now for the sake of a brighter future. As she said, “You are paying money now, but you will get great bang for your buck; the value of a college degree across a life span is two million dollars.” Results of the study showed that the role model experimental group had higher grades and lower failing and withdrawal rates as compared to the control group that did not read a letter from any role model.

Moreover, a limited representation of women in STEM fields creates a cycle of gender gap, as fewer women graduate students and faculty role models are available to undergraduate students, who are the next generation of women in STEM. In contrast to positive impact of role models, research also considers the negative impact, for example if a role model’s achievements
seem unattainable to the participants, they may feel discouraged and drive negative social comparison. Thus, it is important for role models to discuss their own challenging experiences with participants to connect at a personal level (Lin-Siegler et al., 2016).

**Conclusion.**

A review of literature on the role of gender in science shows that gender based self-efficacy, self-perception, self-identity, stereotypes, and role models interplay to influence the gender based behavior of participants in science. In general, women tend to have lower self-perception and self-efficacy when it comes to many STEM fields such as physical science, technology, and engineering. Lower participation of women in these fields creates stereotypes that they are not good in math, physics, or engineering, and these fields are meant for men. These perceptions and social practices result in a cycle of low participation and under representation of women in STEM fields. As an intervention to this problem, researchers suggest breaking the cycle by deconstructing stereotypes, and intentionally depicting a balance of gender in science fields by using curriculum conducive to women’s preferences, such as incorporating team work and providing early experience with science. The literature reviewed in this section poses a clear picture on latent constructs responsible for the distinction between sexes in relation to STEM fields. However, a good portion of literature on self-identity with science and career aspiration in STEM comes from studies conducted on middle school children because common consensus among researchers is that adolescence is the time when career orientations are formed. However, one may argue about how much middle school students know about research jobs in science as compared to graduate students. Moreover, research has shown that career orientations are not set in stone; they tend to change with experience. Therefore, focusing mostly on grade school students does a disservice to rest of the student population. Research on graduate students’ career
orientations with a specific focus on the role of gender and race will be a worthwhile pursuit to understand women’s under representation in STEM.

**Career Orientations**

Career orientations are the trends and behaviors that express an individual’s desire to pursue, or apply oneself to, a specific occupation (Gerber et al., 2009). Career orientations develop and adapt with time, and are a complex phenomenon influenced by a myriad of factors. Jaeger et al. (2017) indicated the importance of life experiences and role negotiations in the development of the career trajectories of women in STEM. Social interaction and the mechanism by which gender is embedded in our social and cultural structures form personal identities and career orientations. Archer et al. (2014) emphasized how identity and gender identity, stemming from gender role performance in particular, can contribute in shaping children’s attitudes to science and science aspirations. Using a group of middle school girls this study showed that the gendered identities that participants played in their everyday lives affect the extent to which they align with science aspirations. The popular associations of science with ‘cleverness’ and ‘masculinity’ deter the majority of middle school girls from seeing themselves as a scientist. Girls who aspire for STEM go through considerable identity shift to reconcile their aspirations with ‘acceptable’ gender roles and face additional challenges to maintaining their aspirations over time and retaining in the field of STEM.

Throughout their lifetime a person experiences various factors shaping and molding career orientations. For example, Holmes et al. (2018) used a longitudinal survey of 3rd to 12th grade student which showed that being older, possessing high cultural capital, being male, having a parent in a STEM occupation, and having high prior achievement in reading and numeracy, were significant for students’ orientation in STEM careers. This study suggests the
need of school-based initiatives to improve STEM participation by improving students’ academic achievement in both literacy and numeracy and expanding knowledge of STEM careers, especially for students without familial STEM connections. One of the institutional initiatives in this area may involve offering more science courses at high school level to provide more exposure to science that may boost students’ interest in STEM.

Freeman (2012) has shown that career orientation courses at the college level, designed to increase students’ awareness of potential careers following their undergraduate studies, is a great way to instill career orientation in science. Pre- and post-course surveys of this study indicated an increased level of student awareness about, as well as confidence toward, career preparation. Additionally, surveys of students and mock interviews, indicated students successfully met the course goals related to articulating experience and credentials required for specific careers as well as identifying program requirements to pursue specific careers.

Providing relevant courses at the high school or college level are an effective way to instill career orientation in science. However, there are other personal and competing environmental factors at play, such as stereotype about the field and people working in that field. Review of articles selected under career orientation in science, revealed three main themes including (a) societal impact and gendered role (b) motivation, (c) stereotypes and gender-based career orientation.

**Societal Impact and Gendered Role.**

The societal impact is defined as the effect of an action, activity, project, program or policy on people and communities. Research reveals that occupational sex segregation occurs through gendered roles. Personal career choices tend to change with time, and are informed by their experience (Holmes et al., 2018). Gender based occupational segregation occurs in all
societies, but is likely to be stronger in developed countries possessing liberal gender ideologies compared to the less developed countries possessing traditional gender ideologies (Rosenfeld & Kalleberg, 1991). Research suggests the imbalance between STEM fields may be partly accounted for by higher male interest in ‘things,’ and higher female interest in ‘people’. Lippa et al. (2014) explored the factors associated with occupational sex segregation in the United States over four decades by analyzing U.S. Bureau of Labor Statistics data and conducting a survey on college students. Women's rate of participation in 60 different occupations from 1972 to 2010 was analyzed. This study explored if the occupations' positions on the people-things scale relates to the degree of sex segregation within that occupation, and whether or not these associations have changed over time. Data on occupational status, income and orientation were collected from 78 college students by using a five-point scale that ranged from ‘very low’ to ‘very high’. Results of this study indicate that women increasingly entered high-status occupations from 1972 to 2010, but women's participation in things-oriented occupations (e.g., STEM fields and mechanical and construction trades) remained low and relatively stable. Since women increasingly participated in high-status occupations, therefore occupational status became a weak predictor of women's participation rates in occupations. On the other hand, people-things orientation associated with occupations became an increasingly strong predictor over time.

In contrast, some studies show deviations from findings of Lippa et al. (2014). For example, to understand the career interests of men and women Thelwall et al. (2019) studied the subject from a slightly different angle. They compared the first authored articles published by practicing US male and female researchers in 2017. A comparison based on publishing fields, words used in article titles, abstracts, and keywords, within and between 26 broad fields was made. The results of this study could not be fully explained by the people-thing dimensions
described by Lippa et al. (2014). Exceptions included the greater female interest in veterinary science and cell biology, and greater male interest in abstraction, patients, and power/control fields, such as politics and law. Authors argue that this deviation from people-thing relation may be contributed by other factors, such as the high status of the occupation or the availability of alternative careers to both genders. An interesting by-product of the partial people/thing relationship was that females were more likely to use exploratory and qualitative methods, as compared to higher use of quantitative methods by men. Thelwall et al. (2019), suggested interventional measures to make STEM fields more attractive to women and motivate them to enter and sustain at all levels of academic and professional careers.

**Motivation.**

Motivation is defined as forces acting on or within a person that cause the stimulation, direction, and persistence of goal-directed, voluntary effort. In general, students’ motivation to enter and retain in STEM is a crucial factor that strengthens the career choices in these fields. Moreover, graduate faculty supervising PhD students have cited motivation to be the major factor in PhD students’ retention and success in completing their course of study (Gilmore et al., 2016). Gender-based difference related to the level of motivation to enter or retain in STEM related fields exists (Ronan & Bringardner, 2016). For example, Verdin et al. (2015) articulated that the percent of women earning a bachelor degree in engineering has increased only slightly between 2009 and 2014, from 17.8% to 19.9%. Therefore, a greater effort is needed to increase the number of women receiving undergraduate degrees in engineering at a much higher level to close the gender gap in this field. In general, social issues and curricular policies are considered to be the reason for lower number of women receiving undergraduate degrees in engineering. While higher education may not be able to control social issues but, curriculum changes aligned
with women’s interests and motives can be employed to alleviate this problem. For example, certain curriculum practices such as teamwork, utilizing service projects, and the social impact of engineering can be considered to attract and retain women in engineering (Canney & Bielefeldt, 2015). Several studies have also found that women are more motivated to be engineers if mentor or parental influence is present, whereas men are motivated by their intrinsic behavior. Many researchers have evaluated the negative motivators associated with women enrolling or completing a degree in engineering majors. These motivators include lack of self-efficacy to complete an engineering degree, self-identity to fit in engineering norms, and uncertainty in completing the degree (Matusovich et al., 2010). In contrast, Ronan and Bringardner (2016) studied the impact of positive motivators, ranging from altruistic to individualistic motivators on students’ gender based intention to enroll and retain in engineering fields. A total of 34 females and 69 male first year civil engineering students were surveyed to assess their motivation in enrolling in the course. The results of the study indicated that women are more likely to be motivated to major in engineering, if they can make an impact on society and have an opportunity for a career. This is in contrast to men, who enter engineering because of individualistic gains. An important implication of this study was to improve the curriculum of first-year engineering classes to make them more conducive to women’s interests and motivations, which may enhance retention of female students in these programs. Ronan and Bringardner (2016) suggest that at the high school level more STEM programs should be created so that women can get a head start in engineering academics prior to entering college. First-year curriculum should include projects that promote teamwork and a sense of service to society.

Verdin et al. (2015) not only evaluated the motivation of women but also considered the role of race in the under-representation of women in STEM. They assessed the motivation to
enroll and persist in engineering of eight Latina engineering students. Using Achievement Goal Theory (AGT) as the theoretical framework, this study illuminates some of the reasons why Latinas choose and persist in engineering. Data was collected using one-hour interviews with a semi-structured interview protocol to ask questions such as “Discuss your reasons for choosing your field of engineering as a major.” The results were analyzed in the categories of mastery orientation and performance orientation. Mastery orientation involves mastering a given task using standard of self improvement or progress. Performance orientation focuses on being the best at a given task as compared to other students in the class. Each of these orientation is further divided into two parts, (1) mastery or performance ‘approach’, means working to achieve the goal of mastery or performance, and (2) mastery or performance ‘avoidance’ means avoiding to not to achieve a specific goal. Students who have mastery approach and mastery avoidance tend to do better than students with a performance orientation. For instance, students who have adopted a mastery orientation of motivation may show higher perceptions of academic competence than other students. Importance of mastery is supported by Meece et al. (2006) who found that mastery goals are positively associated with students’ perceptions of their academic ability and self-efficacy. Mastery avoidance does not focus on how one’s performance compares with another. Rather, it involves comparing a person’s performance with their own past performance. Therefore, even though mastery avoidance indicated uncertainty as a threatening factor towards achieving one’s goals, it did not discourage students from accomplishing her goals, but rather it served as a motivating factor. In contrast, students who used a performance-approach used more time and energy on trying to enhance their performance on difficult tasks in relation to others. As an implication of this study, the authors suggest that to promote the
enrollment and retention of Latinas and other minority groups in engineering, curricular programs should focus on achieving mastery goals rather than performance goals.

**Stereotypes and Gender Based Career Orientations.**

As mentioned previously, stereotype is defined as a widely held but fixed and oversimplified image or idea of a particular type of person, thing or profession. Stereotypes of gender and a profession emerge from gendered role and the process of socialization. In general stereotypes play a significant role in a person’s career orientations. Using Gender Role Congruity Theory, Barth et al. (2015) hypothesized that women would be oriented towards masculine-stereotyped occupations and men to feminine-stereotyped occupations, if the occupations were considered to be aligned with affording goals. This study on college STEM students evaluated the impact of occupation stereotypes and life goals related to career status and family support on career interest of students. In this study men showed greater interest in masculine occupations, regardless of their goal alignment with alternative feminine occupation. In contrast women were more likely to choose non-gender aligned job if they paid well, otherwise family friendly work and helping others, aligned better with their choice of career. Practice and norms of society not only contribute to the development of stereotypes, but it can also play a significant role in eradicating those stereotypes. For example, Legewie and DiPrete (2014) revealed that learning environments and the high school community as a whole play a crucial role in weakening or strengthening choices of high school girls in STEM, by debunking women stereotypes related to their performance in STEM fields. There are gender stereotypes about math and physical sciences, even though women are matching up or exceeding men in educational attainment and have gained near gender parity in math performance (DiPrete & Buchmann, 2013). Furthermore, women are outnumbering men as college graduates, and obtaining more than 50% of degrees in
the life sciences, but they still lag behind when it comes to bachelor's degrees awarded in the physical sciences, mathematics, and engineering. Because of parity in performance in high school math and science courses, including AP classes, researchers started to shift their focus on college students to explain the prevalent gender gap in STEM degrees (Mann & DiPrete, 2013). However, performance in STEM subjects is not the only predictor of women’s career intentions. Their interest in jobs involving social interactions and a higher level of emphasis on intrinsic, altruistic, and social rewards associated with an occupation are also parts of the career orientation prediction (Lippa et al., 2014; Ronan & Bringardner, 2016). School environments can help in eradicating stereotypes by moving girls away from an orientation consistent with gender stereotypes and toward an interest in STEM fields, or vice versa. Similarly, environments may attract boys toward an interest in non-STEM. However, gender integration of occupations mainly occurs by efforts of girls to move into formerly male-dominated occupations rather than through men's moving into female-dominated occupations (Legewie & DiPrete, 2014). Boys are likely to be more resistant than girls to local environments that contest their gender stereotypes. Therefore, school environment can help to challenge the negative stereotypes about girls and STEM fields, which may facilitate strengthening occupational orientations of women towards STEM. One strategy to accomplish this goal includes appropriate curriculum design that is aligned with women’s interest in STEM (Cotner et al., 2017).

**Conclusion.**

A review of literature on career orientations in STEM shows that gendered roles, achievement goals theory, motivation to choose science, and stereotypes interact to make males and females behave differently in relation to careers in science. In general, women tend to have lower motivation and different professional goals as compared to men. In relation to their
performance in STEM courses, women tend to do better when mastery is at stake but that is not the case when final evaluation measures involves performance. Women’s preferences for job align with people-oriented jobs instead of thing-oriented jobs. Furthermore, women do not identify themselves with some fields of STEM, in particular physical science and engineering. In order to fit in male dominated fields, women have to alter their identity to see themselves fit. The masculine nature of science, and stereotypes about scientific jobs further deter women to participate in stereotypical fields. The literature reviewed in this section poses a clear picture on latent constructs responsible for distinction between sexes in the context of science orientation. However, it is not clear how these factors interact with each other to create holistic experiences for women that may or may not be favorable for them to choose science related careers. Therefore research to consider experiences of graduate students in doctoral programs with a specific focus on gender and race is likely to be beneficial in pinpointing the causes of higher dropout rates of PhD students and under representation of women in STEM.

Graduate Students’ Experience in STEM

Graduate students have completed a successful journey to reach the final stage of their academic career. At this stage they are very likely to be interested in STEM careers in research, teaching, or industry. Graduate students’ experiences and career orientations can be viewed through a lens of the community of graduate school. This section of the literature review first discusses the theory of socialization in the context of graduate school as a community, then moves further to discuss literature related to all components of the graduate school community.

Graduate school as a community: A community is defined as a group of people in the same place or having a particular characteristic or goal in common. Graduate school is a community in itself consisting of three main components: students, faculty, and administration.
In this community graduate students enter to become scholars by the process of socialization. Weidman et al. (2001) defines socialization as “the process by which persons acquire the knowledge, skills, and dispositions that make them more or less effective members of their society” (p. 4). The theory of socialization applies to graduate students as they interact within the bounds of the community by taking courses, interacting with peers and mentors, performing research and honing future career skills by sharing knowledge from other members of community. Graduate students’ success not only depends on personal factors of students, but structural factors conferred from the community to students are also crucial. The process of socialization and its impact on doctoral students’ success in an education department was researched by Bagaka’s et al. (2015). Doctoral student success was defined broadly to include not only completion and retention rates, but also the ability of the program to produce effective scholars in the field. Utilizing a mixed method approach, Bagaka’s et al. (2015) focused on providing multiple perspectives on the overarching domains on students’ experience: (a) the quality of faculty-student mentorship, (b) students’ engagement in academic research, (c) peer mentorship, and (d) requirements and resource provisions of the doctoral program that may enhance doctoral students’ success. A total of 113 students (80 current and 33 alumni) were surveyed and 20 students participated in two parallel focus group discussions. Focus group topics of discussion included students’ personal experiences regarding research engagement, faculty mentoring, group and peer interaction, and perceived levels of support. Seven domains emerged from the qualitative part of the study including 1) cohort model, 2) program structure, 3) formation of scholars, 4) faculty mentorship, 5) dissertation process, 6) program funding, and 7) traditional versus nontraditional students. Quantitative data was analyzed to determine the extent to which tested constructs of the program predict doctoral student success and satisfaction in the
program. Convergence between qualitative and quantitative data was recognized. Three areas where the two sets of data converged were the impact of program structure, faculty and advisor support, and research engagement or transformation from a student to a scholar. Data on the importance of “cohort” domain and “peer mentorship” was not significant in the quantitative study. However these two themes emerged in the qualitative study. Therefore misalignment between qualitative and quantitative findings warrants the need to test the impact of cohort model and peer interactions in future studies. Furthermore, the authors noted that the findings of this study may not be applicable to doctoral students of STEM programs because participants of this study were selected from education only.

Similar to Bagaka’s et al. (2015) the importance of socialization in graduate school is supported by other researchers. For example, Weidman et al. (2001) argued that throughout the socialization process, graduate students acquire necessary information by way of communication strategies to aid in their transition to becoming scholars. Bragg (1976) states that process of socialization is tri-fold: (a) the interaction of students with the structures of the educational setting, (b) the interaction among students in the same educational program and (c) the interaction between students and faculty members. In particular, faculty members play numerous roles in the socialization of doctoral students, including instructors in the classroom, supervisors for students with assistantships, committee members for the thesis or dissertation, advisor or chair of the research process, and mentor. In this way, faculty members serve as gatekeepers into and out of doctoral programs. Similarly, Tinto (1993) proposed a theory of doctoral student persistence in which he highlighted two key factors: (a) institutional experiences, including program level, which support or inhibit degree attainment, and (b) individuals who provide support to the student throughout the doctoral program. Furthermore, socialization challenges
that students face evolve throughout their progression in the program of study. Ali and Kohun (2006, 2007) argue that students have different socialization goals at each stage of the doctoral program such as preadmission to enrollment, first year, second year through candidacy, and dissertation. Most often these objectives are not properly supported by departmental structures and other socialization processes in place. For example, the initial stage after admission usually lacks any systematic procedures for acclimatizing students into the departmental culture, with the task left largely to the student. Similarly, during the final stage of candidacy, students often suffer from lack of any defined structure and collaborative work regardless of heightened need of significant guidance and communication with supervisors and committee members to successfully complete the program. The lack of support at these stages, can lead to feelings of confusion, isolation, and frustration in students, which in turn can negatively impact their program success, and professional growth and career intentions in the field of study (Ali & Kohun, 2006). As implications of this research, the authors recommend that doctoral programs should incorporate a structured process of socialization at each stage such as early research engagement and effective mentorship activities and overall support from the department to produce sustainable scholarship (Bagaka’s et al., 2015).

