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2020

Women's STEM Success in Biomedical Science Graduate Programs: An Exploratory Study

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THE FLORIDA STATE UNIVERSITY
COLLEGE OF SOCIAL SCIENCES &
PUBLIC POLICY

WOMEN'S STEM SUCCESS IN
BIOMEDICAL SCIENCE
GRADUATE PROGRAMS: AN
EXPLORATORY STUDY

By

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A Thesis submitted to the
Department of Sociology
in partial fulfillment of the requirements for graduation with
Honors in the Major

Degree Awarded:
Spring, 2021

The members of the Defense Committee approve the thesis of Jessica Short defended on November 16, 2020

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INTRODUCTION

While the proportion of women graduates with advanced degrees in STEM has increased in recent years (National Center for Science and Engineering Statistics [NCSES], 2018), disparities across disciplines are profound. In particular, female representation in Biological and Biomedical Sciences programs are much higher than in the other STEM disciplines. The National Center for Science and Engineering Statistics reported that in 2018 women received 54 percent of the doctoral degrees in Biological and Biomedical Sciences while men received 46 percent. This trend of women receiving more Biological and Biomedical Sciences degrees has been occurring for over a decade. However, in other STEM fields, such as Physics and Astronomy, women make up the minority. In 2018, women received 22 percent of the doctoral degrees in Physics and Astronomy while men received 77 percent. Women are also the minority in Chemistry. In 2018, women received 38 percent of the doctoral degrees while men received 62 percent. These discrepancies show that gender representation is not equal across STEM fields (NCSES, 2018).

The reasons behind the difference in gender representation in Biological and Biomedical Sciences compared to other fields is important to understand in order to gain insights into the inclusion tactics that were effective, potentially leading to initiatives that could improve gender equality in other STEM fields. Ensuring that women graduate students feel welcomed equally with men in all STEM fields is critical because allowing these fields to persist as male-dominated may contribute to women choosing not to pursue or continue in these fields (Herzig, 2018). Therefore, addressing gender-related barriers in STEM may lead to more women following or continuing on a STEM path (Robst, Keil & Russo, 1998). Moreover, this increase in women would give younger women a role model, which is shown to be beneficial (De Welde &

Laursen, 2011). On a societal level, an increase of women in male-dominated STEM fields can further economic equality, since Ph.D.-recipients in these fields often make higher-than-average salaries, remedying somewhat the overall gender wage gap (Harmon, Hopkins, Persky & Roy, 2018; Hegewisch & Tesfaselassie, 2019).

In order to understand why the gender distribution is vastly different, I plan to use Biomedical and Biological Sciences (which NCIES groups together) and Chemistry as the two comparison groups. The literature identifies interactions with professors and peers, mentorship, exclusion, and differential access to research opportunities as general barriers STEM women graduate students face. By examining whether these barriers are lower in Biomedical and Biological Sciences than in Chemistry or whether perhaps Biological and Biomedical Sciences have programs in place to mitigate barriers, we may better understand why Biological and Biomedical Sciences has a better retention rate for women. Furthermore, when comparing this to the field of Chemistry we will be able to identify specific barriers that may hinder the field and may be able to develop mitigating factors to address these barriers and help the field reach a more equitable gender distribution. Results may possibly be applicable to fields other than Chemistry that also have poor female representation.

Research Question

To understand how the situation of women graduate students in STEM might be improved, I compare two STEM programs at one university to answer the following questions: What factors lead to better experiences for women graduate students in Biological and Biomedical Sciences? Do the barriers to women in Biological and Biomedical Science differ from those of women in a comparison STEM field, in this case, Chemistry? Are the nature of

barriers similar but less pronounced? Do women in Biological and Biomedical Science have more resources to help them overcome barriers?

LITERATURE REVIEW

This literature review covers the barriers women graduate students face in STEM fields. It also discusses two mitigating factors, social support and women professors, that have been reported to help women succeed in male-dominated graduate programs.

Barriers to Women in STEM

In this section, I discuss a variety of barriers women in STEM graduate programs face, focusing on their relationships with professors and peers and how these affect classroom experiences and social exclusion. I also discuss how unequal opportunities in research affect women in male-dominated STEM fields and the barriers presented by family life.

Professors. Professors make up one of the largest sources of barriers for women graduate students in male-dominated fields (Barthelemy, McCormick & Henderson, 2016; De Welde & Laursen, 2011; Remich, Jones, Wood, Campbell & McGee, 2016). One area that can harm these women is their professor's perceptions. Studies have shown that both men and women science faculty are more likely to rank men as more competent compared to women and offer more mentorship to men even if gender is the only difference between the two (Moss-Racusin, Dovidio, Brescoll, Graham & Handelsman, 2012).

The perception of women as less competent leads professors to doubt the ability of women students who want to pursue careers in male-dominated fields (Barthelemy, McCormick & Henderson, 2016). In some cases, professors also make it clear who they believe belongs in a specific field. Professors convey this by using strictly masculine pronouns when referring to

individuals in the field or giving all-male examples, enforcing the idea that women do not belong in certain fields (Remich, Jones, Wood, Campbell & McGee, 2016).