The next section of literature review focuses on each component of the graduate community: (a) faculty and advisor, (b) peers, (c) courses and research (d) TA engagements, (e) non academic engagements, and (f) becoming a scholar and future career

**Faculty and Advisors.**

In the community of graduate school, faculty play numerous roles in the socialization of doctoral students, including instructors in the classroom, supervisors for students’ research projects, and committee members for the thesis or dissertation (Weidman & Stein, 2003; Tinto,
The role of faculty, and specifically the impact of advisor-advisee relationships, has been researched extensively across many institutions and disciplines. Several studies found that group supervision, a connectedness approach to supervision, and easy access to supervisors all help to create a sustainable community in which students can develop into scholars (Albion & Erwee, 2011; Fenge, 2012; Halse, 2011; Harman, 2003).

Using a mixed method approach, Ray (2007) determined that doctoral students not only look for quality guidance, on subject matter and methodology from their research supervisor, but they also place a great emphasis on productivity, commitment, and partnership with students. Similarly, Bancroft et al. (2016) surveyed scholars from three McNair programs, specifically designed to promote participants’ doctoral success. The survey included items related to scholars' perceptions of their McNair program experiences and the graduate/advisor relationship. Advisors mentor students at each stage of the program in a student centered partnership, such as directing with research activities, presenting at conferences, helping with thesis writing strategies with constructive feedback, and promoting students’ organization and resilience (Odena & Burgess, 2017). McNair program scholars clearly reported their program experiences as beneficial to their science graduate studies and their graduate research advisors as helpful. Literature shows that advisors play a critical role in students’ overall success in the program. What is not clear is the level of direction required by students. Some researchers argued that students, being novice researchers, do require a great deal of direction to successfully complete their program. Others perceive doctoral students to be independent researchers in training (Mason, 2012). Proponents of students needing high level of advice argue that research and dissertation activities are often very fluid in nature which demands a higher level of student self-regulation. Therefore, increasing the risk of attrition, if timely directions from advisors and
committee members are not available to student (Ali & Kohun, 2006). Furthermore, literature indicated that the advisor student relationship is a person-focused partnership to create successful scholars, and degree of partnership tends to vary in different disciplines. For example, doctoral students in engineering programs largely perceived supervision as task focused as opposed to person focused in nature, (Murphy et al., 2007). Nevertheless, task focused activities such as providing research training and monitoring students’ progress only explains 46% of the variability in students’ satisfaction with their supervisors. The rest of the variability (54%) is accounted for by person-focused interactions with supervisors such as help with students’ career development and students’ perceptions of being employed as cheap labor (Zhao et al., 2007).

Research looking into the impact of gender on students’ satisfaction, in the context of the supervisor relationship, showed that females perceived their experiences to be more negative than their male peers. Dissatisfaction with supervisors mainly stemmed from lack of easy access to them because of their high workload (Harman, 2003).

While most of the studies discussed above focus primarily on the responsibility of the supervisor to create and maintain a satisfying experience for their students, researchers are starting to focus on factors that are under the control of students themselves, such as bringing positivity and respect into the relationship and practicing and demonstrating gratitude (Howells et al., 2017). Since the supervisor’s main goal is to ensure that the student becomes an independent researcher, students who consistently respect timelines, prepare for meetings, exhibit openness and respect for feedback, and demonstrate their capabilities in their work, are likely to ensure the satisfaction of their supervisors in the relationship. That shift in focus is likely to be beneficial as it places equal emphasis on responsibility of the student for improving the student supervisor relationship that is within the students’ direct control (Sverdlik et al.,
The main characteristics of good supervisor relationships include easy access, frequent meetings to obtain precise and timely feedback, and support and encouragement to begin research work on topics of interest early in the program to maintain satisfactory progress. Furthermore, an open discussion and understanding of roles and responsibilities of each party is beneficial (Latona & Browne, 2001).

Regardless of role, supervisor student relationship plays in students’ dropout, faculty mostly blame students’ lack of skills and motivation as being the main reason of attrition (Adrian-Taylor et al., 2007; Gardner, 2009). Conducting a semi-structured interview with 60 doctoral students and 34 faculty from U.S. doctoral programs, Gardner (2009) showed faculty to perceive program attrition mainly caused by students’ lack of essential research skills or motivation (74%), followed by complications arising in students’ personal lives that interfered with their doctoral training including mental illness and family issues (15%). Gilmore et al. (2016) conducted a study by interviewing 38 graduate faculty advisors in STEM at a research-intensive university. They captured faculty’s perceptions of factors supporting graduate student success. Using a constant-comparison method, researchers determined that faculty perceptions were aligned with motivated student behaviors, formative student learning experiences, and essential student knowledge and skills. Student motivation was most prominently represented in the findings. Furthermore, these results align with faculty’s perception that graduate students’ failure rests with the students themselves rather than their role or the department’s contribution to attrition (Gardner, 2009).

In summary, faculty and advisors play a crucial role in the success of graduate students and satisfaction with the program (Bagaka’s et al., 2015; Cockrell & Shelley, 2010; Harman, 2003). Students interact with faculty while taking graduate level core courses, comprehensive
exams, and conducting dissertation research. Students’ advisors guide them through different stages of the program while acting as a central and student centered source for dissertation research. Mason (2012) also seemed to validate these findings but, in addition, found a positive relationship between students’ feelings of autonomy over their research and motivation to sustain in graduate school, highlighting the importance of mentorship while providing students with academic space to form their own research identity. However, Ali and Kohun (2006) argued that being novice researchers, graduate students require a great deal of guidance during the candidacy stage of their doctoral program. Overall, women tend to be less satisfied with the program mainly because of lack of easy access to their supervisors. Women tend to prefer person centered supervision rather than task centered and suboptimal supervision practices (Harman, 2003).

**Peers.**

Weidman et al. (2001) considered peer interactions an integral and critical part of the graduate school socialization process. Research on the impact of peers on PhD students’ satisfaction with the program produced conflicting results. Peers can play a constructive role by being a collaborator in group projects, writing and editing fellow students’ work, and being moral support through their program of study. In particular, studies have explored the role of collaborative writing in students’ writing related emotions, cognition, and success in contrast to the solitary writing that is the norm for most doctoral writing. Findings show a variety of advantages to collaborative writing including more optimal self-regulation, better time management, and self-monitoring (Ferguson, 2009). Furthermore collaborative writing engenders more positive emotions and motivation with less procrastination (Ferguson, 2009), better writing quality including positive peer reviews (Cotterall, 2011), as well as higher student success and completion rates (Maher et al., 2013). Additionally, collaborative writing with peers
has been found to make the process more enjoyable. These findings thus highlight the discrepancy between collaborative and traditional doctoral expectations such as solitary writing in terms of both professional and personal development. In an interdisciplinary study in which 60 PhD students from different disciplines were interviewed, Gardner (2010) showed that low completing disciplines such as math and engineering lack support from peers. Furthermore, this problem was more prevalent in departments having a higher number of international students. Conversely, high-completing departments often have more positive peer experience (Gardner, 2010).

In contrast to Gardner (2010), other researcher documented evidence of peer effects in the physical sciences but finds no evidence of similar effects in the life sciences (Ost, 2010). For the physical sciences, exposure to peers who have a higher expected probability of persistence is found to increase the probability of persistence of other students with lower probability of persistence. Therefore, the impact of peers is shown to have an important but non-linear relationship where females and unlikely persisters’ experience the greatest gains from exposure to high quality peers (Ost, 2010). Moreover, by studying the influence of gender composition of a cohort within STEM programs a study showed that women with no female peers were 12% less likely to graduate within six years than men in the same cohort. An increase of one percentage point in graduation rate was observed with an increase of 10% in the proportion of female students in a cohort (Bostwick & Weinberg, 2018).

Devos et al. (2017) found that peer support had little impact on PhD students’ final persistence or rate of dropout. They compared eight students who successfully completed a doctoral program of study with 13 non completers. The study conclude that peers may brighten or darken PhD students’ days, help them to cope in case of difficulties through emotional support.
or help with the lab instruments, but, in the end, peers do not make a difference to students’ decisions to persist in or to quit the PhD (Devos et al., 2017).

Overall there is scarcity of research on the role of peers on the satisfaction of PhD students in their program of study. Moreover, available literature presents conflicting results. However, from a limited literature it appears to be that females tend to gain more benefits from peer interactions in contrast to male students (Ost, 2010). Therefore, a study exploring the experience of doctoral students in STEM fields is likely to be a worthwhile addition to literature.

**TA’s Engagements.**

Doctoral training in STEM fields has traditionally consisted of a doctoral student working closely with a faculty advisor to learn the research methods and content knowledge of their field of study to become a researcher and a scholar (Anderson et al., 2011; Mills, 2009). Researchers contend that almost half (46%) of STEM PhDs are going to be involved in some kind of college teaching within five years of PhD completion (Connolly et al., 2016, 2018). Therefore, skill in teaching is needed for the many doctoral students who will teach, train, and mentor the next generation of STEM undergraduates. However, conventional models of doctoral programs do not prepare students to handle the full range of roles and responsibilities of future academic careers that includes teaching. Therefore, socialization of graduate students to the full range of faculty roles is recommended (Austin & McDaniels, 2006). Moreover, STEM graduate students are often encouraged to focus more on their research engagement and minimize teaching obligations. However, the process of teaching students, to engage in inquiry provides practice in the application of important research skills that will assist them in their own research (Feldon et al., 2011).
In addition to the lack of training in teaching of doctoral students, researchers have also been almost solely focusing on development of doctoral students as researchers, whereas studies on preparation for teaching, is mostly absent from the discussion. Limited amounts of available literature on this issue indicates that doctoral students often feel very confident about their research skills but that is not the case when it comes to teaching and advising students in their future career as faculty (Cockrell & Shelley, 2010). Moreover, teaching skills are likely to increase students’ future employability in academia (Mantai, 2019), necessitating the need to focus on this front. Using a narrative inquiry methodology, Mantai (2019) studied 15 doctoral students from two large universities in Australia to learn about their perception of the program in context of their future orientation in an academic career. Participants of this study were nearing the submission of their dissertation and were aspiring for a career in academia. Students defined their identities and evaluated their academic development in relation to their perceived ‘market value’ in academia. To increase their employability, students engaged in university teaching and focused on strategic networking. Furthermore, they considered that development as a researcher being the main focus of a doctorate program is not adequate for a future career in academia. Therefore, doctoral education needs to facilitate student socialization into the program, encourage synergies between teaching and research, and support non academic work experiences to strengthen researcher identity development (Mantai, 2019).

As an intervention strategy emerging from extensive research on the problem of retention of students in STEM at the undergraduate level, recent policies emphasize the need of superb teaching skill development of faculty. Therefore, future faculty programs that emphasize on teaching development (TD) are starting to grow slowly however; there is limited literature on the impact of TD programs on preparation of future college instructors. Using social cognitive career
theory, Connolly et al. (2018) examined the effects of TD programs on early career STEM scholars’ sense of self-efficacy as postsecondary teachers. In this longitudinal study, data was collected in 2011 by administering a survey questionnaire to 2156 participants who in the year 2009 were doctoral students in STEM departments at three U.S. research universities. Sixty-seven percent of participants (1445) responded to the survey. Data was analyzed by regression analysis that revealed positive relationships between TD participation and participants’ college teaching self-efficacy. This study showed a positive interaction effect for women as compared to men. However, women’s pre TD program self efficacy was significantly lower than men. As an implication of this study the authors suggest that these findings may be used to improve the quality and quantity of TD offerings and help them gain wider acceptance (Connolly et al., 2018).

In summary, PhD programs prepare students to become researchers and scholars, while almost 50% of doctoral students aspire for careers in academia (Mantai, 2019). Having good teaching skills and knowledge about teaching pedagogies is crucial to become efficient post-secondary faculty. However, most doctoral programs do not offer that expertise to students. Therefore, programs on the development of teaching skills of PhD students, and research on the efficacy of such programs is needed. Moreover, research on the experience of TAs in the context of socialization with other TAs and faculty, and the impact of TA duties on their progress in the doctoral program appears to present a major gap in the literature.

**Courses and Research.**

Doctoral students go through different stages as they progress in their program of study. These stages include, taking courses, conducting research, writing, presentation and defense of their dissertation. The process of socialization at graduate school impacts PhD students’
satisfaction and success at each milestone of the program. Research on students’ success in course work indicates that while students’ own planning and goal-orientation is imperative for their success in coursework, peers and faculty support complements their success (Martinsuo & Turkulainen, 2011). Similarly, progress in research is promoted by time commitment and peer support, as well as time commitment in conjunction with supervisor support. The complementary effect of time commitment and supervisor support on research progress emphasizes that successful research work is a product of positive interaction between the students’ continuous effort and regular communication with the supervisor. As an implication of this study, Martinsuo and Turkulainen, (2011), recommended the development of a personal study plan, and a formal evaluation process to assess progress in adhering to the plan. Secondly, formation of peer and discussion groups should be implemented because it seems that peer support plays a strong role in supporting progress in both coursework and research. Faculty could also take initiatives in the forming of peer groups and emphasize their importance to new students. In contrast to several previous studies (Seagram et al., 1998; Stack, 2004), Martinsuo and Turkulainen (2011) showed that women performed better in terms of research progress that include total number of publications, such as academic journal articles, conference papers, and other publications. A future qualitative study has been suggested to see the real impact of gender, and peers’ groups on the research progress in doctoral programs.

Overall, PhD curriculum is composed of various courses, such as general, special, and research skill courses, comprehensive exams, research projects, and the dissertation defense. There is not much research on PhD students’ perception of graduate courses and its impact on their retention and satisfaction in the program. Furthermore, only a very few studies talk about the various forms of comprehensive exams given by different universities and programs of study.
(Ponder et al., 2004). One of the purposes of the written comprehensive exam is to test students’ ability to synthesize information in developing research ideas (Franke et al., 1992). Some researchers describe comprehensive exams as a “rite of passage” (Estrem & Lucas, 2003; Hadjioannou et al., 2007) to prove graduates students’ worth in a discipline (DiPietro et al., 2010). However, preparing for this exam takes considerable study time, effort, and adds stress on students, so faculty members should have a clear picture of what they want to accomplish from such an exam. Moreover, some doctoral study programs may be moving away from a traditional one or two day long closed-book exams, therefore exploring the reason behind this shift may be beneficial.

Ponder et al. (2004) used Bloom’s taxonomy of educational objectives, to address various issues concerning the written comprehensive exam process. They surveyed 97 doctoral coordinators of marketing departments of various universities throughout the United States, to evaluate both the purpose and structure of comprehensive exams. The movement to nontraditional exam structures was documented, and a description of several of these nontraditional approaches was provided. Most of the participants gave traditional style comprehensive exam, and they agreed this method to be a good way to test general knowledge that is lower order of learning objectives. However, many participants did not see any negative in the structure of this type of exam. Some however question the exams’ limitation in assessing students’ conceptualization skills and ability to design an original research project. Out of 97 participants 20 programs evaluated in this study used nonconventional forms of the comprehensive exam, such as development of an original paper that can be developed further into a dissertation project or taking open book or take-home exams. Stating the advantages and disadvantages of alternative comprehensive exams, participants argued that the positive aspect of
doing an original paper in lieu of the standard exam is that students can launch a thesis and perhaps a highly productive research career out of it, but they are not likely to display knowledge in various topics other than their own topic of dissertation. Other program variations of compressive exams included a literature review, open book test with article critique, a take home exam with more time, or no exam at all. This study concluded with a discussion of comprehensive exam issues and provided a recommendation for ongoing assessments of exam choices based on specific program objectives (Ponder et al., 2004). Research on the purpose and structure of comprehensive exams in STEM fields is lacking, so future study evaluating the advantages and disadvantages of comprehensive exams and its impact on students’ success in the program will be beneficial.

In addition to taking courses, writing in research is another area of a PhD program where students tend to show dissatisfaction. Wring skills appear to be central to success of PhD students, to graduate and become successful researchers in their field. One study shows that peers and supervisors play an important role in this area (Cotterall, 2011). Supervisors not only guide in practical research aspects, but contribute significantly to students’ writing skills in many ways. González-Ocampo and Castelló (2018) evaluated the supervisor’s role in students’ writing, and revealed three different ways, where supervisors do help. By evaluating the perception of 61 supervisors using an open-ended survey, they showed that supervisors attributed different roles to doctoral writing, ranging from process to product oriented and focusing on 1) producing appropriate academic texts, 2) generating epistemic activity, and 3) promoting communication and socialization. Mainly supervisors were involved in writing in three ways: 1) telling the students what to do, 2) reviewing and editing students’ writing, and 3) collaboratively discussing students’ writing. A significant number of supervisors did not attribute any role to writing but
acknowledged writing as an important, and neglected activity (González-Ocampo & Castelló, 2018).

In sum, research related to PhD students’ course and research experiences specify that faculty and peers play a significant role in students’ success in graduate courses. There is not much research on the benefits and types of comprehensive exams in doctorate programs, and the limited available research presents conflicting results. Roles of supervisors have been researched extensively and are crucial in students’ research projects, writing, publications, and overall success. Gender stereotypes against female graduate students continue at this final stage of their academic career, where faculty, regardless of their gender, are likely to believe that females are less committed to course and research work than men (Ellemers et al., 2004).

Non Academic Engagements.

In addition to the graduate school community, students’ non academic factors such as family, work, and school balance plays a vital role in predicting students’ success. Despite the literature documenting the importance of family in students’ success, academic-family integration has not been researched much. Grunert and Bodner (2011) indicate that a major challenge of the success of doctoral students lies in making the departmental culture more supportive of families that align with the work-life balance of female graduate students. The challenge of integrating doctoral degree programs and family is a central concern for doctoral students and higher education personnel. Therefore, setting up boundaries to achieve a satisfactory balance between academic and family life is an issue that affects doctoral students’ decision to persist (Rockinson-Szapkiw, 2019). Another study conducted by surveying 250 students, indicated that family and school balance is the main reason young females drop out from doctoral programs (Castelló et al., 2017). The most frequent factors of dissatisfaction across
all participants included difficulties in achieving a balance between work, personal life, and doctoral studies, and problems with socialization.

Overall, research related to doctoral students’ non academic engagements offers a complex picture warranting the strategies for optimum doctoral program design that align with needs of non-conventional and female students to facilitate their academic and personal integration in the scientific community. Solutions to promote academic-family culture are imperative to prevent institutional neglect, which pushes female students away from doctoral programs (Castelló et al., 2017).

**Becoming a Scholar and Future Career.**

Inherent in the developmental process of socialization is the process of transitioning from one phase of doctoral program to another (Bragg, 1976; Gardner, 2007) as well as the transition from role of student to that of a professional (Golde, 1998; Weidman et al., 2001). Gee (2000) defined identity as how an individual defines oneself as a “kind of person.” Graduate students usually develop their research identities during their graduate program (Colbeck, 2008; Hall & Burns, 2009; Sverdlik et al., 2018). In general students’ scholarly work and their ability to evaluate themselves improves throughout doctoral training, it is perhaps not surprising that novice doctoral students have been found to be most concerned about their worth as scholars (Di Pierro, 2007). They are often overly ambitious early in their doctoral program (Grover, 2007), and thus tend to associate external processes such as reviewers’ criticism with their self-worth and not feeling scholarly (Hughes & Kleist, 2005).

According to Chen (2014), graduate students develop their identities through research experiences in their program, and identity development is influenced by several factors including level of competence in research and collaborations with other research group members. Chen
(2014) evaluated the performance of 11 Canadian doctoral candidates as researchers in their final doctoral defense in handling questions that they identified as ‘difficult to answer’. Utilizing the theory of communities of practice, this research views the dissertation defense as an examination in which a novice researcher demonstrates knowledge to a group of experienced researchers in order to gain the membership of a scholarly community. Each student was interviewed before the defense about their preparation experience and after the defense to assess defense experience. Thorough observations were made, questions from the defense committees and candidates were recorded. Data also included participants’ background information and institutional documents regarding the conduct of the PhD dissertation defense. This study showed that 41% of the questions were considered difficult by students because of questioners’ different perspectives. This difference in perspective arose because examiners were either form different discipline or did not have background in topics of students’ dissertation. However, all the defense examinations were successful; indicating that these candidates were all thought of as competent researchers, yet, only those who considered themselves as novice researchers felt satisfied with their performance. Novice researchers accepted not knowing the answers to difficult questions more easily than those who thought about themselves as experienced researchers. They got the satisfaction of obtaining membership in the community of science scholars, and recognition of being accepted as a scientist. In the context of impact of gender on students’ satisfaction in the program, research indicated that female PhD students experience both formal and informal barriers. These barriers impact the level of attrition from programs of study and satisfaction with their chosen STEM fields (Welde & Laursen, 2008).

In sum, existing research on identity formation in doctoral students with respect to academic tasks such as courses, research, scientific writing, and presentations underscores the
importance of socialization to achieve satisfactory progress in the program. Success in a doctoral 
program not only develops and strengthens students’ identity in the field, but may also predict 
students’ future careers in their field of study.

**Conclusion.**

A review of literature on the experiences of graduate students in science shows that 
graduate school is a community. In this community structure of the program of study, 
administration, faculty, peers, and mentors play a significant role to provide appropriate 
experiences to students. These experiences assist students in overcoming challenges to complete 
the program of study, become research scholars, and maintain career orientations in STEM. 
Faculty place a high weight on the importance of doctoral students’ motivation to complete the 
program of study successfully (Gilmore et al., 2016).

When it comes to the timings of starting research, there are conflicting results, as some 
recommend jumping on to any research project as early as possible to gain experience, while 
others suggest waiting for a suitable research project (Cockrell & Shelley, 2010). Faculty prefer 
to focus more on research than taking teaching assignments, in order to publish and become 
established in their respective fields of expertise. Peers are often skeptical of the benefits 
graduate students are likely to gain from teaching assignments (Connolly et al., 2018). Therefore 
taking courses, teaching, and research are three competing priorities that graduate students 
struggle to balance.

Upon completing the course requirements, the successful completion of research projects 
is a catalyst to publish in a peer review journal or present at a conference. Moreover, the number 
of publications is used as a yard stick to measure scholarship capabilities of students to become 
future research scholars and STEM professionals. However, in the arena of publications, females
often lag behind men when it comes to publishing first author articles indicating a subtle predictor of dissatisfaction of female graduate students in STEM.

Furthermore, women and minority scholars overwhelmingly report experiences related to stereotype threat supporting racial and gender disparity. Therefore, studies that consider the impact of gender and race may identify factors crucial for the success of graduate school in generating diverse research scholars. Overall, strong scientific and critical thinking skills, complemented with sound research skills that develop by the process of socialization in graduate school are the foundation of success for graduate students. However, the majority of research on doctoral students focuses on various factors individually, so future research in which the cumulative impact of all factors discussed in this review, particularly with respect to process of socialization is recommended (Sverdlik et al., 2018).

Moreover, a comprehensive literature review indicates that overall, there is a scarcity of research exploring female graduate student’s experience in comparison to their male peers. Such a study is likely to distinguish potential predictors of doctoral students’ satisfaction in the program of study and impact on future career intentions in STEM. Furthermore, a gender based comparative study may pinpoint the factors crucial for women’s success in the program and interest in STEM careers.

**Study Focus and Significance**

The under-representation of women in some fields of STEM and overall higher attrition of graduate students in STEM related doctoral programs warrants the need of research on graduate students’ experience to detect factors associated with success in the program, and any gender or discipline based differences that may exist. This study focuses on PhD students’ perception of educational environment to explore the potential factors crucial for their success in
the program and future career orientations in STEM. This study also intended to establish any
gender or field based difference in student’s experiences and career orientations. Educational
environment for the purpose of this study referred to all the components of graduate school as a
community including program curriculum, research and teaching engagement, interactions with
peers, faculty and support from department, whereas graduate students means only doctoral
students in STEM. This study was extended to include any non academic factors also. As such,
this study sought to evaluate the holistic learning experiences doctoral students as compared to
their male counterparts. The following research questions were asked.

Research Questions

Overarching Question

What are doctoral students' perceptions of their educational environment in STEM? What
factors do they associate with their perception of success, problems, and future career intentions?

What type of gender-based and/or discipline-based differences exist that may be
associated with students’ perception of success, problems, and future career intentions?

Sub Questions

- How do graduate students’ perceptions of program curriculum design and
departmental support, impact their success in the program?
- How do they perceive graduate or teaching assistantships as enhancing or impeding
the efficiency to complete their degree and be ready for their future career?
- How do they perceive the role(s) of their supervisors and other faculty?
- How do they describe the experience of peer collaboration, if any, in the process of
their doctoral studies?
• How do graduate students describe their non-academic commitments during the doctoral studies?

• How do graduate students relate their current perception of their graduate program to the perception of their future jobs?
CHAPTER III

METHODOLOGY

Study Design

This study was designed as a qualitative multiple comparative case study utilizing a criterion sample of doctoral students, from seven STEM disciplines, discussing their learning experiences and future careers, in a focus group setting. The case study approach aligned with the purpose of this research, as a case study involves the evaluation of behavior in the context of a “bounded system,” or particular setting or circumstance (Stake, 1995; Yin, 2009). Furthermore, a case study is deemed to be an appropriate tool when research questions involve how or why, and context of the phenomenon cannot be controlled or altered. In the context of this research, graduate school is a “bound system” and students’ perception of learning environments cannot be altered or controlled by the researcher. Moreover, the study was designed as a multiple comparative case study methodology because of its alignment with the purpose of exploring the experiences and career orientations of graduate students in STEM and to distinguish any gender or discipline-based differences. The selected methodology provides a purposive sample and the potential for generalizability of findings (Patton, 2002), by offering a rigorous and complete approach to confer triangulation of evidence from the use of multiple cases rather than a single case study (Yin, 2009). Having a multiple case composition, this study not only examined the in-depth details, context, and features of each individual, but also provided an exploration of contrasts, similarities, or patterns within and between the five groups of cases (Levy, 2008). Each participant within a focus group was defined as a case for unit of analysis. Additionally, each focus group composed of multiple participants was collectively used as a unit of analysis within the study.
In contrast to quantitative research, this qualitative study does not directly divulge any cause and effect relationships of independent and dependent variables, meaning it does not directly correlate students’ experiences to their satisfaction and future career aspirations, it rather establishes this phenomenon in a credible manner by ‘generative mechanisms’ or ‘causal powers’ to facilitate these inferences (Guba & Lincoln, 1994; Merriam, 1998; Miles & Huberman, 1994; Yazan, 2015; Yin, 2013). To establish credibility in a case study it is important to collect data from multiple sources, as triangulation in qualitative research is often employed as a means of better capturing the complexity of the phenomenon being studied (Yazan, 2015). Thus, data in this project was collected using multiple sources.

**Data Sources**

Forms of data collected in the study were aligned with the data collection approach in qualitative research (Creswell, 2014; Richards, 2014; Saldaña, 2015). Data was collected from following sources.

**Focus Group Discussion**

The focus group technique of data collection promotes a comfortable atmosphere of disclosure in which people can share their ideas, experiences, and attitudes about a topic (Rabiee, 2004; Williams & Katz, 2001). Focus groups attempt to obtain data in a social context where people can consider their own views in the context of other people’s views (Krueger & Casey, 2009; Patton, 2012). The key elements that contribute to focus groups being an effective tool for researchers are the levels of "synergy, stimulation, and spontaneity" that a group dynamic can generate (Catterall & Maclaran, 1997).

In our study the focus group approach for data collection provided a better understanding of the extent to which various constructs play a role in students’ success, and
formation/strengthening of career orientations, because participants from different fields tended to clarify their fellow students’ response on the spot while trying to reach a consensus, or contrast their own experience. Additionally, the focus group setting allowed comparing and contrasting experience of students from different fields. As each group was composed of students from different departments, students were able to validate any emerging difference in real-time. Furthermore, mixed gender composition of two of the focus groups was beneficial in deriving gender-based differences in students’ experiences and career aspirations.

For this study, five focus group discussions were conducted each containing four PhD students, all coming from different disciplines of STEM. Focus group # 1, 2 and 3 were conducted by a female student researcher, whereas focus group # 4 and 5 were moderated by a trained male moderator. Details of each focus group composition are described in table 1 below.

Table 1
Composition of Five Focus Group Sessions

<table>
<thead>
<tr>
<th>Focus group #</th>
<th>Gender composition</th>
<th>Disciplines included</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mixed gender</td>
<td>Biology, Chemistry, Physics, Geosciences</td>
</tr>
<tr>
<td>2</td>
<td>All females</td>
<td>Biology, Chemistry, Physics, Geosciences</td>
</tr>
<tr>
<td>3</td>
<td>All females</td>
<td>Biology, Math, Computer Science and Engineering</td>
</tr>
<tr>
<td>4</td>
<td>All males</td>
<td>Biology, Math, Physics and Engineering</td>
</tr>
<tr>
<td>5</td>
<td>Mixed gender</td>
<td>Biology, Chemistry, Physics, Engineering</td>
</tr>
<tr>
<td>6</td>
<td>All males planned as per research protocol but not conducted</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA= Not applicable

Research protocol for this project was written to conduct six focus groups. However, because of the onset of corona virus pandemic in March, 2020, the university imposed
restrictions on social gathering, following local and state laws. Therefore, only five focus groups were conducted, as the sixth ‘all males’ focus group could have not been moderated. Data collected through five focus groups, however indicated the saturation of most of themes emerging from the study.

Review of Program of Study Documents

A second source of data collection included a review of departmental documents describing PhD program requirements for each field of study. To determine the difference among different disciplines of study, and to corroborate data generated from focus groups, information about the requirements of course credits; such as qualifying exams, comprehensive exams, research proposals, and mandatory numbers of publications were collected for review from each department. In order to understand the status of gender diversity in different departments, students’ enrollment and the number of students graduated each year over a period of five years (2015-2019) were also reviewed. The average annual enrollment was calculated by adding up annual enrollment for five years and dividing by five. Similarly, average graduation was calculated by adding up number of students graduated each year for five years and dividing by five. Percent graduation rate for each department and gender was also calculated by dividing annual average graduation by annual average enrollment and multiplying with 100. Percent graduation rate calculated this way did not represent total graduation rate by department or gender. Purpose of these calculations was to make interdepartmental and gender-based comparisons.
Sampling, Subjects, Access, and Setting

Participants

Participants for this study were current PhD students enrolled in STEM doctoral programs at a mid-sized public university located in the Midwest of the USA. Twelve females and eight male PhD students from seven different disciplines participated in the study. Composition of each focus group including gender and discipline is described in table 1. All doctoral students in predetermined disciplines were invited to participate in a focus group discussion; the process of recruitment is presented in figure 2. Twenty students were recruited into five focus groups, each containing four students. Demographic information such as students’ discipline of study, year in the program, gender, ethnicity, and teaching assistantships is depicted in table 2. For the purpose of this study gender was defined on a binary basis only.
Table 2

Demographic Information of Participants

<table>
<thead>
<tr>
<th>Focus group #</th>
<th>Participant #</th>
<th>Field of Study</th>
<th>Year</th>
<th>TA</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CF1</td>
<td>Chemistry</td>
<td>5</td>
<td>Yes</td>
<td>White</td>
</tr>
<tr>
<td>1</td>
<td>GF2</td>
<td>Geosciences</td>
<td>5</td>
<td>Yes</td>
<td>White</td>
</tr>
<tr>
<td>1</td>
<td>BM1</td>
<td>Biology</td>
<td>5</td>
<td>Yes</td>
<td>Latino</td>
</tr>
<tr>
<td>1</td>
<td>PM2</td>
<td>Physics</td>
<td>6</td>
<td>Yes</td>
<td>Asian*</td>
</tr>
<tr>
<td>2</td>
<td>BF3</td>
<td>Biology</td>
<td>2</td>
<td>Yes</td>
<td>Asian</td>
</tr>
<tr>
<td>2</td>
<td>CF4</td>
<td>Chemistry</td>
<td>4</td>
<td>Yes</td>
<td>White</td>
</tr>
<tr>
<td>2</td>
<td>GF5</td>
<td>Geosciences</td>
<td>5</td>
<td>Yes</td>
<td>White</td>
</tr>
<tr>
<td>2</td>
<td>PF6</td>
<td>Physics</td>
<td>4</td>
<td>Yes</td>
<td>Asian</td>
</tr>
<tr>
<td>3</td>
<td>BF7</td>
<td>Biology</td>
<td>5</td>
<td>Yes</td>
<td>White*</td>
</tr>
<tr>
<td>3</td>
<td>CSF8</td>
<td>CS</td>
<td>5</td>
<td>Yes^</td>
<td>Arab*</td>
</tr>
<tr>
<td>3</td>
<td>MF9</td>
<td>Math</td>
<td>3</td>
<td>Yes</td>
<td>White</td>
</tr>
<tr>
<td>3</td>
<td>EF10</td>
<td>Engineering</td>
<td>2</td>
<td>No</td>
<td>Arab*</td>
</tr>
<tr>
<td>4</td>
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<td>2</td>
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</tr>
<tr>
<td>4</td>
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<td>Physics</td>
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</tr>
<tr>
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<td>EM6</td>
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<td>PM8</td>
<td>Physics</td>
<td>4</td>
<td>Yes</td>
<td>Black*</td>
</tr>
</tbody>
</table>

^Limited TA experience, * International student, CS=Computer science

Recruitment Process

To recruit participants, a study protocol describing the detailed procedure of the project was submitted to the Human Subjects Institutional Review Board (HSIRB) of researcher’s institution of study. Study was conducted upon receiving the approval of study protocol from HSIRB (Appendix A). As described in figure 2, upon approval from HSIRB, contact information
of the department heads was identified using university or specific department website. A request to obtain email addresses of all PhD students was made to selected department chairs by email, assuring that students’ email address will only be used to invite students to participate in the study. A brief description and purpose of the study was also included in the email written to department chairs. A majority of the chairs contacted by the researcher only agreed to distribute the study recruitment flyer to their students, instead of providing students’ email addresses to researchers. Additionally, copies of the invitation to participate flyers were also posted on posting boards in various buildings at the university campus. The recruitment flyer provided instructions to contact the student researcher for more information on the study if they were interested in participating. For those students who decided to participate, the researcher provided a consent form stating a summary of the study and potential risks and benefits of participation.

The participant sample was selected based on the selection criteria to form six focus groups of four students each. However, only five focus groups were conducted because of the onset of COVID-19 pandemic in the spring of 2020 in the US. The selection criteria included (a) female graduate students, (b) male graduate students (c) students enrolled in any of seven STEM disciplines (biology, chemistry, physics, math, geosciences, computer science, and engineering). All participants were selected on a first come first selected basis, and all four students in each group were from different departments. Upon receipt of an adequate number of responses for participation, a time and place of each focus group session was scheduled after coordination with all interested students via email.

**Data Collection Procedures, and Instrumentation**

The graduation requirements for each doctoral program were collected from departmental websites. Collected information was categorized into required course credits, need for qualifying
exams, comprehensive exams, grant writing requirements, and presentation or publication requirements for each department of study. Data on student enrollment and graduation number for last five years (2015-2019) was collected from institutional research website.

On the day of each scheduled focus group session, immediately prior to start of the discussion, each participant reviewed and signed a consent form (Appendix B). Focus group discussions were conducted following a semi structured protocol (Appendix C). Focus group discussion included students’ experience with courses/research, interactions with faculty /advisor and peers, teaching experience, non academic engagements, and future career intensions impacted by program of their study. Focus group discussions were audio and videotaped, and notes were taken. Audio recordings were transcribed verbatim, and each participant was assigned a unique participant number or pseudo code as shown in table 2.

Data Analysis

As described by Wolcott (2008), data analysis consisted of three somewhat distinct components including description, analysis, and interpretation. Data analysis included data organization, theme development, interpretation, and report writing (Marshall & Rossman, 2014, p. 214; Richards, 2014; Saldaña, 2015). Data collected under this study were ordered into different files, groups, and subgroups of cases to provide a structure. Data were coded using a priori coding to give meaning to descriptions of experiences provided by the participants. An emphasis was given to systematic, and multilevel analysis of data appropriate for a comparative case study research (Miles & Huberman, 1994; Yin, 2009).

As described in figure 3, the process of cyclic coding, consisting of a first cycle of elemental codes, followed by in vivo coding was used. Elemental coding applies a basic but focused filter to the data and works as a building block for future coding. Elemental coding is
composed of many categories; this project used a structural and textual coding in which a phrase representing the topic of the research is applied to a segment of data that relates to a specific construct or research question of the focus group such as peer interactions. *In vivo* coding was also utilized, where participants’ own language or words act as codes (Saldaña, 2015). Segments of transcripts were coded and categorized using the qualitative research software HyperRESEARCH version 4.5.0. All codes were compiled into a code book. The code book and category codes were revised further as needed. Categories that emerged from each case were exported as Microsoft Excel 2007 worksheets using the report builder feature of HyperRESEARCH 4.5.0.

The unit of analysis for this study varied by research question. For first research question all participants (n=20) were considered separately. However, for second research question, male participants (n=8), female participants (n=12), and focus groups (n=5) were used for analysis. A comparison between different categories was made from report tables to distinguish the similarities and differences between male and female students, and different disciplines of study. Each emerged category or theme was discussed further in detail in the context of the theoretical framework and relevant literature.