Another barrier women face from professors in STEM graduate programs is sexual objectification and sexual harassment. Women in the sciences reported experiences of male professors offering higher grades in return for inappropriate sexual favors (De Welde & Laursen, 2011). This problem is not limited to STEM fields and takes place in Liberal Arts graduate programs as well. Graduate-student women in Philosophy, which is male dominated, for example, have reported experiences of inappropriate emails from professors and professors overlooking sexual harassment claims from students (Wilson, 2014).

The gender composition of the faculty can also matter for women's success. In male-dominated fields, professors are often men, and this can have an impact on the faculty and student relationship. According to a study, women graduate students tend to have more positive experiences with women major professors, women with women major professors are more likely to say the basis for choosing their major professor revolved around a supportiveness/nurturance quality, and these women were more likely to say they chose their professor based on her gender (Schroeder & Mynatt, 1993). Furthermore, women with women professors ranked their professors more highly than did women with male professors. These rankings looked at whether professors were more likely to be concerned about students, shared better and more interactions with students, viewed students as more competent, and served as better mentors. (Schroeder & Mynatt, 1993).

Peer Interactions. Peers also create barriers, specifically during in-class interactions. Women report that men sometimes question them about why they are in the field (Remich, Jones, Wood, Campbell & McGee, 2016). Men also tend to doubt their intelligence, ignore their

suggestions, and refuse to accept their contributions as valid until after men offer the same ideas (Barthelemy, McCormick & Henderson, 2016). In group projects, women report that peers tend to assign them easier roles, such as the “group secretary” (Barthelemy, McCormick & Henderson, 2016). One woman even admitted to consciously taking an easier role in group activities because she viewed herself as slower than her male peers (Danielsson, 2012). Women also deal with peers making inappropriate or sexist comments and jokes in the classroom (Barthelemy, McCormick & Henderson, 2016). Male peers also attempted to romantically pursue some women. The common experience in graduate school of male peers romantically pursuing women in their field is not inherently discouraging to women's ambition, but some women said that it led them to question whether male peers were genuinely interested in working with them due to their intelligence and skills or because of romantic or sexual interest, undermining their professional self-assurance (Barthelemy, McCormick & Henderson, 2016). Some developed tactics such as wearing a wedding band or acting less feminine to avoid such interest (De Welde & Laursen, 2011).

Social Exclusion. Male professors and male students often connect more easily due to a shared gender, common interests, and experiences, and these connections can lead to social interactions, such as getting coffee or otherwise spending time together outside of the classroom (De Welde & Laursen, 2011). In situations where women do gain an invitation to male-dominated events, such as going out for drinks or sports, women feel they are required to present themselves as less feminine and act like a man in these situations. These women felt that being with men required to adapt to a harsher social environment and that they must be prepared to participate in debates or competitions, and one even reported being required to develop a “tough

skin” in these situations (De Welde & Laursen, 2011). These experiences are not limited to out-of-classroom events and also occur in academic spaces.

Research and Publication. Being in a male-dominated field hinders women from conducting research and being published (Feldon, Peugh, Maher, Roksa & Grehl, 2017; Miller & Roksa, 2020). Women reported that their time in laboratories is often focused on administrative duties instead of research, while most men did not report being required to complete administrative tasks (Miller & Roksa, 2020). Women of all races described these experiences, but women of color encountered the worst experiences due to the fact that their advisors did not have much concern for how the administrative work interfered with their research, and in some cases, the work extended outside of the school period (Miller & Roksa, 2020).

Another aspect of the research experience, collaboration, is also negatively affected for women in male-dominated fields. Advisors and Primary Investigators sometimes prevented women from collaborating with investigators in other labs, and sometimes even in their own labs (Miller & Roksa 2020). White men were allowed to collaborate with other students and investigators in other labs and were often selected over women for in-lab projects (Miller & Roksa, 2020).

The lack of opportunity to participate in research harms these women. Women who took longer to complete their Ph.D. compared to other students reported one of the reasons was lack of experience in research and knowledge of the research process (Maher, Ford & Thompson, 2004). A lack of research puts women at a disadvantage for publication, which is already a barrier for women. One study reported that even when men and women spend the same time on research, men are 15 percent more likely to publish academic articles than women (Feldon, Peugh, Maher, Roksa & Grehl, 2017). Considering the importance of publication for academic

careers, the lack of research experience and discrepancy in publication rates hinder women in graduate school.

Family Responsibilities and Motherhood. Barriers presented by family obligations are not limited to women in STEM, as women in all fields report births, marriage, childcare, and caring for other family members as barriers to completing their degrees in a timely manner or completing the program at all (Maher, Ford & Thompson, 2004; Stage & Maple, 1996). Women in STEM describe these problems, and many women describe how obligations to family hinder their progress (Maher, Ford & Thompson, 2004; Stage & Maple, 1996). Some women even detailed that they planned out their careers and education in order to schedule when they would have children (De Welde & Laursen, 2011). For example, one woman in Mathematics considered abandoning her Ph.D. program if it ever began to have negative effects on her marriage or family (Stage & Maple, 1996). While men also face the barrier of family responsibilities, it appears to be less of a barrier for them.

The lack of role models—professors who are also mothers and wives—means that women in these fields find difficulty in seeing how they can balance academia and family life (De Welde & Laursen, 2011). The importance of role models also shows how difficult it is to combine a scientific career with motherhood, and this is clear when women describe their ideal role model. Almost all described a woman who was balancing academia and family life (De Welde & Laursen, 2011). Many women explained how they hoped to connect with a woman faculty member with children in order to discuss this struggle (Remich, Jones, Wood, Campbell & McGee, 2016). Women also said they thought women balancing academia and family life were rare and speculated that women faculty may have waited longer to have children or did not have children at all due to the difficult balance (De Welde & Laursen, 2011). For many women

students, seeing how difficult it is to balance motherhood and academia may be discouraging to them and may even make them doubt their chosen field.

Mitigating Factors

While the foregoing section presents a daunting set of barriers, research has shown some factors that mitigate the barriers women face in male-dominated fields. In particular, I address the presence of women professors and social support from peers.

Same-Gendered Professors. Several studies show that same-gender professors have a positive impact on women in STEM (Carrell, Page & West, 2010; Robst, Keil & Russo, 1998). Women enrolled in math and science classes taught by women professors earned higher grades than women enrolled in courses taught by male professors, an effect even more compelling for women earning top scores on math standardized tests (Carrell, Page & West, 2010). These results show the impact women faculty can have academically, specifically for students who may pursue graduate level STEM degrees. Another study, this one focusing on retention rates, showed that women's retention rates in STEM fields were higher when they took math and science classes taught by women professors, an effect that was larger in classes with lower proportions of women (Robst, Keil, Russo, 1998). Considering that most STEM courses are taught by male professors, women students' grades and retention rates are harmed by the lack of female instructors. This effect is important when considering the gender breakdown of STEM instructors, who tend to be men (De Welde & Laursen, 2011).

Another benefit of female professors for women students is the ability of these professors to serve as role models and inspirations to these students, as noted above. Women describe seeing women faculty who were able to balance academia and family life and thinking they may also be able to achieve those goals (De Welde & Laursen, 2011). Same-gendered advisors were

also able to motivate women students to pursue graduate education while counseling them about the challenges they may face (De Welde & Laursen, 2011).

Social Support. Women in male-dominated fields often find it difficult to connect with other women, but when given the chance to do so, they see several positive results (Bhatia & Amati, 2010; Maher, Ford & Thompson, 2004; Stage & Maple, 1996). One woman described how connecting with women was important, so she formed an informal social support system for new women in her program (Stage & Maple, 1996). Another stated that one of the most beneficial things during her time in graduate studies was a same-gendered peer who provided her with support and encouragement to continue to persevere through the program (Maher, Ford & Thompson, 2004). Organizing formal peer mentoring program also benefits women graduate students in these programs. Groups focused on peer mentoring in STEM served as places for women to connect and develop social support (Bhatia & Amati, 2010). Respondents said that seeing their women peers struggle and overcome similar issues helped them feel empowered in their own lives (Bhatia & Amati, 2010).

What We Know About Biological and Biomedical Sciences

The Biological and Biomedical Sciences field stands out from other STEM disciplines in regard to gender on four dimensions. It has more Ph.D.-recipients, higher levels of gender representation in faculty, higher rates of women faculty serving as full professors, and a smaller pay gap compared to other STEM disciplines. More women enroll in Biological and Biomedical Science courses than in any other STEM field (NCSES, 2018). As noted above, women earned slightly over half of the doctoral degrees in Biological and Biomedical Sciences in 2018 (NCSES, 2018) and between one-half and two-thirds of the bachelor's degrees (Chronicle of Higher Education, 2019). In the top-100 departments of science and engineering, women make

up 24.4 percent of all faculty in Biological Science fields, comprising 35 percent of assistant professors, 30 percent of associate professors, and 17.4 percent of full professors (Nelson & Brammer, 2017). By way of comparison, in Chemistry, women only make up 13.7 percent of faculty, with 21.2 percent as assistant professors, 19.6 percent as associate professors, and 9.7 percent as full professors (Nelson & Brammer, 2017).

We also know that women in Biological and Biomedical Science fields with academic jobs make around \$16,000 less than men in similar positions (Umbach, 2007). But women in Chemistry make approximately \$34,000 less (Umbach, 2007). Using these proportions of gender representation of faculty and faculty salary we can see the women in Biological and Biomedical Sciences fare better in salaries compared to women in Chemistry (Nelson & Brammer, 2007; Umbach, 2007).

METHODS

I conducted in-depth interviews with ten women Ph.D. students at a major research university. Five were enrolled in Biomedical Sciences (a degree program in the College of Medicine) and five were enrolled in Chemistry (a degree program in the College of Arts and Sciences). At this University, Biomedical Sciences compared to Chemistry has much stronger representation of women graduate students and faculty, and better representation of women in senior ranks. In the Biomedical Sciences Ph.D. program, 27 women and 17 men are currently enrolled. Out of the 44 faculty members in this department, 15 are women. Six of these women are full professors, two are associate professors, one is an assistant professor, five are exclusively research faculty, and one was unlisted in regard to position (FSU Biomedical Sciences Faculty, n.d.). The enrollment for the Chemistry and Biochemistry Department Ph.D. program is made up of 100 male and 55 female PhD students (FSU Institutional Research, n.d.). Out of the 34

research faculty members, only four are women. Two women are full professors, one is an associate professor, and one is an assistant professor (FSU Chemistry & Biochemistry Faculty, n.d.)