A cross analysis of data generated from each case was conducted by comparing data from each source to confirm validity. For instance, the themes emerging from notes, focus group transcripts, analytic memos, and departmental documents were reviewed for consistency of the emerged themes from individual cases and between cases. Any inconsistency in data was resolved by member checking and reviewing documents as described by Creswell and Clark (2017).
A cross case analysis within each focus group was performed by comparing the emerged categories and themes between cases of each group (Bogdan & Biklen, 2007, p. 45). For the purpose of this study, groups were formed on the bases of a focus group, gender, and discipline and compared with each other. For example, the general themes or central phenomenon of female focus group was compared with the general themes of all male and or mixed gender focus group and so on. An analysis of similarities and differences based on gender and disciplines were discussed in the context of findings from the literature.

**Inter Coder Reliability**

The approach to inter-coder reliability involved the utilization of the consensual qualitative research model (Hill et al., 2005). The focus group transcripts were coded using a combination of preset codes related to different constructs of the socialization theoretical framework, and emergent codes arising from transcripts. To ensure the validity of the coding process, two trained coders independently coded a sample of transcripts, and the results were compared to establish percent reliability. Preset codes achieved more than 70% agreement during first pass. After the first pass of inter coder comparison, the code book was revised to achieve consensus on emergent codes. Transcripts were coded by the student researcher using the revised code book. To verify the validity of the revised coding process, two trained coders independently coded a 20% sample of transcripts, and more than 80% agreement between coders was observed.
Figure 2

Recruitment and Focus Group Session Process

**Recruitment of Participants**

- Email to pre-selected department chairs to obtain email addresses of all PhD students
- Received email addresses?
  - Yes: Email the invitation flyer to students
    - Received response back with interest to participate
      - Is response adequate?
        - Yes: Ask for availability
          - Are enough students available to run a focus group?
            - Yes: Schedule focus group and email the time and place to students
              - Send a reminder email a day ahead of focus group schedule
            - No: Include more disciplines of study
              - Yes: Provide lunch/dinner prior to the session
                - Assign seats
                  - Sign consent form
                    - Brief introduction followed by discussion
                      - Conclusion of focus group
                        - Appreciation draw
                          - End
        - No: Include more disciplines of study
          - Yes: Provide lunch/dinner prior to the session
            - Assign seats
              - Sign consent form
                - Brief introduction followed by discussion
                  - Conclusion of focus group
                    - Appreciation draw
                      - End
    - No: Include more disciplines of study
      - Yes: Provide lunch/dinner prior to the session
        - Assign seats
          - Sign consent form
            - Brief introduction followed by discussion
              - Conclusion of focus group
                - Appreciation draw
                  - End

- No: Send invitation flyer email to students via chairs, Post flyer on posting boards
  - Include more disciplines of study

Figure 3

Coding Process

Organize transcripts, memos, observation notes for each group → Upload text files to HyperResearch → Cyclic coding → Elemental coding, In vivo coding, Emergent coding → Code book and code descriptions → Code a sample of transcripts by 2 independent coders → Is intercoder reliability ≥80%?

No

Yes

Generate reports

Export to Excel workbooks → Create themes
The Researcher (Reflexivity)

While I may have a differing opinion on whether my personal beliefs and characteristics exert an effect on research findings, I have sought out my subjectivity systematically while research was in progress to see the impact of my reflexivity on the research outcomes or perception and action in research settings. A brief description about my background and experience relevant to the case study may help the reader’s understanding of the findings (Creswell & Clark, 2017; Marshall & Rossman, 2014; Richards, 2014).

Being a non-traditional, off campus female PhD student myself, I have my own perception of the learning environment and socialization process in graduate school at Western Michigan University. My own experiences as a student are likely to color the lens through which participants’ narratives were inferred to draw conclusions. My perspective about STEM is not limited to the academic career of a PhD student, as my work as a research scientist in industry helps me to reflect on participants’ future careers as well. Some of the participants of my study also transitioned from industry to graduate school. I am not working as a TA though I do have TA and teaching experience to relate with participants. Being married, with children and a side job, I have plenty of non-academics engagements. Furthermore, being a native of India, and dual citizen of Canada and the US, I have quite broad socio-cultural, educational, and professional experiences that provide me with a unique insight of eastern and western norms of education.

Growing up in India I experienced a culture where books were considered sacred and importance of education was instilled by my parents both of whom were teachers. The status of science was very high as compared to non-science subjects, so I was groomed to study science, biology in particular, though the field of engineering was reserved for my brother. In India the field of biology was very much over represented by women. Career choices of the majority
aligned merely with status, availability, and pay scale of a profession rather than personal interest. Competition for higher education was so high that most of the time one’s capability to obtain admission in a particular field at college level alone would dictate a person’s career. Capability in that situation meant a combination of students’ positions in scholarly merit and financial status of their parents. Financial status of students’ parents was important because not everyone could afford cost of college, and students’ loans were not readily available. I considered myself fortunate having just enough of both. I obtained my master’s degree in biology from Canada that has a similar education system as here in the US, and like in the US personal interests plays a significant role in career choices of people in Canada.

With my diverse experience I am in a position to relate with both domestic and international students at many levels, including being a woman of color, a non-traditional PhD student, a professional in a STEM field, and seeing female students’ lack of interest in STEM, in particular engineering. Therefore, I am more likely than not to draw on my own broader socio-cultural, academic, and professional experiences when interpreting data collected from my participants. On one hand it is helpful because I can understand a range of perspectives, but by the same token, it may cause a bias in my interpretation because I may easily attribute behavior to something that I have experience with, but participants have not. For example, a participant in chemistry indicated that as a part of their curriculum they have to prepare a grant on a topic that is not related to their dissertation’s topic of research. She perceived that task to be a colossal waste of time, and other participants of her focus group perfectly agreed with her, but my experience as a researcher tells me that grant writing is the most valuable skill that will come handy if they pursue a career in research. In this case, if I don’t bracket my own view then there is a risk of bias incorporation in the interpretation of data. However, studying science education
as a doctoral student, I reviewed literature on qualitative research tools, specifically on
conducting qualitative case study and how to manage the potential subjectivity as a researcher.
Throughout the study I was mindful of my bias and have managed myself by bracketing my
opinion in written memos/epochs at the beginning, during, and at the end of the research
(Marshall & Rossman, 2014; Richards, 2014; Saldaña, 2015).

**Trustworthiness in Collecting and Analyzing Data**

The study was conducted ethically, following a systematic and rigorous approach of a
case study prescribed in the literature (Creswell & Clark, 2017; Marshall & Rossman, 2014). To
incorporate transparency in data collection, an audit trail of documents was established by
keeping source method recoding data. Memo writing was used to capture ongoing details
throughout the study to document everything to increase the trustworthiness (Marshall and

The subjectivity inherent in the case study method was mitigated through a careful
sampling, a semi structured focus group, and a structured process of recording, transcribing and
interpreting the data (Guba & Lincoln 1994). Thus, a chain of evidence was established from the
beginning of the research questions through data collection to the final conclusions,

As a researcher and graduate student myself, I was aware of ethical issues that may arise
during the data collection, therefore the confidentiality and privacy of the participants were
maintained as described in the consent document. Furthermore, I assured that all participants
were comfortable, so a general interview warm up procedure was applied as suggested by
Nespor and Groenke (2009). Moderators were mindful of various factors that may impact the
outcome of discussions; therefore, a rapport was established with participants by talking in
general and making them comfortable before starting discussions. A smoother transition of the
conversation during focus groups was maintained by knowing the protocol very well and not reading off the transcript word for word (Guest et al., 2017).

A pilot focus group composed of six participants was conducted to assure that the process of data collection worked as planned and questions were clear and elicited the information of interest to answer research questions. According to Maxwell (2012), the key to collecting good qualitative data is creating good questions; therefore, piloting the questions was crucial (p. 95). Participants of the pilot test recommended scaling down the number of participants to ensure all participants had an equal chance to respond in depth to the topics of interest, while the duration of the discussion stayed within 90 minutes. Therefore, the number of participants in each focus group was reduced to four from the original protocol with up to six. Furthermore, this number was adequate to provide ample opportunity to identify themes and pattern across the cases (Creswell & Clark, 2017). Moreover, including a greater number of cases in a case study dilutes the ‘attention to details’ characteristic of a case study (Wolcott, 2008). The participants of pilot study participants also recommended starting the discussion with broader questions and then to probe further based on participant responses.

As a researcher I was the primary measurement instrument in this study. However, to mitigate ‘moderator or gender impact’ on the outcome of discussions, one focus group containing all male participants and one mixed gender group was moderated by a trained male moderator. For training purposes the moderator participated in the pilot focus group for this study, observed one focus group as an observer and was trained by the researcher to watch for any important specifics, such as to provide an equal opportunity for all participants to talk, probe any unclear responses further, and summarize the responses of the group before switching from one topic of discussion to next.
Data triangulation was incorporated by using more than one source of data collection and including multiple numbers of cases (participants and focus groups). Dependability and conformability of obtained data was established through an auditing of the research process and cross analysis of each form of data. Member checking was utilized wherever needed (Creswell & Clark, 2017; Saldaña, 2015).

A constant comparison approach was applied to data collection and data analysis throughout the study. Analytic memos were written to capture my thoughts on the emerging themes, and clusters of data patterns on a continuous basis, after running each focus group. Outcomes of the data collection and analysis of a particular focus group were compared frequently to the proceeding focus groups to remove any discrepancies between the uses of focus group protocols and to establish validity of the data as per a constant comparative method (Bogdan & Biklen, 2007, p. 45). Results of data analysis were reviewed by an experienced researcher to reach an agreement.

Findings from this study may be limited to the university and programs included in this study with a limited generalization to similar population at other graduate schools.
CHAPTER IV

RESULTS

As described in chapter I, this study sought to answer two research questions:

Q1. What are doctoral students' perceptions of their educational environment in STEM? What factors do they associate with their perception of success, problems, and future career intentions?

Q2. What type of gender-based and/or discipline-based differences exist that may be associated with students’ perception of success, problems, and future career intentions?

These two research questions were further divided into six sub questions, aligned with different constructs of socialization theoretical framework used in the study. Five focus groups composed of four PhD students, one each from different STEM fields were conducted to ascertain graduate students’ perceptions of graduate courses, TA work, interactions with faculty, advisors, peers, and any non-academic activities. Additionally, students’ future career plans, potentially impacted by their successes and challenges of PhD study, were also a point of focus.

To provide a descriptive overview of PhD programs of study, graduation requirements of seven different disciplines used in this study were compiled. A review of program requirements prior to the analysis of focus group data was likely to add to the understanding of participants’ responses as they refer to program details during focus group discussions. In order to understand the status of gender diversity in different departments, students’ enrollment and the number of students graduated each year, over a period of five years (2015-2019) were also analyzed. Following sections, first describe the results of documents review followed by findings from focus groups.
**Document Review of Departments of Study**

From all seven departments of study, graduation requirements, number of students enrolled annually for last five years, and number of students graduated were tabulated, and graphed.

**Graduation Requirements**

Doctoral programs’ graduation requirements for all seven departments of study were reviewed, and an interdisciplinary comparison was made to understand the differences. Different requirements that must be fulfilled to graduate in different departments are presented in table 3. Overall, all departments required students to take 30 credit hours of courses, 15 hours of dissertation research and 15 for dissertation and oral defense, except in computer science. In computer science dissertation work could be between 12 and 24 credits. Some departments considered grades obtained in core courses in lieu of a qualifying exam. However, in chemistry, math, computer science, and physics, students had to take one to three qualifying or comprehensive exams, in addition to maintain a minimum GPA. Comprehensive exams, or at least portions of it, could be repeated once. Failure of comprehensive exams resulted in automatic expulsion from the program. Departments without comprehensive exams, including biology, geosciences, and engineering used the dissertation research proposal as a qualifying metric to grant candidacy. Geosciences students had to meet the requirement of one peer reviewed paper accepted for publication in order to graduate, in addition to requirements for presenting at a conference. All departments required research tools or skill tests, and participations in seminars. Math and physics appeared to be very theory intensive with a high number of set core courses and three comprehensive exams. Field experience or an internship
was required for chemistry, geosciences and engineering. A teaching course, and a teaching practicum was required by biology and math respectively.

**Table 3**

*Graduation Requirements of Departments of Study*

<table>
<thead>
<tr>
<th>Department (number of credits to graduate)</th>
<th>Core courses</th>
<th>Electives</th>
<th>Research tools</th>
<th>Comprehensive exam/research proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology (61)</td>
<td>Six hours of core courses, 3 hrs of seminar, 3 hr of teaching and learning in the college classroom</td>
<td>19 hours of elective related to research and interests agreed upon by committee</td>
<td>Research tool requirements</td>
<td>Research proposal preparation and defense</td>
</tr>
<tr>
<td>Computer Science (74)</td>
<td>18 credit hours of regular course, 3 credit hours of CS 7100 (Independent Research), to be successfully completed by the third semester of enrollment, followed by three credit hours of CS 7350 (Graduate Research), an approved research report submitted to the department; and</td>
<td>Six credit hours of course work that may include regular courses, independent study, research, seminars and professional field experience</td>
<td>Competency in two research skills. A foreign language other than English, with competency equivalent to a 4000-level course; Statistics or probability at the level of MATH 3620 or MATH 3640. Computer document preparation and library tools.</td>
<td>Three qualifying exams passed at least with BA grade. Only one exam can be repeated once. Preliminary examination that is an approval by committee for dissertation topic and plan</td>
</tr>
<tr>
<td>Department</td>
<td>Required Credits</td>
<td>Core Courses</td>
<td>Research Courses</td>
<td>Specific Requirements</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------</td>
<td>--------------</td>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Chemistry (60)</td>
<td>15 to 21</td>
<td>Two research</td>
<td>Two computer</td>
<td>Three Qualifying exams consist of six cumulative examinations (CUMEs) to cover all major areas in chemistry, Unique Proposal defense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core courses</td>
<td>tool courses or</td>
<td>instrument or language courses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>equivalency</td>
<td></td>
</tr>
<tr>
<td>Geosciences (60)</td>
<td>Four Core</td>
<td>Seminar hours,</td>
<td>Three core</td>
<td>One scientific presentation and one first authored paper should be accepted</td>
</tr>
<tr>
<td></td>
<td>courses in given</td>
<td>proficiency in</td>
<td>courses with not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fields and three</td>
<td>two research</td>
<td>less than BA</td>
<td></td>
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<tr>
<td></td>
<td>research courses</td>
<td>tool</td>
<td>grade act as</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>qualifying exams</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Research</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Proposal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>examination</td>
<td></td>
</tr>
<tr>
<td>Engineering (60)</td>
<td>30</td>
<td>Two research</td>
<td>Qualifying exam</td>
<td>Research proposal is comprehensive exam</td>
</tr>
<tr>
<td></td>
<td>course hours</td>
<td>tools courses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Math (60)</td>
<td>Three series of</td>
<td>Research tool</td>
<td>Compete</td>
<td>Three comprehensive exams one could be from other than core courses series, two attempts allowed</td>
</tr>
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<td></td>
<td>core courses</td>
<td>requirements</td>
<td>teaching</td>
<td></td>
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<td>two semester long,</td>
<td></td>
<td>practicum, one</td>
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<td>one series can be</td>
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<td>replaced with</td>
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<td>course</td>
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<td>research related</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>courses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics (60)</td>
<td>27</td>
<td>Research tools</td>
<td>Special courses</td>
<td>Comprehensive exam, can be repeated once</td>
</tr>
<tr>
<td></td>
<td>credits of core</td>
<td></td>
<td>related to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>courses must get</td>
<td></td>
<td>research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BA in seven</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>given core</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>courses</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CS= Computer science

**Student Enrollment in Different Departments**

In order to understand the gender diversity of each department of study, last five years data (2015 to 2019) on enrollment and graduation of PhD students were obtained from
university’s institution of research. Data on enrollment including numbers of females and male students, average yearly enrollment for five years, and percentage enrollment by gender is presented in table 4. Additionally, data on average number of males and female students’ enrollment is depicted in figure 4.

Table 4 and figure 4 indicate that biology is the only department having higher enrollment of females as compared to males. Average enrollment from 2015 to 2019 for biology was 15 females and 11 males. All the other departments had higher numbers of males than females. Lowest number of female students’ enrollment was observed in the engineering department having only one female enrolled in 2015. Highest number of female enrollment was observed in biology department having 17 female students in 2019. The lowest number of male enrollment was observed in biology having only nine male students enrolled in 2015. Highest enrollment of male students was in computer science during 2015 when 35 male students were enrolled. An interdepartmental and gender-based comparison of enrollment in each department indicates that highest % of women enrollment was observed in biology (59%) and lowest in engineering (13%). Percent enrollment of women in geosciences (41%), chemistry (40%), math (36%), physics (32%), and computer sciences (24%) was in between biology and engineering.

Total number of students enrolled in all seven departments over the period of five years ranged from 162 in 2019 and 188 in 2017 with an average enrollment of 180.

A review of variation of males and female students’ enrollment in each department over the period of five years shows that male students in computer science observed the highest fluctuation in enrollment (28±7.70). Lowest variation in enrollment was observed in math female students (11±0.71). Overall male students had higher variation in enrollment than female students’ enrollment (figure 4). Among female students physics showed highest variation in
enrollment (7 ±2.59) and math was the lowest (11±0.71). Among male students computer sciences showed the highest variation in enrollment (28±7.70) and engineering observed the lowest (17±1.03).