Regarding the sample, all women, except one, were U.S.-born and all had been enrolled in the Ph.D. program for at least one full year. For my sample of Biological and Biomedical Sciences women, I began by soliciting women via an email invitation to a Biology organization for graduate students. The Cell and Molecular Biology Graduate Student Association is a mixed-sex group with the mission of building connections among graduate students in Biology. This email yielded no eligible volunteers, so I reached out to the President of the Graduate Women in STEM Organization, who referred me to a member who participated in the interview. I asked her for referrals, and through this snowball sampling method, I successfully reached out to four other women who agreed to be interviewed.

I chose Chemistry as a comparison group because the female graduation rate nationwide is one of the lowest of the STEM disciplines (NCSES, 2018). To find women in Chemistry, I first contacted the President of the Graduate Women in STEM Organization who suggested I send an email to the women in the organization. This email also produced no participants, but I was able to find information on one woman in the Chemistry Ph.D. program via the FSU website, and she agreed to participate. She referred me to four other women who were also in this group.

Because of the snowball sampling method, I ended up with a Chemistry sample in which all interviewees were members of a women-orientated group (Graduate Women in STEM). While I did not inquire of the Biomedical Sciences women if they were members of this group, two volunteered this information. This introduces the potential for bias. Because of the nature of

these women-centered organizations, it is possible the interviewees were more attuned to the barriers women in STEM face and were more quick than students who had not joined a woman's group to notice barriers. Moreover, since these meetings served as a place for women to share their struggles, interviewees likely heard more stories about the negative experiences of other members that they were then able to share as examples in their interviews. Because of this possible bias, the sample may overrepresent the extent of barriers in Chemistry and, to a lesser extent, in Biomedical Sciences. Also, to the extent that such groups are effective in helping women students overcome barriers, which the literature indicates they are, then these women are likely to be more successful than women in their fields who were not group members, which again would mean they are not representative.

I conducted semi-structured interviews. While two pre-pandemic interviews occurred in-person at a student's chosen locations, due to the pandemic, the rest took place over Zoom. Interviews lasted approximately one hour and covered topics such as their experiences with professors and peers, classroom and research experiences, gendered expectations, exclusion, isolation and future career and family expectations. Interviews were recorded and transcribed. I then used grounded theory to analyze and develop themes from the interviews (Charmaz, 1996). Using this theory, I examined my data by conducting line by line coding and building codes and categories as my interviews progressed (Charmaz, 1996). Before conducting my interviews, I expected themes such as those I read about in the literature to be present. However, one new theme also developed as I conducted my interviews and coded them (Charmaz, 1996). The themes centering on barriers that my interviewees mentioned were similar to those in the literature: interpersonal interactions and challenges of motherhood, along with the mitigating factors of same-gendered peers and professors. The new theme that emerged was interviewees'

negative experiences with women professors, so I added a section to the literature review to cover this phenomenon.

RESULTS

The interviews showed that women in both Biomedical Sciences and Chemistry were experiencing many of the barriers described in the research literature. Out of the ten women, seven reported negative classroom experiences with male professors or peers. Most also reported either current or anticipated challenges due to motherhood and family life. While clear barriers were displayed, two mitigating factors seemed to aid women in graduate school, the presence of female professors and social support gained from female peers in the program. These mitigating factors were more prevalent in Biomedical Sciences, which created an advantage for these students and even reduced some of the barriers they faced.

Interpersonal Interactions

In this section, I describe the classroom experiences women in both fields encountered, which centered on being interrupted or ignored by male peers and professors, male students and male professors questioning their intelligence or ignoring them, and professors holding them to higher standards than men. A Biomedical Sciences student, Courtney, described her experience:

It happens all the time...in class it happened with most professors also talking over you. Usually male professors. And even now, if I'm talking to other professors or the Chair of our department, very often do I get cut off, and I have noticed that that doesn't seem to happen as much with my male peers. ... the male grad students, they don't seem to get cut off as much.

Another women in Biomedical Sciences reported how a professor completely ignored her:

So, there was someone who I had to work with for my project and he was pretty sexist. He would never speak to me unless I had my advisor with me, or I cc my advisor on emails. But then I know other students who had to work with him, and they didn't have that issue. And so that was a bit annoying that I always had to get my advisor involved, because I don't know if he didn't think that I was smart enough to talk to about the project or he just was not interested in dealing with me.

Women also reported negative experiences with male peers. A Chemistry student named Stephanie was upset by her experience:

There was a guy that I was talking to, and I got an A in a class, and he had taken that class previously. He's like, "How did you get an A?" I was like, "I don't know. I just ... I did." I don't know. How do you describe that? I did well on the assignments, I did well on the exams. I got an A. . . . He's like, "But I didn't get an A!" Okay? I don't know how to describe that to you, either. It's a little bit difficult. And at the end of the day, I know he took a lot of issue with that and with the fact that I didn't have to take the prerequisite course, and stuff like that.... It's difficult really, because sometimes you can go through that and you can have a lot of things on your side that show that you deserve something.... It doesn't matter how many papers you've had. It doesn't matter how many awards you've won. That's not going to be part of the argument....At the end of the day, there's just nothing. . . I can really do about it but just keep getting papers and just keep doing well, and then that's all I can at that point. I can't control them.

These negative experiences with professors and peers also occurred off-campus. A Chemistry student named Brittany described her experience when she and one of her lab mates visited another lab:

Recently, we went to a national lab, me and one of my coworkers. We were talking with one of the scientists there.... The scientist [at the national lab] was directing all of the questions to him [my lab partner], even though it was my project.