**Table 4**

*Number of PhD Students Enrolled in Each Department of Study from 2015 to 2019*

<table>
<thead>
<tr>
<th>Department</th>
<th>Gender</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>Average</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>Females</td>
<td>15</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>15</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>14</td>
<td>10</td>
<td>11</td>
<td>41</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Females</td>
<td>9</td>
<td>11</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>22</td>
<td>17</td>
<td>14</td>
<td>12</td>
<td>11</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Geo.</td>
<td>Females</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>11</td>
<td>59</td>
</tr>
<tr>
<td>Physics</td>
<td>Females</td>
<td>7</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>7</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>14</td>
<td>14</td>
<td>12</td>
<td>17</td>
<td>19</td>
<td>15</td>
<td>68</td>
</tr>
<tr>
<td>Math</td>
<td>Females</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>20</td>
<td>20</td>
<td>23</td>
<td>19</td>
<td>14</td>
<td>19</td>
<td>64</td>
</tr>
<tr>
<td>CS</td>
<td>Females</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>35</td>
<td>34</td>
<td>32</td>
<td>24</td>
<td>17</td>
<td>28</td>
<td>76</td>
</tr>
<tr>
<td>Engi.</td>
<td>Females</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>15</td>
<td>16</td>
<td>18</td>
<td>17</td>
<td>18</td>
<td>17</td>
<td>88</td>
</tr>
<tr>
<td>Total students</td>
<td></td>
<td>183</td>
<td>185</td>
<td>188</td>
<td>180</td>
<td>162</td>
<td>180</td>
<td>NA</td>
</tr>
</tbody>
</table>

CS = Computer science, Geo. = Geological and environmental science, Engi. = Engineering fields
Figure 4

Average Number of Students Enrolled Annually in Different Departments From 2015 to 2019

<table>
<thead>
<tr>
<th>Department</th>
<th>Average Number of Students Enrolled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>Females 15 ± 2, Males 10 ± 3</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Females 12 ± 1, Males 9 ± 3</td>
</tr>
<tr>
<td>Geological and environmental sciences</td>
<td>Females 18 ± 4, Males 12 ± 3</td>
</tr>
<tr>
<td>Physics</td>
<td>Females 14 ± 2, Males 9 ± 3</td>
</tr>
<tr>
<td>Math</td>
<td>Females 16 ± 2, Males 14 ± 3</td>
</tr>
<tr>
<td>CS</td>
<td>Females 30 ± 5, Males 28 ± 4</td>
</tr>
<tr>
<td>Engineering</td>
<td>Females 5 ± 1, Males 3 ± 2</td>
</tr>
</tbody>
</table>

CS= Computer science

Number of Students Graduated in Different Departments

Data on graduation including number of females and male students graduated each year, average number graduated from 2015 to 2019, and percentage of students graduated each year by gender is presented in table 5. Additionally, data on the average number of females and male students graduated along with variation in the form of standard deviation are presented in figure 5.

The numbers of students graduating each year ranged from as low as zero to as high as eight. However, engineering is the only department where none of the female student graduated over the period of five years. Overall the average number of female students graduated for all
departments were less than male students. Highest number of female graduations was observed in chemistry department having four female students graduated in 2018. Highest graduation number of male students was eight in computer science during 2018. A gender based and interdepartmental comparison showed that highest % of females graduated in chemistry and biology (46%), and lowest in engineering (0%). Physics (40%), geosciences (38%), math (35%), and computer sciences (14%) ranked in between chemistry-biology and engineering. Total number of students graduated each year in all seven departments combined ranged from lowest (20) in 2017 to highest (31) in 2018 with an annual average of 24 over a period of five years.

A review of variation of males and female students’ graduation number in each department over a period of five years shows that male students in computer science observed the highest fluctuation in graduation (3.6±3.29). Lowest variation in graduation numbers was observed in biology female students (1.2±0.45). Overall male students had higher variation in graduation as compared to female students (figure 5). Among female students, chemistry showed the highest variation in graduation (2.2 ±1.30) and biology was the lowest (1.2±0.45). Among male students, computer sciences showed the highest variation in average graduation (3.6±3.29) and geosciences observed the lowest (1.6±0.55).
Table 5

Number of Students Graduated Yearly in Different Departments from 2015 to 2019

<table>
<thead>
<tr>
<th>Department</th>
<th>Gender</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>Average</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>Females</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1.2</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1.4</td>
<td>54</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Females</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2.2</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>2.6</td>
<td>54</td>
</tr>
<tr>
<td>Geo.</td>
<td>Females</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1.0</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1.6</td>
<td>62</td>
</tr>
<tr>
<td>Physics</td>
<td>Females</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1.2</td>
<td>60</td>
</tr>
<tr>
<td>Math</td>
<td>Females</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1.6</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>3.0</td>
<td>65</td>
</tr>
<tr>
<td>CS</td>
<td>Females</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.6</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>6</td>
<td>3.6</td>
<td>86</td>
</tr>
<tr>
<td>Engineering</td>
<td>Females</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>2.8</td>
<td>100</td>
</tr>
<tr>
<td>Total students in all departments</td>
<td>24</td>
<td>15</td>
<td>20</td>
<td>31</td>
<td>28</td>
<td>24</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

CS= Computer science, Geo. =Geological and environmental sciences
Figure 5

Average Number of Students Graduated Annually in Different Departments From 2015 to 2019

![Graph showing average number of students graduated annually in different departments.]

CS = Computer science

Average Enrollment vs. Graduation Percentage in Different Departments

Percent of students graduated each year based on the average five years enrollment in each department was calculated for males and females, and all PhD students. As shown in table 6 and figure 6 chemistry and physics had higher percentage of female students graduated each year than their male counterparts. In chemistry 22% females graduated in contrast to 17.1% male students. In physics 11.1% females graduated as compared to 7.9% male students. Geosciences and math had similar level of graduation in both females and males. In geosciences 12.8%
females graduated as compared to 14% males. In math females’ graduation was 14.5% and males’ 15.6%.

As shown in table 6 and figure 7, the average annual graduation of all PhD students in a department was highest in chemistry (19.1%), and lowest in physics (8.93%). Math (15.2%), engineering (14.6%), geosciences (13.5%), computer science (11.3%) and biology (9.92%) ranked in between in a decreasing order of graduation.

**Table 6**

*Percent Students Graduated Based on Average Annual Enrollment Over a Five Year Period (2015-2019)*

<table>
<thead>
<tr>
<th>Department</th>
<th>Gender</th>
<th>Annual average by gender</th>
<th>Annual average by department</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enrolled</td>
<td>Graduated</td>
<td>% Graduated</td>
</tr>
<tr>
<td>Biology</td>
<td>Females</td>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>11</td>
<td>1.4</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Females</td>
<td>10</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>15</td>
<td>2.6</td>
</tr>
<tr>
<td>Geo.</td>
<td>Females</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>11</td>
<td>1.6</td>
</tr>
<tr>
<td>Physics</td>
<td>Females</td>
<td>7</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>Math</td>
<td>Females</td>
<td>11</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>CS</td>
<td>Females</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>28</td>
<td>3.6</td>
</tr>
<tr>
<td>Engi.</td>
<td>Females</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>17</td>
<td>2.8</td>
</tr>
<tr>
<td>Total of all departments</td>
<td>180</td>
<td>23.6</td>
<td>13.1</td>
</tr>
</tbody>
</table>

_Cs= Computer science, Geo. =Geological and environmental sciences, Engi.=Engineering_
Figure 6

Percentage of Male and Female Students Graduated Annually Based on Average Enrollment in Different Departments From 2015 to 2019

CS = Computer science
Focus Group Findings

This section summarizes the thematic experiences of graduate students categorized under each construct or factor assessed as a part of this study. The following section is organized into six groups (1) student’s perception of graduate level courses (2) TA experiences (3) advisor support and faculty mentorship (4) peer interactions (5) non academic engagements (6) future career plans. Results under each category are further divided into four parts to distinguish (a) positive views, (b) negative views, (c) gender-based differences, and (d) any discipline-based differences in students’ perceptions related to each factor.

Students’ Perception of Graduate Level Courses

Course taking, experience involve availability of course, relevance of course content to their future career interest or research, and teaching style of teachers. Students gain experience as
they interact with fellow students, and faculty teaching courses. According to Cambridge English dictionary, interaction is defined as a situation where two or more people or things communicate with each other or react to one another. Therefore, for the purpose of this study students’ reaction to course content and communication with teachers and fellow students are called interactions with courses.

This section describes students’ experience with curriculum including coursework, comprehensive exam, or other requirements such as writing research grant proposals. The section is divided into positive experience; negative experiences, followed by gender based, and discipline differences.

**Positive Experiences With Courses.**

Response about participants’ experience with graduate courses and curriculum design represented mixed perceptions. In general, the negatives about course work far outweighed the positives. But the one positives aspect of courses was about gaining in depth knowledge that participants perceived interesting and potentially useful in future careers in academia or industry. Below are some of the selected excerpts from the focus groups that show students’ positive perception of courses taken during their program of doctoral study.

"The coursework, yeah, it can help me for future career. I'm a faculty member at an international university. They are sponsoring me for my PhD. So the coursework will be helpful for my future career as faculty as it will increase my knowledge in the area of study (EM6)."

"I think overall the classes themselves were interesting and I feel like they broadened my perspective, even if they weren't particularly related to my research area (MM5)."

"Before I came here, I worked in industry as an analytical chemist. And so if I were to go that route one day, a couple of the classes I took would probably be useful for that. Like, I took the mass spec course and that's probably (useful), well I did take an inorganic chemistry course which was interesting. I don't know if it would be useful but, it was pretty interesting (CF1)."
As a part of their curriculum of study, PhD students in some departments claimed that they obtained training in writing research grants. To students, grant writing appeared to be a very favorable skill they learned during their program of study. Students claimed that this skill not only helped them with their own doctoral study, but also prepared them for their future career in research at a university or a research position in industry. A conversation between two participants reflects this perception as follows:

**BF7:** But in biology, we write our own grant and this is our own research and basically by the end of third year you have to present this and this is you basically telling your committee, these are my goals, my preliminary data and so on.

**CF1:** But this is a good way to teach you how to do the grant, to help you in future jobs....

**BF7:** Yes, I agree.

There were few occasions when one participant perceived courses as positive while another participant had somewhat opposite view. One participant (first year physics student) was sharing his perception about the potential benefits of graduate courses in his future career, when another participant who was in his fifth year responded with a different opinion:

**PM4:** Being in those courses are not just useful, but they are necessary for the future career because if you're going to do research in the future, then when you read the paper and you suddenly don't understand anything. Especially for physics, there are many theories that you haven't seen it before.... You really need to master quantum mechanics and ... those sorts of things. So far, it's my first year so it's really a review.

**MM5:** It's interesting that you say learning (from all these courses) is beneficial or needed. I think that if you really wanted to have everything you needed, all the courses you need to be successful in your academic career, and you would probably be here forever.

**PM4:** That’s true

**Negative Experiences With Courses.**

The negative aspects of course included unavailability of courses, lack of relevance to research or future careers, heavy focus on grades, and perception of unfair grading. In general,
majority of participants stated that many courses taken were just a ‘check in the box’ to complete credits required to graduate. Participants also believed that availability of courses was a problem in all departments except geosciences. Math and physics students explained that some of the courses critical for passing comprehensive exams got cancelled at the last minute. They had to prepare for this critical milestone by themselves, with little perceived guidance from the faculty. Furthermore, some students believed that comprehensive exams did not confer any meaningful learning; students had to study “to just pass the exam”. It appeared to be that in general, departments with comprehensive exam requirements did not provide a very positive learning experience to students as compared to students from other departments. A female participant explained her view of graduate courses in the context of unavailability, and lack of relevancy to her research topic:

*I finished my coursework, but I think none was related to my field. It was a general coursework about mechanical engineering. My area is fluid and heat. So it was a general course about those subjects which were not helping me in anyway. And, I was looking to choose, a course about laser spectroscopy or these related course throughout the department. None was available. And even in whole university I couldn’t find any. I was also looking for someone who knows something about simulation, industrial type of simulation, there wasn’t any. ....There is no beginner or advanced course about coding, which I think for engineering department, there should be because, most of our simulation is coding Python.... Uh, most of these courses are for undergrads and as a PhD I cannot join them, and those undergraduate courses are very basic anyway (EF12).*

Unavailability of courses was perceived to be a prevalent issue in all departments except geosciences. Students claimed that sometimes courses were cancelled because of low enrollment, right at the time when they needed to take those courses the most. Some students had to take course outside of their departments to meet course requirements.

*Well, let's say all my coursework is pretty relevant and interesting. But one issue that I ran into at [at this university] was I had a class canceled on me that was required and I had to take a comprehensive exam in that subject. So that was really challenging. They changed it to like a reading course. So, it was essentially an independent study. It was really, really difficult too, that was very frustrating (MF9).*
In chemistry, courses (courses being offered) are very limited. What's offered and when, and sometimes the numbers are so low that the classes are in danger of not running at all. And so to get in all the credits that you need, you pretty much have to just take what's offered (CF1).

Because I had my master from (this university), so when I started my PhD, I faced an issue that I already took most of the graduate level courses offered by the department. I had to go out from our department to take courses to fulfill the PhD coursework requirements (EM6).

Another common theme that emerged from focus group discussion was ‘study to pass the exam not to learn,’ in particular for comprehensive exams. Students from departments that required comprehensive exams appeared to be envious of students from departments that only needed research or grant proposals. Some students found the comprehensive exams to be “exhausting.”

A female participant from physics shared her struggle with courses, reflecting on her perception on how these courses act as weeding tools to kick students out of the program:

The story (struggle) went on, but I kind of figured that how to survive. I knew I was not learning, but I could not afford to fail .... So I say that we were like about eight students when I started. Right now only three students are left in my batch that was started in 2016. But situation is worse for 2017 batch of PhD students as there is no one in department from 2017 batch. Everyone dropped out (PF6).

This view from a physics female student was corroborated by a male graduate student from math. His perception of comprehensive exams is reflected as follows:

I don't know that having these comprehensive tests is helpful because it was just like, I don't know, it felt like a lot of work to be prepared to do these questions on these tests, which are very theoretical and were very tricky in terms of problem solving, but since we were so focused on just getting through these exams, once we got through them I feel like my mastery of those questions I'd practiced has just declined since I was so focused on just getting through that test and less so about understanding the big picture of those subjects. I guess in that respect, I didn't think those were as helpful (MM5).

Furthermore, another participant argued against the usefulness of many courses that graduate students take to fill credit requirements:

A lot of them (courses) were just checking the boxes, getting them done. I would say I think we have to take eight classes that are like specifically required. .....And you have to
pass six cumulative exams..., and then our proposal, which our proposal has to be nothing related to our research (CF4).

In my opinion, in PhD level the focus should be more on research and to me taking many courses interrupts research activities. ...To be honest, most of the courses that I have passed are not helping me in doing the experiments and writing the dissertation (EF10).

**Gender Differences Related to Course Experience.**

As far as graduate level courses or curriculum was concerned, there appeared to be some gender differences in all disciplines. For example, women in all disciplines complained about their negative perception of experiences, especially the lack of resources, rigidity of some senior professors related to teaching style, and extreme grading policies. Some male students also mentioned negatives about courses including unavailability of some courses, and questioning the benefit of comprehensive exams. However, male students did not note any gender bias. Moreover, the discussion about gender bias only came up during ‘all female’ or mixed gender focus groups. Female students’ perception is reflected in the following quotes:

> And they're very set in their ways on just doing what they want to do. They're not really considerate of their students and what we want. So, they're very, like, for example having very rigid grading scales where it's like you get an A or you get a D and that's it (MF9).

> I have the habit of going to the professor and get the photocopy of my answer sheets so that I know what I did (right) and what I did (wrong). So what happened for my final exam is that my grades were B. I was sure that I was going to get AB. When I went to professor, he didn't give me the copy of answer sheet...which means he probably gave me a lower score than I deserved....Even when I was taking the classes, I went to his office hours (to ask questions) and he's like, you are a grad student. You should figure it out by yourself (PF6).

Gender bias in chemistry, physics and geosciences emerged from discussion on courses. As one female chemistry student explained, she had to take physical chemistry as a pre-requisite of her program because she had not taken that course as an undergraduate student. However, a few male students of her cohort did not have to take that course. She told her female advisor and her advisor tried to find out the reason behind this discrepancy. However, she stated that none of the reasons provided by the department were sufficient. According to her statement, the faculty
responsible for reviewing admission applications were ‘both, older, white, male faculty’. Below is an excerpt indicating student’s perception:

\[
\text{But luckily my advisor, again, who is female and meet up another female in the department who like really took offense to this, they had no idea. And so they're like our biggest cheerleaders. I mean, obviously I took the class and I passed it. It was, I mean it's hard. but yeah, that's one of my big complaints in our department. We have a very, male dominated school and, and they are sexist (CF4).}
\]

Similarly, a physics female student also described her incident of gender bias, where a faculty in physics refused to give her a copy of her answer sheet submitted during an exam while he gave the similar copy to her two male colleagues. She believed the reason behind his refusal was that her exam was graded unfairly. Additionally, she also stated that she was told that “\textit{she is from continent xx}” and “\textit{physics is difficult for a woman}”. Below is an excerpt to reflect her perception:

\[
\text{..so I thought probably past international students (from my country) were weak in performance. So that's why they (professors) were being little bias. But, next semester the same professor was teaching subject xx and there was a domestic female student in his class. The professor was being bias to domestic female student too. Even in the class students could say that he is misbehaving with that girl. He would insult her questions, who would like de-motivate her .. It went so bad (PF6).}
\]

**Discipline Based Differences in Course Experiences.**

In addition to gender differences, some discipline based differences emerged among students related to their course taking experience. A female student from math contrasted her experience with her fellow students from biology and computer science as follow:

\[
\text{Yeah, I guess I kind of have a lot to say and it's sort of a bit conflicting (with other participants’ experience). If I could go back, I would not come to [this university] for graduate school. Most of my professors are, a lot of the professors in the math department are very old and it's, especially from like, you know, seeing them teach classes, they don't really care. And they're very set in their ways on just doing what they want to do. They're not really considerate of their students and what we want. So they're very, like, for example having very rigid grading scales where it's like you get an A or you get a D and that's it. Like stuff like that and it's just feels very, you know, ridiculous. They're very set in their ways. There are definitely professors that care and will reach out to you and help (MF9).}
\]
Overall participants from disciplines without the requirement of comprehensive exams such as biology, chemistry, geosciences and engineering perceived their experiences with graduate courses more positively than math, physics and computer sciences. Additionally, the availability of courses was perceived as an issue by participants from all departments except geosciences. Participants from geosciences however, complained about the content of some courses to be very out dated.

*We didn't have problem of course availability in geosciences department. It's actually a lack of students signing up for certain classes. I had one class that I found helpful. Okay. Every other class in my department are rather lacking or being taught from material from the 1970s. Um, that being said, it's still kind of what geology is (GF2).*

**TA Experiences**

Teaching assistants (TA) are defined as graduate students who work on teaching assignments as part of their program of study. In return they get financial support and teaching experience, important for their future careers in academia. During the process of teaching, student TAs socialize with fellow TAs and faculty whose courses or labs they are assigned to teach. In this category, students’ interactions with the department and structural aspects such as schedule of teaching assignments’, content of the courses they teach is also part of socialization (Bagaka’s et al., 2015).

**Positive Impact of TA Roles.**

Students viewed teaching experience gained during their program of study as quite beneficial, as it boosts their skills in teaching to prepare them for future careers as university faculty or for a lecturer position at college. Furthermore, working as a TA conferred time management, organizational, and people skills to students, all of which are considered to be backbone of any successful career, not just a job in teaching. Students’ positive view of TA
work, regardless of amount of time it took away from their other activities was summed up in the excerpts given below:

Yeah, I love being a TA. That's what I want to do eventually is teach. And so I absolutely love it. It's just on top of everything else, it's just a lot because it's dedicated time that you have to set aside every week planning off the side of the, actually being in the lab, grading papers. And so it's just a lot of time. But other than that, it's great. I feel like I'm prepared to teach it. ... And I've also been able to teach a lot of different classes, so I feel like that's also been good experience (CF1).