So, he [my lab partner] was there with me because we were working overnight, and you have to have two people to do overnight shifts. But it was my project, but he [the national lab scientist] would cut me off and ask my lab mate the questions! That was a little irritating.

Another way professors and peers created barriers for women was by holding them to a higher standard than their male counterparts. Professors enforced these higher standards in a variety of settings including classrooms, laboratories, and even department social events. Haley, a Chemistry student, described a male professor who she believed operated on a double standard:

I've explained to him that I have had health issues... I was hospitalized last summer for about five, six days. And when I got back, he expected me to be 100% to efficiency and running experiments left and right....Now there are other students in our lab, one in particular who became a postdoc....We kept him on until he could find a job. And he comes in maybe three days a week. He just slept in all day, you know? It's kind of the running joke in our group. We're like, "Is he going to show up today?" And the fact that it's a joke is an issue. But if I go missing and I don't tell anybody, I'm in trouble. I get reprimanded for it: "Why aren't you here? Why aren't you going to work?"

Courtney, the Biomedical Sciences student, also perceived a double standard:

There's a couple of guys in our journal club, one specifically, whenever he gives the presentation, even if it's garbage, people [professors] afterwards are like, "Oh, good job, good job!" You know, it was very great even though I didn't think it was. But then I feel

if I did that same kind of quality work, I would get called out on it, not just by my professor, but other professors.

Being held to higher standards was not something that occurred just in the classroom and laboratories for these students; it also occurred in social engagements held by the department. Some women reported they acted in a particular way in these situations and that certain topics were off-limits, despite the fact that men talked about them. Samantha, a student in Biomedical Sciences, described how she felt forced to maintain a formal persona in a way that men don't during these events:

Especially when it comes to events, sometimes we'll serve alcohol, we have annual retreat, I feel like the guys get to, they loosen up a little bit more. Whereas, the girls, they still see this as a precious setting [for professional development]. We still have to be professional, and we're more likely to dress nice for certain events.

She continued:

I feel like a lot of times, I guess in social situations, men tend to take the lead in conversations and then sometimes, depending on who I'm around, I feel I have to be careful what I say, because I feel people can judge you based on things that you say if you're a woman, that they probably wouldn't if you were a man. So for instance, I'm very careful when I talk about my social life, because I don't want to bring up anything revolving around my dating life or if I went out drinking or something, because I feel I would be judged if I brought up anything like that. So I usually keep conversations more on the surface.

These examples highlight the barriers women face due to negative social interactions with professors and peers. Women in both Chemistry and Biomedical Sciences encountered

professors and peers who questioned their intelligence, interrupted or ignored them, and held them to higher standards, and I did not perceive that the barriers were more extensive in one discipline than in the other.

Challenges of Motherhood and Anticipated Motherhood

The majority of women indicated that they either currently faced barriers due to motherhood (two of the ten were mothers) or they anticipated facing them in their academic careers. Eight out of ten women indicated someone has expressed to them how difficult it would be to balance motherhood and academia. Moreover, they felt there was a clear choice to be made between a career and family life and they also reported societal expectations about motherhood as something that bothered them. These anticipated challenges were not limited to one field, and women in both Chemistry and Biomedical Sciences reported these barriers.

One barrier they reported was that they felt men and women in the program were held to different standards when it came to parenthood. Courtney, a Biomedical Sciences student, reflected on a new father in the program and noted that things would be different if he were a woman:

Yeah, one of our students graduated, less than a year ago. He had a baby a couple years ago, so when he was about midway through the program and he's still got awards every year for being the best grad student and that, "Oh, he's so hard working." I don't know if he would have got that kind of praise if he were the woman that had the child.

She continued her reflection by speculating about reasons administrators might not support motherhood among graduate students:

It's kind of in the air that the people in charge like the Chair, don't like girls, and specifically women, to have children and start a family in the program because it takes so

much time away from their research so that they're here longer, they're costing more money because they pay our tuition and your PI, their grant pays for you. So, it's just, it's a money suck. I think the higher ups see that as [a money suck], but then the professors themselves are usually fine with it.

Regardless of the reason departments might have for discouraging graduate-student motherhood, students perceived that motherhood was frowned upon. Samantha, a Biomedical Sciences student, described her friend's fraught maternity-leave experience:

My friend who got pregnant last year and now has a baby, when she was talking about maternity leave, it was a huge battle, a big tug of war to let her have the amount of maternity leave that she wanted. I think she wanted 10 weeks. And then of course we're paid, so that's paid time off even though it's maternity leave. And they gave her a really hard time about it and then they made her. . . make up the seminars that she missed on her maternity leave, which is total BS.

The difficulty did not stop once women returned from maternity leave. Several women described either the difficulty they experienced juggling a STEM career and children or the difficulty they anticipated, although their complaints centered more on societal expectations rather than on any lack of departmental support. Stephanie, a Chemistry student, described the challenge she faced when she received a prestigious award:

I just got a Fulbright award to go to France, so I'm going to be going to France from January to August. I can't bring my daughter with me because she's starting kindergarten. She has to go to school, even though she doesn't want to. There's going to be these obstacles that I feel, to be honest, as society, if a guy were to make the same choice, it would have been like, "He's going out there and he's making something out of himself."

When a woman does it, it's, "What kind of mom is she? She just left her kid!" You know? And then, we're raised in that society. ...For me, those are the differences in expectations when it comes to being a woman and a man in STEM. What do you think a woman's role is in this world? And then, are they able to still fulfill being successful in a STEM field and maintain your expectations of what a woman should do?

Several other women said that they felt as though it was necessary plan their life transitions, such as getting married or having children, well in advance. A common sentiment was feeling as though they were required to pick one or the other to focus on one at a time.

Haley, a Chemistry student, offered an example of this mindset:

When you're a woman in STEM, these are things that you have to consider. Which one are you going to put first at this point in your life? Because if you had a kid now, you're not only prolonging your time in school, but you're also limiting the amount of places that you can go to be employed. And if you're at the end of your program and pregnant, nobody's going to hire you because as soon as you get hired, you're going to be on six months' leave, and this is from a purely business standpoint. And I understand it from a manager or person in charge's standpoint that, "Why am I going to hire an employee with full benefits if they're just going to take off for six months to have a kid within the first year of working?"

In short, the interview material about motherhood highlights the barriers and challenges women face or anticipate facing in graduate school and beyond in regard to balancing work and motherhood. Women in both Chemistry and Biomedical Sciences made it clear they believed double standards existed regarding parenthood and negative attitudes from departments regarding choosing motherhood. They also reported timing life transitions around graduate

school and feeling of having to make a choice between motherhood and an academic career. I did not perceive that these barriers of motherhood or anticipated motherhood differed between the disciplines.

Mitigating Factors

The interviews also revealed two mitigating factors that seemed to help women succeed and that decreased the negative effect of barriers. These mitigating factors were the presence of female faculty and the presence of fellow women in the program, and they seemed to occur more often in Biomedical Sciences and served as an advantage for women in this department. While there were female faculty in Chemistry, these faculty were not supportive of female students, and this served as a barrier for the students in this department. Therefore, women in Biomedical Sciences were at an advantage due to the supportive faculty and greater number of female students.

Women Faculty

One factor that improved the prospects of women in Biomedical Sciences was the presence of women professors in the department to serve as role models and to make the environment feel comfortable and secure. The mere presence of these professors showed women students that they could accomplish their goals, as examples of women who had done so were visible. As for creating a comfortable and secure environment Courtney, a Biomedical Sciences student, said this:

Our graduate program coordinator for the past couple of years has been a woman, Dr. Smith. And she is very inspirational. She's a very strong woman, and there's a lot of female professors in my program, which is nice to see because I came from an undergrad department where there was one female in the whole department. So, it is nice to see,

because we've had problems in the past when she wasn't in charge, just departmental wise that, girls were getting treated a little differently and talked to differently when it came to starting families. But now that she's in charge, if I were interested in starting a family while I was here I wouldn't feel as pressured to not to as I would've before she was in charge.

Rachel, another women in Biomedical Sciences, described a similar story. After a weekend of hosting a guest speaker who made her feel uncomfortable due to his actions and comments, she was able to turn to her female program advisor:

He was weird. He was an old dude who was in industry. I think because of his age, he made inappropriate comments. Both during the seminar, in front of everyone, and then during [the grad student lunch]... not so much to me, personally. But during the grad student lunch, it was a weird environment. But I was able to go to the graduate program committee person, who is a woman, and I told her, "Hey, this is what happened. I'm just letting you know. I kept my distance." She apologized, offered me candy.... I just wanted to make sure it was documented, so if he said anything, like "Oh, she wasn't being accommodating, she wasn't doing this," it's like no. I did everything in my power, but he was creeping me out.... I'm just letting you know [she told the advisor], that if I didn't seem friendly enough it's because he made me very uncomfortable.

Women also reported another benefit of having women faculty in the department, which was that these faculty served as role models. Students were inspired by a certain type of women in their departments. They admired women who had achieved a Ph.D. and women who went on to run their own labs and to serve as Primary Investigators. This inspiration was helpful because these women showed the students, they themselves could achieve these goals even though they

were difficult. Furthermore, their presence meant someone existed in the department who understood their struggles. One Chemistry student, Madison, described the importance of seeing a professor like this:

I think it would be good to have more female PIs that you can go [to] ... More of a mentor situation, even if they're not your PI. It's nice to have somebody that you can connect to that's a female in that role that knows what you're going through and that you can talk to. That would be good, for one thing. I think it's good to see women succeed and run their own labs and be successful. I think that that's inspiring for other women scientists.

The sense of loss in lacking a viable role model was acute for a Black woman, Emma, a Biomedical Sciences student:

I think I'm craving for the day that I find somebody who's a productive PI who's a woman, and who is Black, and who's in my department too, because it's really difficult to be in a department, and not really see yourself, or see someone as such as yourself being in a space. It's a battle, constantly saying, "Hey, do I belong? Did I pick the right area? I'm in over my head with that. Am I going to make it?" And it came to a point where I'm like, "Are they going to let me make it?"

While most women students in Biomedical Sciences felt that having female faculty was a boon to them, several women in Chemistry described women faculty as actively unsupportive of female students. Only one woman in Biomedical Sciences described this problem, but it was common for Chemistry students to witness female professors who undermined female graduate students, which negatively impacted them even if the event did not happen to them directly.