I'm working as a teaching faculty, so all these experiences I'm very excited to be a part of, but yes, down the road I want to teach, but I think it takes time right now in getting the research done to actually get the degree to do that (BM3).

Teaching could be helpful in students’ own research pursuit by providing opportunities for review of basic courses taken in past.

Sometimes with the passage of time, I forget many small things which are related to basic science and they are pretty important for my research. So I think teaching general chemistry helps me in revising my basic science stuff (CF11).

TA positions broaden students’ skills by providing unique opportunities. One such example was mentioned by a participant who learned how to design and teach a course for students with disabilities.

I actually got to work with a couple of visually impaired students, which I think is really cool that the geology department is trying to incorporate that because you know, sciences are not always super friendly for people who can't see. Yeah, so we're working on trying to incorporate more of that type of stuff. It was difficult, honestly, trying to make things friendly for people who have little to no vision. ..., but I also want to teach eventually. So I think that was a really cool opportunity for me being able to work with students with disabilities and not like the normal disabilities that you think about (GF5).

Participants perceived that teaching assignments not only instill teaching skills in graduate students, but they also teach other critical job skills that are important for non-academic roles:

I also think that if I choose to go into a non-academic career, it also is helpful to... I think it (Teaching) really helped some of my organization and leadership skills, since you have to do a lot of planning for the class and you have to do a lot of management of the students and things like that (MM5).
Negative Impact of TA Roles.

Graduate students believed that working as TAs were not free from some challenges that they faced, mainly because of lack of training prior to commencement of their teaching assignments.

*I think that this university could do a better job at least in the biology department on getting you prepared for that. Because luckily for me, I had taken course before, it wasn't like a big learning curve on the content, but even just the logistics of, like you have to make sure you turn this into the office on time so they can get your copies ready for you. This is how you upload your crap to e-learning, you know? this, that, and the other things. They gave us a half a day’s training on what we needed to do. And then they said, here's your instructor of record, don't date your students. You know, that's pretty much it (BF7).*

Participants suggested that during their first semester TAs should observe more experienced TAs teaching course content to students, so that they can see the teaching process in real time. While some departments already followed that process of observation, but that was not the case in all departments.

*Yeah. Which realistically they should be for everybody observed other to do it because for us, we don't (observe teaching sessions conducted by experienced TAs), and I'm sure it's similar in other departments. We have some grad students who in the past there's been a few occasions where they had no idea (about the content of the course). They hadn't even taken a class on the subject. They (department) were just like, Oh, you know, this is kind of related to your research, you teach this class (GF5).*

Students’ perception of lacking strong training in teaching was not only taxing on graduate students’ time, but also appeared to be a source of stress for many students:

*...as a TA, we're not really given substantial training in teaching things, so especially when you're the sole provider of the content in the course at that point, I find myself putting in some additional time beyond that trying to just actually figure out how to teach. That was a time expense that caused, that continues to cause, stress during my career, where I'm at now (MM5).*

Gender Difference in TA Experience.

Regardless of similarities related to benefits and challenges of teaching, there were striking gender differences that emerged in this study related to solving TA challenges. In
general, female students tried to improve the process of teaching after suffering from the consequences of lack of training or uniformity in the content of courses. While all students did complain about the lack of TA training, but the high level of commitment reflected by female students did not emerge from male participants. Even in the ‘mixed focus group’ discussions females appeared to be more passionate about teaching. At least three female participants all from ‘female focus group’ went above and beyond their assigned tasks. For example, one female student from computer science incorporated a new style of quiz in her class. She called it ‘happy quiz’ in which she included hard questions, but students did not lose grade points if they could not solve them correctly. She also sought feedback from students on those hard questions and then provided answers to all questions in the classroom for the benefit of all students. Other female participants commented positively providing their own logic of good teaching and students’ interactions:

See, because you are still a student yourself, so it's like you bring your own experiences. I still remember how it was, one of my students in evaluation said back in the day, “I can tell that she knows how it is because she was recently a student herself in this class.” So you know, you can project on that experience and see. Well I would teach it in a little different way because I think this would help them better. And you see it, and you care about students that way (BF7).

Similarly, female students from biology and math worked extra hours to bring consistency in the curriculum from one semester to next so that future TAs would not have to go through the struggle that they themselves had.

And then I did a similar thing to you (BF7 and CSF10) where I spent a bunch of time, like I reached out to people in the department and I was like, look, this isn't okay. We need to make changes. So I'd say, you know, it's my third year since the very beginning I've been putting pretty much all my time into this, either my own studies or teaching and just way more time than is required because I feel that it's important that people don't have the same struggles that I have. …. Cause I, I hate what happened to me and I don't want to see that to happen to someone else. Now I lecture part of the time and all the other part of the time I had them work on activity. So overall it was a really good experience to learn how to teach in that way (MF9).
Discipline Difference in TA Experience.

TA experiences across different departments appeared to be very similar. One difference, though, was that participants from engineering did not have much experience with teaching. Additionally, students from some departments did not realize that biology provided TA assignments during summer semesters. The physics department provided some teaching intensive training during summer to selected TAs. A female math student expressed her feeling about the availability of TA assignments as follow:

*Wow! That's not in math. We really don’t have that (many TA assignments in summer). If you are about to graduate with your PhD, then you might be allowed to teach in summer I or summer II but other than that we have no funding for the summer. Well, sorry, actually, excuse me. You could have some kind of research funding, but they are few and far between (MF9).*

In summary, overall participants enjoyed their work as TAs, though there was an agreement on the lack of training prior to beginning their TA assignments, especially during first semester or first TA assignment. Balancing priorities between, teaching, research and coursework was at the forefront of discussion related to students’ roles as TAs. However, a majority of students viewed TA positions quite positively. Female students went well beyond the required efforts to improve the process of teaching.

Faculty and Advisor Interactions With PhD Students

Interactions with faculty and research advisor include students’ interactions with faculty teaching graduate courses and supervising their research projects, serving on research committee and acting as mentors. Under socialization theory (Bagaka’s et al., 2015) interactions with faculty play a critical role in students’ success in the program and their transformation to become scholars. According to Gildersleeve et al. (2011), faculty interactions occurs through “socialization”, which is defined as “the process by which doctoral students learn the customs,
traditions, and values of any given discipline or field through mentoring and advising relationships as well as by engaging in research, service, and teaching” (p. 94).

Positive Perception of Faculty and Advisor Interactions

Most of the interactions with faculty emerged from taking courses taught by faculty. Participants from most of the departments viewed faculty interactions positively. Faculty also supported students’ development as future scholars by providing workshops on grant writings and helping with scholarship applications to present at conferences. Participants claimed that biology faculty cared about students’ interest, and they wanted students to have a good work family balance.

*It's really refreshing because, you know? we all know grad school is hard. It doesn't matter what walk of life you are. It is hard. And the thing that they reiterated to us over and over again was to make sure you (we) have a good work life balance (BF3).*

*In relation to the department or support, I think at least in the biology department I had, like for any professor who I approach and asked for help with some issue or some advising they are very friendly and very approachable, very accessible (BM1).*

*Today I got approval for my research proposal outline. My committee gave helpful comments; they (faculty on committee) are very understandable (EM6).*

Most students’ perceptions of advisor interactions appeared to be very positive. Participants claimed their advisors are good mentors, who care for students’ future careers, and help them finding funding to attend conferences.

*I love my advisor and she is very supportive also of presenting my research and finding money for me to go to conferences (CF4).*

*My advisor is great. If I had a different advisor, I honestly I wouldn't be in the department still. But my advisor is super helpful. We meet once a week. She meets with all of the students as one group. So, we have a group meeting and then we have individual meetings either weekly or biweekly depending on where you're at. Yeah, that's great and super supportive (CF1).*

Student participants of this study perceived that advisors not only support in research, they also are mindful of students’ future career plans, and assure that students stay on track to
fulfill career aspirations. An excerpt from a participant explained how her advisor is mentoring and helping her to achieve career goal in teaching:

*Well, for me, that’s what my advisor asked. He said, what is your end game when you graduate? Or what do you want to do? And I said I want to teach. And he said, great. Well then here, you know, here are the things that we will work on and we’ll make sure that your CV reflects that so that we will get you ready to go. Cause if you’re, if you’re not interested in research or industry, I’m not going to push you this way. You know, we’ll go this way. So for TA, it was really exciting for me cause that’s, that’s what I want to do (BF3).*

As mentioned above most of the students in all focus groups praised their advisors, while some mentioned other people having problems in their departments. Some did mention that they chose their advisor very carefully by looking at faculty profiles and talking to their friends. Furthermore, at least three male participants indicated that they had done undergraduate research with their advisors before so, they had the advantage of a previous relationship.

In summary, interactions with faculty teaching graduate courses were positive in biology and engineering. Interactions with advisors were positive for the majority of students. But biology and chemistry females appeared to have more advisory support, to the extent that they thought of their advisors as great mentors, and cheerleaders.

**Negative Perception of Faculty and Advisor Interactions.**

Student’s perception of faculty revealed that many departments, except biology and engineering; tend to have sporadic problems with faculty, specifically with senior professors. In their opinion very senior professors’ behavior was less than appropriate because they reflected characteristics of gender bias. One student emphasized that even though the whole department was aware of that behavioral situation, nothing was being done. Similarly, another female graduate student stated that some professors in her department were very rigid in their way of teaching regardless of having a superior content knowledge.
.. my impression with the professors is that they, ... care about like their own research and they don't really care about teaching. And there are a handful of professors that I really do love their teaching and they have that passion for the subject. But it just seems like they're very poor at communicating on what they know to students. Because they're just stuck in how they think and they don't care about actually,.. like reaching out to us and seeing how we were going to be able to process that information. So, they're very inflexible I would say (MF9). -

Some students perceived that senior professors in chemistry, geosciences, physics and math need better people skills, and have rigid ways of teaching. According to students’ views, those professors are hard to communicate with, and their graduate students are more likely to suffer.

And I feel like, ironically a lot of the other older men (faculty) in our department are not research active. And so the people that are working under them, I don't feel like they have the opportunity. They are not in that case; I don't feel like they're discriminating against women. I feel like whoever is in their lab, they just don't care (CF4).

So it kind of depends on what field you go into and who you pick (as advisor). Like in my field graph theory, all the professors are actually really cool and, and helpful and they're younger and mostly, but if you get into a field that's more specialized and they don't have as many PhD students, but like I said, several of my friends who are in those specialties are struggling and their research is taking long as those professors just aren't putting in their time. Like my advisor is (MF9).

Yeah. I mean, honestly, I really do think that, at least within my department, we're bringing in all of these new faculties that it will get better. Yeah. I mean, even the men in our department definitely know that a couple of (senior) faculty members are like inappropriate. Often, I heard that. And it's, I mean it's not a secret (GF5).

While the majority of students appeared to have good relationships with their own research advisors and committee, there were few students who believed their experience could have been improved with more advisory support, guidance and communication at a personal level. One male student complained that his supervisor was more helpful during undergraduate research that was not the case anymore. He perceived that his supervisor’s communications were not satisfactory regarding the support on his graduate research. But he stated that his research committee was helpful in guiding his research project.
One male student from physics also stated having different expectations than his supervisor and he associated that difference to his cultural background. He explains:

Yeah. I think the, the challenge in the research is like somehow there is the difference between what I expect from my supervisor what she expects from me. Sometimes it's a misleading because I came from a background where supervisor is supposed to really guide you. But, somehow I didn't know that the doctoral students really have to be independent. Yeah. So it's like it's a big culture shock in the middle of my doctorate studies (PM2).

Another student believed that getting supportive advisor is a matter of chance just like ‘rolling dice’.

Yeah, this is a very touchy issue because I've come to see by experience that, it's more like rolling a dice. You either get a very good adviser or not. It is a 50, 50 chance! (PM8).

Similarly, couple of female students associated the lack of research progress to the level of guidance received from research advisors. One participant stated her advisor has too much on her plate. Consequently, this student perceived her progress in the program is suffering.

You have to do it basically yourself; my adviser tends to pay attention to me. Then all of a sudden (she got busy) I get put on the back burner for half a semester to a whole semester, which is why I haven't moved forward for about a year. ….. Yeah. So, you're just kind of left to your own devices to do your own research and get it done with (GF2).

Similarly, another female student stated the lack of project and funding impacted her progress in research:

For the past two and half years, my advisor didn't push me in any direction because we did not have (any research project and funding) to start my research. So, my advisor basically was okay with everything going on in my doctorate. But at the same time, I had to work independently and do everything by myself. I had to come up with research idea, appropriate methods with the relevant path, and everything else by myself. It is super frustrating (EF12).

Commenting on level of communications among advisors and students, a female participant from physics stated that she found out from undergraduate students that her advisor was going for more than two month long vacation. Similarly, another female student stated that her advisor does not provide person focused guidance:
My advisor never asks me if I'm okay.. if I'm doing fine or ... if as a person I need something. ... I know it's not her responsibility, but at the same time I think good communication would have been beneficial for both of us. You know, it is important to have more of humane type of conversation than only a research based conversation between a scientist/professor and the student (EF12).

Gender Based Differences of Faculty and Advisor Interactions.

There was a clear gender based difference related to interactions with faculty teaching courses. Majority of the male participants did not say much positive or negatives about their interactions with faculty. However female participants from almost all departments except biology and engineering mentioned some negative views about faculty interactions including gender bias.

Gender bias in chemistry, physics and geosciences emerged from discussion on courses in the context of interactions with faculty. As one female chemistry student explained, she had to take physical chemistry as a pre-requisite of her program because she had not taken that course as an undergraduate student. However, a few male students of her cohort did not have to take that course. She told her female advisor and her advisor tried to find out the reason but as per her opinion none of the reasons provided by the department were sufficient. According to her statement, the faculty responsible for reviewing admission applications were both, older, white, male faculty.

Similarly, a physics female student also described her incident of gender bias, where a faculty in physics refused to give her a copy of her answer sheet submitted during an exam while he gave the same to her two male colleagues. She believed the reason behind that was that her exam was graded unfairly. Additionally, she also stated that she was told that she is from “continent xx” and “physics is difficult for a woman"
Female participants perceived some male senior professors being rigid in their teaching and communication styles. Though they perceived interactions with advisors positively (regardless of seniority):

*I don't know. I'm not really sure (what is the reason behind this problem). I mean, because it's not all of them. Like my... my advisor is one of the older men in the department and he's great. Like I think, you know, he's got a daughter my age, so I think he understands like where, where I'm coming from (GF2).*

A comparison between male and female participants also indicated that females had more negatives about faculty. Except in one mixed gender group a couple of male participants did mention a cursory complaint about faculty not being very helpful mentors.

..*I think one of the things that I feel that department has failed to train faculty to become research mentors. They just assume that if you have exceptional research performance in your field of study, anybody can learn the science from you. But there is more involvement of personal communication skill than just knowing the science (PM8).*

On the other hand, most of the participants perceived their advisors to be supportive overall except few students. Therefore, there was no distinct gender difference related to student-advisor interactions. Majority of female participants believed their interactions with advisors to be very positive, except couple of female students who associated their poor advisor interactions to faculty having extremely high workload and lack of funding in the lab. Similarly, majority of male students had positive interactions with research advisors except a few being more vocal in stating minor grievances about their advisors. For example one male student said, his interaction level had deteriorated as compared to his experience during undergraduate research.

*The last three months I've just been in the lab, doing my thing (without directions), not knowing if I'm headed in the right direction or not (BM7).*

Another male student claimed misalignment between the level of guidance he received from his advisor and his own expectations.
Discipline Based Difference in Faculty and Advisor Interactions.

Participants from different departments appeared to perceive the faculty interactions differently. However, most of these differences overlapped with departmental differences in course taking experiences and gender based differences described in the previous sections. For example students of math and physics perceived comprehensive exam as weeding tool to kick students out of PhD program. Students from these departments only mentioned negatives about faculty teaching those courses. Females from chemistry, physics; geosciences stated some level of gender bias that was related to faculty interactions. Biology and engineering students appeared to perceive faculty interactions positivity.

Peer Interactions

In the context of this study a PhD student from department ‘A’ is considered a peer to another PhD student from the same department or school. Therefore, interactions with peers mean communication or reactions among PhD students who belong to same department, class cohort or college. Interactions with peers include collaborations in research projects, writing or group projects or simply spending some free time in an out of school setting.

Positive Peer Interactions.

Overall students described their experience with peers as positive and helpful in their success and sustainability in the program. They received mutual support via study groups, proofread each other’s assignments and research work, and substitute for fellow students’ TA assignments and so on. Excerpts below are reflections of overall views that emerged from this study:

*In my math classes I'd say there's like a big comradery with everybody. It's like we are all friends. I think it's pretty well agreed that to really need to be good at math. It helps to communicate it with others and learn from others, get multiple perspectives. So, I would say in just about every math class I've taken, we had study groups. We met all up and
tried to, because we wanted to all be experts in the material, right? So, we really work together. There wasn't, there's never really competition. We all want everybody else to succeed and I think just having those peers to work with was like a really big part of my success. So, like when I didn't have it for that one semester, it was terrible. It was really, really hard (MF9).

Without support from peers, female students felt weird and uncomfortable. One participant described her experience during the first year as weird because she did not have any peer support then. She missed opportunity to connect with peers by not starting at the beginning of fall semester, when students most likely make connections with peers by attending student orientations.

First year was really rough because I started in between semesters. I was in two different departments technically and so nobody knew who I was because I just, I came in by myself because it was in between, and it was just a really weird, weird time. It was like nobody knew who I was so nobody talked to me until the next year when the new group finally came in (CF1).

International students depend on their peers for cultural and non academic support. They interact with peers in out of school settings as well.

So sometimes we have this gathering and we share food because we are all from different countries, so we have a good company. And in the courses also we were excellent group because we explain course material to each other. So, I don't think I can possibly survive without them. Because when we are international students in a different country, we need this feeling of family and system of help. Also, my friends, they have kids so we share playtime by going together to the park. So I, I don't think so without having gathering and relaxing time with peers, we can go through the tough journey of PhD (CSF8).

Another participant agreed with the computer science participant’s view:

I would agree with that without all my friends. I don't know. I've been here (MF9).

Students in general only interact with their lab mates or with those whom they share a research project with.

I think the lines of social interaction tend to get drawn with the disciplines. I work in a molecular cellular lab even though I'm a biologist. I tend to interact mostly with people from the labs who do similar work. There are some people that I can rely on if I need someone to cover a TA session for me. I haven't done any collaboration outside of my lab, but in my lab my first paper publication was actually collaboration with a fellow
student in the lab. It actually was her first authored paper, that that was my full first year was collaborating and my project stemmed from that, so context dependent (BM3).

**Negative or Nonexistent Peer Interactions.**

Levels of peer interactions may depend on personality in addition to other factors. Some students discussed a lack of or negative aspects of peer interactions:

*I guess you could say that there’s really no interaction anymore. Even at school. Like no one's there because they're all at school, they're all there. They're all like boring adults. They're all, yeah, no, you, this is like, they don't realize grad school is this liberal land of non-adulting really (GF5).*

*I have just one friend. We started together in our program and we did our research together. We have been working together for certain projects. The other students are in the lab. But we discuss with them only when we have general questions. So, during most of my research, I just have one colleague (EM6).*

*Biological department is not very people's person department. I work a lot. I teach a lot. I'm busy all in there. I have a lot of work to do. I know people get together, so there are some groups and they get together. And this is, yeah, this is nice. Some no, I'm happy with my, my friend and a person from the lab, another graduate student. And we just mostly hang out together in the lab. And so, but it's nice environment. It's, it's good BF7*

*In my department, also other grad students are like busy in their life and they don't like to socialize. So we don't have that network (PF6).*

Another female student from geosciences explained the negative impact of socialization with peers.

*You socialize; you don't get anything done, right? Yeah. Every time I try to, or we have like a, we call it the grad lands. It's like a locker room where all the cubicles are. Yeah. It's the grad lands. and if I go back there, cause that's where like our community refrigerator is, it's where it's the microwave is. And I go back there to eat lunch and start working on stuff and I never get anything done because inevitably somebody will come in and talk to me. They'll leave, somebody else will come in and I'm just like, okay, I'm going to go hide in my office (GF5).*

**Gender Based Differences in Peer Interactions.**

Females’ students appeared to have more positive peer interactions as compared to male students. They interact with peers in many different settings including collaboration in publications.
In our research lab, we have published a lot of conference and peer reviewed journal articles together. We enjoyed sharing ideas and experiences (EF10).

A female student from chemistry stated that male students only interact with other male students as their peers. A conversation between two female participants reflected this opinion.

CF4: ... I guess we see each other (male and female students) sometimes at seminars only, but we don't have a close relationship, if anything. I think the guys only interact with the other guys. Yeah, I feel like there's a divide.

GF5: And I've also heard from other people that that's just pretty common in the chemistry world in general. But women and men don't really mesh for some reason.

CF4: Yes, I don't know why? May be there's just a sense of arrogance. Like organic chemistry people may feel that they're superior over analytical.

Male students were not very forthcoming disclosing their negative peer interactions. Below is an example of conversation between a male student from biology and female from geosciences, after male student mentioned all the good stuff about his peers:

GF2: Do they talk down to you?

BM1: Oh, they are asses so I'm not going to talk with asses.

GF2: There we go. Yup!

BM1: That's it. I mean it's only like two people. That's all, the rest I can talk and have conversation. Even with the asses, I have conversations with them.

GF2: You just round it up. Exactly.

As can be seen from the conversation given above male student was reluctant to say something negative about his peers. After probing he was more transparent about his interactions with peers. Below is example of somewhat negative peer interactions from biology:

We have a lot of shared equipment in our department, like a half a million dollar confocal microscope. It's the only one that the university has, and there are a lot of people who use it and people who use it who don't know how to use it, so they break it and everybody's research is dependent on that, and you never know who breaks it. Then it takes weeks for the department, because then the department has to find funds to fix it and it's... That's a pretty big thing in the department. There are groups of people who discuss who they thought broke it this time, and the blame tends to go between three groups of people who they point the finger at them, they point the finger at them, they
point the finger at them. That's just one example, yeah. Sorry, you said let loose. I had a conversation about this about an hour ago (BM3).

Discipline Based Differences in Peer Interactions.

As described in previous sections students from physics and engineering tend not to have much peer interactions. Otherwise it was hard to draw any field dependent ideas about peer interactions. It appeared to depend more on the student’s personality than field of study. Though biology appeared to be the one discipline where more people tend to interact with peers whether it is positive, negative or organized peers’ interactions. In organized peer interactions, some student’s took initiatives to set up regular meetings to go out as a group and discuss their issues in casual settings.

In summary, there was a range of responses on peer interactions among PhD students. Most peer interactions appeared to have positive impacts on students’ academic life. However, some negative impacts did emerge upon probing during focus group discussions. The level of peer interactions depended on gender, phase of life, student’s personality, and discipline of study. Females appeared to benefit or depend more on peer interactions, as compared to male students. Physics and engineering students had very little to no peer interactions, while biology students had more and organized peer activities.

Non Academic Interactions/Responsibilities

Non-academic interactions for the purpose of this study include any out of school responsibilities that may impact students’ satisfaction with the program such as family responsibilities, part time employment, sports or hobbies.

Positive Impact of Non Academic Interactions.

As positive factors in the context of non academic activities, an array of activities was mentioned that include working out to keep fit, going out to socialize on a regular basis to avoid
getting burnt from graduate school stress, and cooking for fun. Some of the students appeared to understand the benefit of these activities yet did not have time to engage in any. Some of the nonacademic interactions understandably did overlap with peer interactions because in some cases peers were the ones that students interacted outside the school setting. In some cases, these out of school activities appeared to be a fine line defining success vs. failure in the program as explained by one female participant:

*We are a very small ethnic student community here. I think less than 30 people. And I guess that small community is the only thing that kept me alive and sane because in my lab I'm alone. I don't work in a group. I do not communicate with my supervisor often. There are very few PhD students in my department, and I don't have any sort of social life. And I don't know, if I didn't know these few ethnic people, I guess, I would go crazy (EF12).*

In contrast a male student explained that he did not need any relationship or other non academic interactions because he was not planning to stay in the area after graduation.

*When you're in graduate school, you assume that you're going to be in that area temporarily. Maybe not, depending, but since I'm interested in academia and there are not many institutions or universities in the area (for future jobs). There is some things like finding a spouse or partner or getting super involved with certain community organizations, I feel like I just have not done as much just from the knowledge that I'll have to leave anyway soon (MM5).*

**Negative Impact of Non Academic Engagements.**

Some of the negatives of non academic behavior include having a family with younger children who need expensive daycare, being away from family with no opportunity to depend on them for support, in particular for international students.

*Yeah, there's the life beside the academics. So my wife and I are expecting a baby next month. So there is going to be more stress on me ....it’s like I keep thinking about baby and baby related stuff while studying (EM6).*

This is the fact that PhD students are at the phase of their life when they are about to start their family. Female students appeared to juggle between priorities of taking care of kids and starting or completing graduate school.
Being a PhD student is more like having a job instead of being a conventional student. We have more responsibilities both in academic and non-academic commitments (EF10).

It appeared to be that women who are determined to go out of their way (by beating society’s standard set for women) to face the challenge to balance competing priorities, are the ones likely to enroll and succeed in demanding STEM programs. A perfect example can be seen from the excerpt below:

*I was in industry for like five years before starting grad school. I got married during that time, and wanted start family, it did not happen. So, went back to grad school and said, I'm not going to let grad school decide who I am. Those other goals (starting family) didn't go away. As a woman in STEM, I'm not going to let somebody say you can't have both. So I have two young children. I work 20 hours a week at a daycare on top of three TA lab sessions. I'm getting my research done. Right now I'm killing it. I might be on the verge of a mental breakdown, but I'm doing it. But the biggest thing is I told myself I'm not going to let other people's standards determine what I can and can't do. And if I get to the point where I have to give something up ...., then at that point, I mean, I'm not going to give up my kids (CF1).*

Worrying about financial responsibility was the other factor on students’ mind, especially those whose family depended on them.

*Also and as a dependent for her (his spouse) health insurance is just like way higher than for me. You know, like as women, it's way higher. Maybe the university can have some, leverage, negotiating with the insurance company or something or the TA union can help like that because we feel that, at least for our rights as a TA, we'll have some, you know, some sort of privileges extended to our dependents just like regular university employees (BM7).*

**Gender Based Differences in Non Academic Responsibilities.**

Non-academic interaction was an area in which gender-based impacts were very clear. Females with kids stood out from all the participants, claiming that these responsibilities required good time management skills to balance non academic priorities in addition to their course work, teaching assistantships, and research work. One female participant mentioned that she did not want to get into non-academic activities, because that would have put her PhD on the back
burner, and she did not want to get lost. In this discussion a male participant was having a hard
time to understand woman’s perspective. A segment of conversation below provides a glimpse:

PM2: What do you mean by putting PhD on the back burner or getting lost? Meaning
you will abandon it (PhD)?

GF2: The work is like the 40th thing you do because you know, first you have teaching,
then you have..., all right, now I've got to make sure the kids get food, the kids get to
sleep, they get to school, and they have clothes that fit them. The husband makes it out of
the house with the kids so that I can have 15 minutes of time to myself just to sit and not
want to kill myself or them.

PM2: So that’s the line that defines women in STEM.

GF2: No, it is! It really is because it's a cultural thing, where we had been taught ...yeah.
[We have been taught] to give up ourselves for everybody else. And even if you actively
try not to, you find yourself doing it anyways and it sneaks up on you.

In summary female participants appeared to have more non academic engagements than
their male counterparts. Female students discussed their responsibilities toward their family
including parents and children that impact success in the program of study.

**Discipline Based Differences in Non Academic Responsibilities.**

There was no clear difference between disciplines related to non-academic
responsibilities other than those associated with peer interactions category. For example, students
from physics did not indicate any non-academic behaviors that were significant for their success
in the program.

**Impact of Program of Study on Career Aspirations in STEM**

Career orientations are the trends and behaviors that express an individual’s desire to
pursue or apply oneself to a specific occupation (Gerber et al., 2009). Success for the purpose of
this study is defined as students’ perceived satisfaction with the program of study and continued
desire to pursue career in STEM.
Positive Impact of Program of Study on Career Aspirations.

The PhD programs appeared to help students make up their minds for future careers that ranged from college teaching, to research in industry, to faculty positions at university. Graduate students’ experience appeared to have positive impact in strengthening or positively evolving the career plans of some participants.

*And so yeah, I think I'm, I'm starting and finishing with the same mindset of, that I wanted to teach at a community college. I got that validation. I loved it (CF4).*

*For me I think my plan is mostly the same as when I went into grad school, I was planning on getting a job at a university doing teaching and research. That's what I'm trying to do, I'm now trying to get a job (MM5).*

Excerpt below shows how career plan of one participant evolved as she gained confidence in teaching and research.

*So originally when I started, my goal was to either get my PhD then to teach at like a community college or something like that. But the more I do research, the more I realize that it's important and I can do it. Cause there was always that piece of doubt like, can I actually do it? And the more and more I do it, the more and more I realized like I'm capable of doing it (CF1).*

Negative Impact of Program of Study on Future Career Aspirations.

Graduate school experience made some participants to rethink their future career plans in STEM. Their experience with research, teaching, interactions with faculty, and research advisors helped in reshaping their career orientations in STEM. Some students perceived that the mundane nature of dissertation research changed their future career aspirations, and they do not want to do this type of research in their future career.

*I am tired of working on the fundamental research. I'm tired of writing and grants that this could help us to cure cancer. No, I want to be on the stage where I know that my research in five years will be translated by the next stage of the pipeline and it will go into production. I want to be in the lab to market sector and that's my motivation. I feel like I don't want to be doing this fundamental research anymore (BF7).*

Seeing faculty juggle with research, teaching, and administrative jobs, deters female students from faculty position aspirations. They would rather teach at community colleges,
where there are likely fewer research requirements. Furthermore, students do not want to be rigid teachers, like some of their professors.

_I mean it just seems like a lot of their research and stuff that's required. And I guess, sorry, I'll have to think a little bit harder about what the things are that deter me from wanting to be a faculty, like at a university. I definitely have a list, it just seems like a community college job is a lot more focused on teaching, whereas university job is just, I guess part of it is also a lot of my professors don't care about teaching because they are focused on their research and so I don't want to be like them (MF9)._ 

Students have come to realization that they may not be able to achieve their goal of career as faculty because of competition.

_It's very difficult because it's just the way higher education is now, there's just not as many tenure track jobs available, so whether or not that's going to happen is maybe in the air. I am open to maybe other experiences and maybe trying to do some industry job or something like that if I can find something that my skills transfer over to (MM5)._ 

_Before I started my doctorate, I just wanted to be a professor. But now it seems I can't because just a small portion of PhD students can get tenure and become faculty. So, that makes it really difficult for me to achieve my goal. But so far, this difficulty didn't change my mind. Honestly, I don't know what else I can do besides academic job. I believe this is my only path (PM2)._ 

International female students’ career orientations appeared to be quite complicated because of the dire situation in some of their home countries, and their children knowing only the US as their home country. Future career appeared to be the last thing on their mind. In this instance it is not only gender but race and nationality also appear to be at play when making decision of future career.

_I just want to finish. Then I will decide if I want to go back or stay here or just take care of my kids. I don't know. I just want to finish my PhD journey. Yeah, it was my plan in the past to go back home, but unfortunately everything is so bad back home. For myself, I can go anywhere, I don't care. But my kids grew up here about seven or six years. And thinking about my kids' future, I think they need a good life in future too so I do not want to leave (CSF8)._ 

Another female student described how her future career had taken a worse turn as a result of her PhD in engineering, because of some sensitive research issues and her nationality:
For me, I see lots of limitations and lots of judgments due to my nationality. I cannot go to certain places and I cannot even register for certain courses inside the university. After I finish here, I cannot probably work in my PhD field in United States because it's considered sensitive job field and recruiters just cannot let me go through those due to government restriction on hiring internationals for such classified job. So, for me it became even worse than it was before starting PhD, because now I see it by myself and I feel the adversity of my career every day. So I don’t know. Right now I have almost no plan for my future. I am just going with a flow (EF12).

Gender Based Differences in Career Aspirations.

Future career as a teacher at community college was exclusive for women in this study. The second choice was faculty position that emerged as the most desired career choice for male participants from all fields of study. Only couple of female students who had previous industry experience viewed faculty position as their future career.

Before joining PhD, I was working in industry .... But now after joining here, I feel that I have more courage to, strive for the faculty position (CF11).

I have taught some classes at a college as an adjunct...so yeah, I think I'm, I'm starting and finishing graduate school with the same mindset of ... I wanted to teach at a community college. I got that validation. I loved it (CF4).

Almost every participant provided a reasons for their choice of career that was either influenced by their previous experience, role model or determination to show their worth to the society. For example, one female student from geosciences enrolled into the PhD program because she wanted to prove to her small town community that females can also obtain higher education.

But I grew up in the boonies and you know, you want to prove them wrong. It's like, I'm, worth something. I'm not just from this town. And so that was part of doing PhD, that was part of the fact that I really enjoy learning and I think I always will enjoy learning. But now I don't really know if I want to teach in academia. And I'm thinking more about doing like research or maybe teaching over in a different country, which is very easy, easy to do in geology because it's such a, it's like a world field be like, Hey, like my research area is down in New Zealand (GF2).

So originally when I started (PhD), my goal was to get my PhD then teach at like a community college or something like that. ...And the more and more research I do, the more and more I realized like I'm capable of doing it. And I actually kind of like it. So I don’t know, probably looking at like the faculty position somewhere, hopefully.-CF1
I do want to be outside of academia but still do research. So, I will look for any organizational or industrial research position (BF7).

My interest is in research activities and writing novel research articles (EF10).

Majority of male participants aspired for faculty positions that can be seen from a few excerpts below.

My motivation for getting a PhD is to teach. I like the research here. As I've moved along, I'm starting to shift away from just a teaching position to more of maybe trying to get a traditional tenure track position (BM1).

I want to become that faculty someday (PM4).

A participant who was nearing the completion of his PhD stated his continued intention to obtain a faculty position:

I went to grad school; I was planning on getting a job in teaching and research at university. That's what I'm trying to do now as well. I'm now trying to get a job as faculty (MM5).

**Discipline Based Difference in Career Aspirations.**

The main three career choices of participants included teaching at college, faculty at university, or industrial research. In contrast to gender based differences it was hard to detect any discipline based difference in students’ career orientation. Female students aspiring for faculty positions at community college were either from biology, geosciences, chemistry or math department. Female students form computer science, engineering and physics were not sure about their future career plans, and they were all international students. Male students from all departments were aiming for faculty positions in their respective field of study.

In summary, students continued to aspire for academic careers in their respective fields. All male students wanted to be faculty at a university. Majority of females were interested in either a teaching jobs at a community college or industrial research. However, there were two women with previous industrial experience who wanted to get a position as faculty. In contrast two international female students did not know what to think of their future careers.
CHAPTER V

DISCUSSION AND IMPLICATIONS

This study was conducted to understand the experiences and career orientations of STEM doctorate students. Five focus group discussions were conducted to meet two primary research objectives. The first goal of the study was to understand doctoral students’ perceptions of the learning environment in the context of socialization in a graduate school community. The second goal of the study was to determine gender based and or discipline based differences that students might associate with success, barriers, or future career intentions. A secondary objective of this study was to evaluate the graduation requirements for each discipline of study so that meaningful comparison among doctoral students of different departments could be made. Additionally, to understand the real time gender diversity in each department, gender based enrollment and graduation in each department was also assessed and compared.

Highlights of themes emerging from this study were discussed in the context of research questions and relevant literature as follows.

Doctoral Students' Perception of Educational Environment (Question 1)

Our research suggests that in general students perceive the environment of their program of study positively. Throughout their program of study students appear to have positive interactions with faculty, administration, and peers within the graduate community. Through these interactions students gain required skills and norms to become effective members of a scholarly community. The problems students experienced were not directly related to the program of study but rather with constrained details of the programs. Some of these issues may be inevitable for departments to change, for example inabilities to offer a wide range of courses related to students’ specific topics of interest. Other problems, however such as the use of
comprehensive exams, attitudes of senior male faculty, task focused advising styles, the lack of teaching training, and providing an environment of inclusion, could all be addressed within departments.

**Courses and Comprehensive Exams**

In general students had limited benefits from graduate level courses as they related to their research, future careers, and success in the program. With the exception of a few research related courses, other courses were portrayed as ‘check in the box’ to complete required credit hours for graduation. Specifically, the benefit of comprehensive exams does not appear to be worth the time and added stress, and was considered as a tool to weed out students from their program of study. In contrast, the alternatives to these exams, such as writing research proposal or publishing peer reviewed papers, appear to provide beneficial skills to doctoral students. Limited literature available on the utilization of comprehensive exams in doctoral programs also suggests the reconsideration of this requirement by finding alternatives (DiPietro et al., 2010). Moreover, comprehensive exams tend to take considerable study time, effort, and causes stress on doctoral students. Therefore a frequent review and revisions of curriculum design should be considered to provide appropriate benefits of graduate level courses to students.