According to Haley:

There was one of our newer professors, I don't really know her personally. I just know from her interactions in public. But there was a student who presented her talk and [the professor] ripped her apart and told her that her research had already been done. ... She needed to find a new research [topic] because what she was doing was dumb and it was pointless, and she had already done it. Rather than encouraging her, like, "Hey, maybe you should take it in this direction," she just tore this girl down rather than trying to boost her back up.

Another woman, Lucy, in the Chemistry department expressed a similar sentiment of wishing the female professors would support the students instead of bringing them down. When reflecting on her candidacy committee she was hurt by the fact that the one female professor was not as supportive as she wished:

I think, oddly enough...when I was doing my candidacy exam. I was just being attacked by questions, but it was... funny enough, it was the female member of my committee who was the most discouraging compared to the rest of my committee members, which were male. So, I think... I think it hurts worse, than from a male, because you feel like, okay, there're females here, we got to stick together....But at the same time, I almost wonder if it's just more that she feels more open to criticize me.

Several women tried to propose explanations for this behavior. Lucy speculated that women professors felt more comfortable criticizing women. One woman, Miranda, a Chemistry student, speculated that diminishing women students made them seem like "one of the guys":

I think it has a lot to do with them trying to prove themselves. And I've seen it more so in our department with younger female professors, who tend to be very mean. And I think it

has a lot to do with trying to prove that you belong there and trying to act like the men. I just see it more in younger professors, as far as their meanness.

The explanations given by these women to justify the behaviors did not erase the fact that the students felt they lacked the female support and mentorship they desired. It was clear they wished the professors could encourage the other female students in the department and build them up during the difficult process of graduate school, and when this did not happen, they were left feeling hurt. Without this support, it is easy to see how these relationships can be harmful and discourage women students in the end.

Women Peers

The second mitigating factor that was evident from my interviews was the presence of women peers and the social support they offered. Several women in both fields reported feeling comfortable in environments, both academic and social, where there were more women. Courtney from the Biomedical Sciences department described a recent student government meeting:

I felt really included, but that also might be because the President of our SGA Student Government Association is a girl. Most of the board is girls. There's one guy that he's homosexual. So he was very, you know, open to our struggle. And there's another guy, but he's very young. So the fact that the Board is almost all female automatically makes me more comforted because, I feel my opinions are heard...they're more receptive to my comments.

Rachel, also from Biomedical Sciences, felt the power of female solidarity:

I think there are definitely times when you can feel more comfortable. My [male] PI said something that was really stupid and derogatory and I don't even think he realized how

derogatory it was, and I called him out on it. I was just like, "You can't say all women are emotional. That's super stupid and this is why." I think if I was surrounded by men, I might not have been as comfortable to talk back to him about woman subjects. Versus when I have three other woman graduate students around me that are like "Yeah, no, David, you're being an asshole! Don't say that." So you have this camaraderie that we've all experienced shitty situations. And so, when someone comes into our lab and tries to say something, we're like "No: you're very wrong."

Another way women were able to discuss their shared struggles was in organizations for graduate women in the field. Miranda, a Chemistry student, described topics that one of the groups discussed:

Normally, they talk about generally just experiences you have. If someone in the workplace makes a comment about when are you going to have children, or where are your children, who's taking care of our children?.... Other things include when to have children, when to get married. I guess we focus a lot more on the life part of work and balance, or work, life, balance.... So, I think that's mainly a lot of people ask questions about the life part, and then how you can take that and still be able to balance out work. And moving forward, and moving up, in the world of science.

Haley, a Chemistry student, described a similar description of a different women-in-STEM organization:

We are a part of this organization because of what it stands for. It's not just an organization for women. It's an organization for those who support women in STEM... Like this conversation we're having, these are conversations that need to be had. And [this organization] is there to help provide that.

Stories such as these highlight the importance of women having other women peers in their program and in having women-centered organizations. Having many women in the program allowed Biomedical Sciences women to navigate and discuss difficult situations that they may have struggled to handle on their own, and it created an environment where women felt seen and heard, which the literature indicates is often lacking in STEM fields. They also gained from women-center organizations, but not as much as women in Chemistry. Women in Chemistry, who lacked a preponderance of women peers, reported the importance of being in women-centered organizations. In short, having other women around is important, whether it is in the everyday nature of classrooms and laboratories or in specialized organizations designed for women.

DISCUSSION AND CONCLUSION

Despite the fact that the number of women receiving graduate degrees in STEM fields has increased over the years, it is evident that disparities exist among the different fields (NCSES, 2018). Fields such as Chemistry continue to report fewer women receiving doctoral degrees compared to fields such as Biological and Biomedical Sciences (NCSES, 2018). In order to examine what could be causing this discrepancy in gender representation this thesis used in-depth interviews with women pursuing Ph.Ds. in Biomedical Sciences and Chemistry at a research university. Through these interviews, I focused on whether the barriers differed between the departments and whether there were resources that helped the women in Biological and Biomedical Sciences overcome barriers, resources that were perhaps less available to graduate student women in Chemistry.

Findings showed that women in both departments faced barriers due to negative social interactions with professors and peers and to real or anticipated work-family balance problems.

Women reported being ignored or interrupted, having their intelligence questioned, and being held to different standards than their male peers. Women in both departments also reported penalties and negative attitudes associated with a decision to have children, they worried about having to carefully plan and time their life transitions, and they struggled with the societal expectations that came along with motherhood.