**Faculty Interactions**

Students interact with faculty while taking courses, conducting research, and attending seminars. Our research indicates that overall, students view interactions with faculty positively. However, some students appear to experience bias in faculty attitude and communication, including rigid teaching styles and strict grading policies in exams. Since faculty play a role of a gate keeper to grant membership in the scholarly community of students’ field of study, these issues appear to play a negative role in students’ success in the program and future career
orientations. Furthermore, issues of task-focused and hands-off advising styles of some faculty appear to conflict with students’ preference of student-focused and hands-on-directions from their advisors. This study further reveals that dissertation research and writing activities tend to be unpredictable in nature which demands a higher level of and more timely direction from advisors and research committee members. This study indicates that an ideal advisor is likely to be hands-on, and not only guides the dissertation project but also takes interest in students’ overall wellbeing and future career preparation. Consistent with our study other researchers argue that students, being novice researchers, do require a great deal of direction to successfully complete their program of study (Ali & Kohun, 2006). Others, however, perceive doctoral students to be independent researchers in training (Mason, 2012). Perhaps a balance between the level of mentorship and providing students with academic space to form their own research identity will be beneficial.

Lack of Teaching Training

In addition to taking courses and conducting dissertation research, a majority of doctoral students in STEM work as teaching assistants. They either teach undergraduate classes or take lab sections for faculty in their departments. Our research reveals that in general students view teaching assignments quite positively because they provide skills for future careers in teaching. However, students are not provided with adequate training to prepare them for teaching roles. The lack of training in teaching likely results from the research focused environment of STEM departments. Doctoral training in STEM fields has traditionally consisted of students working closely with a faculty advisor to learn the research methods and content knowledge of their field of study. Therefore, the main objective of most PhD programs appears to be to produce researchers and scholars (Mills, 2009; Walker et al., 2009; Anderson et al., 2011). However, our
study suggests that a majority of doctoral students intend for jobs in academia that involve both teaching and research. Similarly, Connolly et al. (2016) contend that almost half (46%) of STEM PhDs are going to be involved in some kind of college teaching within five years of PhD completion. Therefore, gaining skills in teaching should be given as high a priority as research. These doctoral students are the ones who will teach, train, and mentor the next generation of STEM undergraduates. The socialization of graduate students to the full range of faculty roles including training of teaching is likely crucial for their future careers. Furthermore, our study indicates that experience gained working as a TA during doctoral programs not only offers valuable teaching opportunities to students, but may also assist in research and time management skills. These skills are likely to be beneficial for students in managing priorities in research and any future career, whether it is in STEM or not.

**Gender Based Differences in Students’ Perception (Question 2 Part 1)**

This study reveals that men and women perceive the impact of various factors and social interactions on the success in the program, and their future career, quite differently. Main gender based differences relate to interactions with faculty teaching graduate courses, peer interactions, roles as teaching assistants, non academic engagements, and future career plans.

**Graduate Level Courses and Faculty Interactions**

Our research suggests that generally female students have more negative experiences related to graduate courses as compared to male students. This difference in satisfaction appears to emerge from female students’ problematic interactions with some senior white male faculty, relating to gender bias, rigidity in teaching style, and reflection of gender stereotypes. Occurrence of gender bias has been reported by other researchers in non academic settings however literature on doctoral students’ experience with faculty teaching graduate courses in
STEM is scarce. In a study conducted to understand the perception of faculty of graduate students, Ellemers et al. (2004) indicates that faculty members may perceive female doctoral students to be less committed to their course and research work as compared to male students. Our study however was focused on the perception of graduate students only. In a non-academic setting, Castilla and Benard (2010), shows that managerial positions tend to favor a male employee over an equally qualified female employee when a given task involves consideration of merit. Consistent with Welde and Laursen (2011) our study appears to indicate the existence of an “Old Boy’s Club” culture that creates an environment of exclusion and has implicit barriers for women in STEM. These barriers may shape women’s career pathways away from STEM. Therefore, an educational environment free of gender bias and stereotypes is crucial to promote the success of women and gender diversity in doctoral programs and careers in STEM.

Lack of TA Training

This study further indicates that in general female students tend to aspire for careers in teaching however doctoral programs appear to fail to provide adequate training to TAs. Perhaps to compensate for this deficiency in training and to prepare themselves for future careers in teaching, female students appear to go well beyond the required efforts of their teaching assignments. This type of passion in teaching did not emerge from male students of this study. Moreover, having good teaching skills and knowledge about teaching pedagogies is crucial to become efficient post-secondary faculty. Teaching skills are likely to increase students’ future employability in academia (Mantai, 2019). However, most doctoral programs do not appear to offer that expertise to students. Therefore, programs on the development of teaching skills of PhD students, and research on the efficacy of such programs is needed. Moreover, the lack of research on the gender based experience of TAs in the context of socialization with other TAs
Peer Interactions

Our research indicates that women are likely to benefit more from peer interactions as compared to male students. Ost (2010) shows that females tend to gain more benefits from peer interactions in contrast to male students. Additionally, our study indicates that departments with overall lower peer interactions appear to have lower enrollment and graduation of female students. This trend may indicate the relationship between peer interaction and graduation rate or enrollment and peer interactions. Meaning departments with lower enrollment of women may tend to have lower peer interactions, or departments with lower peer interaction may tend to graduate fewer women. In contrast, Devos et al. (2017), shows that peer support has little impact on PhD students’ final persistence or rate of dropout. Bostwick and Weinberg (2018) on the other hand show that a 10% increase in women’s enrollment in a cohort increases their graduation rate by one percentage point. Additionally, our study indicates that international female students tend to depend more on peer interactions as compared to their male counterparts. Their dependency on peers does not appear to be limited to course work and research projects, but they also need cultural support to adapt to their new social and cultural norms.

Non Academic Engagements

This study shows that female participants are likely to have more family related non-academic engagements than their male peers. Non academic activities, such as taking care of young children, and part time employment taken for financial stability, appear to impact students’ success in the program and future career orientations. Our study shows that women often place familial needs before their study and careers. Castelló et al. (2017) indicate that
family and school balance is the main reason young females drop out from doctoral programs or do not pursue careers in STEM. Therefore, setting up boundaries to achieve a satisfactory balance between academic and family life may act as an issue that affects doctoral students’ decisions to persist (Rockinson-Szapkiw, 2019). It appears to be crucial for departments in STEM to provide an environment of gender inclusion. Incorporation of equity is equally important for women to thrive in doctoral programs. To gain meaningful gender diversity, institutions of higher education should design strategies to incorporate and promote work-life balance in doctoral study programs.

**Discipline Based Differences (Question 2 Part 2)**

Distinction among different fields of study appear to emerge in course taking experience related to the use of comprehensive exams, faculty interactions, and peer interactions.

**Comprehensive Exams**

In this study physics and math departments require students to pass comprehensive exams that act as a ‘rite of passage’ to prove graduate students’ worth in those fields. Students from these departments appear to have more negative perception about course work as compared to other disciplines. The comprehensive exams appear to fail to provide any meaningful learning, and cause undue burden and stress on doctoral students, negatively impacting their success in the program and future career outlook. Literature assessing the benefit of comprehensive exams on doctoral students’ success and future career orientations is scarce. Limited literature in this area however, suggests the use of alternatives in lieu of comprehensive exams (DiPietro et al., 2010; Ponder et al., 2004). Therefore, faculty and administration should review course requirements frequently and make appropriate changes to provide optimum benefits to students.
**Interactions With Faculty**

Our research shows that female students from chemistry, geosciences and physics appear to experience gender bias and or gender stereotypes in their interactions with senior male faculty. Additionally, engineering and physics appear to receive task focus guidance from advisors rather than much more needed person focused advice. Murphy (2007), shows that doctoral students in engineering programs largely receive task-focused as opposed to person-focused guidance in research projects. However, according to Zhao et al. (2007), task focused activities such as providing research training and monitoring students’ progress only accounts for 46% of the variability in students’ satisfaction with their supervisors. The rest of the variability (54%) is accounted for by person-focused interactions with supervisors such as help with students’ career development and overall wellbeing. Therefore, strategies to incorporate person based guidance should be promoted by all departments.

**Peer Interactions**

In our study, biology and chemistry tend to have higher peer interactions while physics, geosciences, and engineering show lower peer interactions. Gardner (2010), shows the variation of peer interactions in different departments of STEM. However, they relate the graduation rate to peer interactions, indicating low completing disciplines such as math and engineering lack support from peers. Conversely, high completing departments or cohorts often have more positive peer experience (Gardner, 2010; Bostwick & Weinberg, 2018). This trend appears to be partly true in our study, among all disciplines of this study physics shows overall the lowest yearly graduation level (9%) and low peer interactions. In contrast, chemistry shows higher peer interactions and the highest yearly graduation level (19%) among all seven disciplines. In contrast, the percent graduated students in biology are on the lower side (10%), despite biology
showing a higher level of peer interactions. Furthermore, students from physics appear to report more negatives about their course work as compared to biology, so peers’ impact is unlikely to be the only indicator of success. Therefore, even if the graduation rate was low in biology, students had positive experiences related to courses, and an overall positive perception of the PhD program, and their future career orientations.

Future Research and Interventional Recommendations

Our study distinguishes gender-based differences in most of the constructs of the model of socialization used in this study. Women’s experiences with TA assignments, peer interactions, gender bias, non-academic engagements, and future careers appear to be different than men. However, graduate students’ perception at the intersection of gender and race could not be evaluated because of the lack of racial diversity of participants. Furthermore, this study was limited to participants of seven departments of one university only. Therefore, a study that extends to more institutions of higher education and STEM fields to overcome this limitation will be worthwhile to consider.

Most participants of this study aspired for careers in academia. However, our study indicates a lack of teacher training to prepare students to handle the full range of roles and responsibilities of future academic careers. Gaining teaching skills appear to be crucial for many doctoral students who will teach, train, and mentor the next generation of STEM undergraduates. Therefore, training in teaching would be beneficial for students’ future careers. Perhaps a study that designs, implements, and evaluates a teaching development program in relation to teaching skills of doctoral students will be beneficial.

A study on curriculum design optimization will potentially add value, because students questioned the benefit of comprehensive exams and perceived most of their courses to be a
‘check in the box’ to fulfill credit requirements. Furthermore there is scarcity of literature in this area, so a study to extend the finding of our research is likely to improve doctoral programs in STEM.

In summary, the challenge of integrating doctoral degree programs and non academic engagements related to familial responsibilities was a central concern for a majority of female doctoral students, in particular the international students and women of color. The culture of exclusion, outright sexism, lack of women role models, task focused advising styles, and lack of peer interactions of some STEM disciplines appeared to pose implicit barriers for women. A study focusing on these central issues for female students should be considered to design appropriate strategies to promote gender diversity in STEM.
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APPENDICES

A. HSIRB Study Approval Letter

WESTERN MICHIGAN UNIVERSITY

Date: December 12, 2019

To: Brandy Pleasants, Principal Investigator
   Jasvir Pannu, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: IRB Project Number 19-12-02

This letter will serve as confirmation that your research project titled “Female Graduate Student's Experiences and Career Orientations in STEM: A Comparative Study” has been approved under the expedited category of review by the Western Michigan University Institutional Review Board (IRB). The conditions and duration of this approval are specified in the policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes to this project (e.g., add an investigator, increase number of subjects beyond the number stated in your application, etc.). Failure to obtain approval for changes will result in a protocol deviation.

In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the IRB for consultation.

The Board wishes you success in the pursuit of your research goals.

A status report is required on or prior to (no more than 30 days) December 11, 2020 and each year thereafter until closing of the study.

When this study closes, submit the required Final Report found at https://wmich.edu/research/forms.

Note: All research data must be kept in a secure location on the WMU campus for at least three (3) years after the study closes.
B. Consent Form

Western Michigan University
Mallinson Institute for Science Education

Principal Investigator: Dr. Brandy Pleasants
Student Investigator: Jasvir Pannu
Title of Study: Female Graduate Students’ Experiences and Career Orientations in STEM: A Comparative Study

STUDY SUMMARY: This consent form is part of an informed consent process for a research study and it will provide information that will help you decide whether you want to take part in this study. Participation in this study is completely voluntary. The purpose of the research is to: explore the experiences of female graduate students as compared to male students in various Science and engineering disciplines. This project will serve as Jessie Pannu’s research project for the Dissertation in the Doctoral program of Science Education through the Mallinson Institute for Science Education. If you take part in the research, you will be asked to answer few questions in a focus group setting to express your opinion about the program of study and interactions with administration, faculty and peers that may be impacting your success in the program. Your time in the study will take 60-90 minutes to participate in the focus group discussion. Possible risk to you for taking part in the study may be the chance for others to recognize your responses in the published or presented results. There is no direct benefit of taking part in the study, but you may benefit by sharing your experience as a graduate student and providing your ideas and suggestions for potential improvements to your program of study. Your alternative to taking part in the research study is not to take part in it.

You have been invited to participate in a research project titled "Female Graduate Students’ Experiences and Career Orientations in STEM: A Comparative Study." This project will serve as Jessie Pannu’s research project for the Dissertation in the Doctoral program of Science Education at Mallinson Institute for Science Education. This consent document will explain the purpose of this research project and will go over all of the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and ask any questions if you need more clarification.

What are we trying to find out in this study?
In this study we are trying to find out the experiences of female graduate students as compared to male students, and to evaluate the impact of these experiences on their future career orientations in STEM fields. We are conducting this study to understand why the number of women obtaining PhD in some of the STEM fields is lower as compared to male graduate students. By understanding this problem in depth, we hope to contribute to the development of ways to fix this issue.

Who can participate in this study?
You can participate in this study, if you are a PhD student enrolled in the program of study in biology, chemistry, physics, earth science, computer science or engineering.

Where will this study take place?
The focus group discussions for this study will take place in a secure room at WMU campus.
What is the time commitment for participating in this study?
Your time commitment with the researcher will be one focus group discussion sessions of 60 to 90 minutes. There may be a second one to one meeting, or email request, to clarify any questions that the researcher may have about your response during the discussion session.

What will you be asked to do if you choose to participate in this study?
If you agree to participate in the study you will be asked to participate in a 60 to 90 minute study focus group session with the researcher. During this session you will be asked to share your experience about the course work, skills learned, research engagement, faculty mentoring, group and peer interaction, and perceived levels of support. Interview will be videotaped and later transcribed.

What information is being measured during the study?
Focus of group discussion will be to record your experience regarding courses and competencies, your responsibilities as teaching assistants, your perception about support and interactions with administration, faculty and your peers. Response to the questions will be video recorded and transcribed later.

What are the risks of participating in this study and how will these risks be minimized?
To mitigate the issue of identification of your response to questions during focus groups, you will be grouped with graduate students from other departments. However, given the nature of data collection, being a group discussion with other graduate students, it may be possible for others to recognize your responses in the published or presented results. To further maintain the confidentiality, you are required not to disclose the names and responses of your fellow participants to anyone outside the settings of your focus group. There is no other known risk of participating into this type of study. Information will be coded and will be kept confidential, transcribed data shall be password protected. Your name will be changed to a pseudonym once the video recording is transcribed. Data will be kept confidential by assigning pseudonyms to each participant immediately after the discussion takes place. This pseudonym will be used in all transcripts, documentation, and reporting and presentations.

What are the benefits of participating in this study?
There is no direct benefit of participating in this study. However, this study should provide you with a valuable opportunity to think and talk about your experiences and future aspirations in STEM. Findings from this study may help to add to the knowledge of the reasons and why female graduate students are underrepresented in some fields of STEM. This may further help in designing the interventions to alleviate the problem of under representation of women in STEM.

Are there any costs associated with participating in this study?
There is no known cost associated with participating in this study except the time commitment of 60 to 90 minutes.
Is there any compensation for participating in this study?
Participant who completes the study will be provided with a lunch or dinner and shall have an opportunity to win a gift certificate in the amount of $20, $50 or $100.

Who will have access to the information collected during this study?
The primary investigator and student investigator are the only ones who will have access to the data collected during this study. It is the intent to publish any relevant findings in student researcher’s dissertation and educational journals. Any results reported will use pseudonyms, reducing the likelihood of participants being identified.

What will happen to my information or biospecimens collected for this research after the study is over?
Should another research study be conducted you will be contacted. The use of identifiable data collected as part of this study will not be used or distributed without your consent. If the researcher(s) are unable to contact you for consent your data will not be used for another study.

What if you want to stop participating in this study?
You can choose to stop participating in the study at any time for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study. The investigator can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the student investigator, Jessie Pannu at 734-277-5767, or via email at Jasvir.k.pannu@wmich.edu. You may also contact primary investigator, Dr. Brandy Pleasants at 269-387-3527 or via email at Brandy.pleasants@wmich.edu. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

I have read this informed consent document. The risks and benefits have been explained to me. I agree to take part in this study.

Please Print Your Name

Participant’s signature ___________________________ Date ___________________________
C. Focus Group Protocol

Western Michigan University
Mallinson Institute for Science Education

This focus group protocol is created for the following two research questions:

1. What are doctoral students' perceptions of their educational environment in science and engineering? What factors do they associate with their perception of success, problems, and future career intentions?
2. What type of gender-based and/or discipline-based differences exist that may be associated with students' perception of success, problems, and future career intentions?

Researcher Facilitator: Please think about your experience as a graduate student since you started in this program. This discussion is divided into different sections.

First, we will talk about the curriculum design such as how many and what types of core and optional courses you are required to take, including the availability of these courses and applicability to your program.

Next we will discuss the contribution of department graduate school such as scheduling various presentations and helping to attend conferences.

Finally, we will move on to the role of supervisor, faculty your peers. We will conclude the discussion with any nonacademic factor that may be crucial in the outcome of your studies such as employment and family etc. Finally will talk about your future career plans and how your experience in school may have impacted you aspirations for STEM fields.

Note: for the purpose of this study ‘success in the program’ means your level of satisfaction with your progress in the program that may result from timely completion of various steps and or production of scholarly articles or presentation at conferences.

Questions:

Please introduce yourself by telling your name, program of study and year you are in.

1. To what extent does the curriculum design and departmental support impact your success in the program and future career orientations? (Discuss courses, including availability, applicability to research and future careers)
2. To what extent does your role as a teaching assistant does enhances or impedes the efficiency to complete your degree and impact future career aspirations?
3. To what extent does your relationship with your supervisor and other faculty impact your satisfaction and success in the program?
4. To what extent do your interactions with your peers impact your success and satisfaction in the program?
5. To what extent do your non-academic commitments impact your studies and future career intentions?
6. To what extent does your experience in the graduate school impacts your future career orientations?
7. Is there anything else that you may want to discuss that we did not included in our discussion today?

*Thank you for your time and commitment. I will contact you if I have any further questions.*

*Please feel free to contact me if you have any questions about this study.*