Interviews also revealed mitigating factors that reduced the burden of these barriers. One was the simple presence of female professors. Yet, women's presence did not have the same effect in Chemistry as in Biomedical Sciences. Students found women professors in Biomedical Sciences to be an asset, describing how they inspired the graduate students and created a comfortable and safe environment for them. The opposite was the case in the Chemistry department, where some female professors were actively unsupportive, leaving students to feel hurt and disappointed. These students felt that as women, these professors should have stuck together and helped the female students.

The literature on women in STEM does not focus on women faculty as barriers, although a couple of studies may be relevant. "Queen Bee Syndrome" describes how successful and higher-up women in male-dominated fields can be overly critical of women subordinates and attribute negative stereotypes to them (Harvey & Tremblay, 2020; Staines, Tavris & Jayaratne, 1974). One study showed that female professors believed that female graduate students compared to male graduate students were less committed to their future academic careers. Male faculty did not report believing there was a gender difference in commitment (Ellemers, Van Den Heuvel, Gilder, Maass, Bonvini, 2004). It is possible that stereotypical beliefs underlay the female faculty behaviors interviewees reported, but it is impossible to know without additional data focusing on women faculty.

The second mitigating factor that surfaced as a theme was the presence of female peers in the program. Several women identified this as a factor that made them more comfortable in their program. While it was less common in Chemistry, one woman in the program reported that they believed they would be more comfortable if more women were in their program. Therefore, there seemed to be an advantage of having a higher percentage of women in the program whom students could bond with, compared to being in other fields that are more male-dominated. Another benefit of female peers was the ability to form clubs and organizations that allowed graduate women to discuss their shared struggles. Within these organizations, women were able to support other women and give advice to each other. In conclusion, my results showed that while women in both departments faced clear barriers, there were a couple of mitigating factors that were more present in Biomedical Sciences that helped women overcome some of the barriers and created a more welcoming environment for them.

When considering the results of my research, I want to propose several recommendations for lowering barriers to women in STEM fields. One would be to increase the proportion of female professors. One result of this would be that the amount of negative experiences women encounter in the classroom would likely decrease because more of their classes and laboratories would be led by women. These female professors would also increase the amount of role models that are available to female students and give them someone to be inspired by. Another effect is if male students encountered more female professors, they may adjust to seeing women in important roles in the STEM community. This experience of seeing successful female professors may change their perspectives and deconstruct some of the sexist culture. It is important to note that teaching roles are not the only solution; women in advising roles are also able to create an

environment that is understanding of the challenges women face regarding balancing STEM and family life, such as Dr. Smith did within Biomedical Sciences.

The data point to a caveat: some women faculty can be unsupportive of women students, and so simply increasing their proportion is not a complete solution. Unsupportive women professors are likely to only create more negative experiences and feelings for the women in the programs, as I found in the case of Chemistry. Training programs designed to inform faculty of best practices in teaching and mentoring for enhancing STEM diversity could create a positive impact.

In regard to increasing the proportion of female faculty advisors and thus being able to help students informally consider work-family balance and other such issues, a caveat is again in order. Female scientists themselves struggle to succeed, and taking on advising roles, which detract from the time they can spend on research, can be detrimental to their careers. Perhaps a solution is to recognize and reward faculty's graduate-student advising role. Recognizing it could take the form of awards for supporting and mentoring students. Rewards are more important, and one solution would be to reduce the teaching load of faculty who seriously commit to the advising role.

My second recommendation arises from the finding that peer support was crucial to the STEM women students who were able to gain access to it. Improving the pipeline of young women into STEM fields is one way to increase peer availability and creating formal peer-support groups is another. Regarding increasing the flow of women into the pipeline, interventions can occur at the undergraduate level and even younger. Many undergraduate women may feel discouraged when considering a STEM graduate or career paths due to the chilly climate they hear about or have experienced. But programs and organizations could

demonstrate that a place for women in STEM exists, which could be encouraging. Moreover, since programming would likely include interaction with women graduate students and faculty, they would be exposed to other women excelling in such programs, making the possibility seem more real. Increasing the number of programs for girls in science at an even younger age, such as middle and high school, could also be beneficial. One woman in Biomedical Sciences, Rachel, detailed her experience of working at a science camp for high schoolers:

It was for girls only, completely free, going into ninth grade. Because a lot of women quit STEM in high school [it is important to reach them early].... They were taught chemistry, marine biology, engineering. They built remote-operated vehicles and stuff. I think having more of those camps where it's not just science camp, it's like hardcore STEM [would be positive]. There's so many different aspects that you really should be exploring.

Programs to increase the young women in the pipeline could lead to beneficial effects on women's presence in STEM. But again, a caveat is in order. Scholars have noted that organizations frequently invoke the "pipeline" argument to deflect the organization's responsibility for retaining women in STEM fields. In other words, rather than address the structural problems in their institution, they can blame the problem of not enough women on structures outside their own, such as the wider culture or the pre-graduate-school system (Wynn & Correll, 2018).

A final recommendation is based on the finding that almost all women reported they have either faced challenges due to motherhood or anticipate future challenges. One way to help overcome these challenges is to promote family-friendly policies, such as flexible scheduling and increased maternal and paternal leave. Moreover, ensuring that these policies are used by both

genders is important so that women who take them are not subjected to “flexibility stigma” (Williams, Blair-Loy & Berdahl, 2013). Studies have shown that women may be afraid to use these policies due to how taking them may negatively affect their workplace progress or due to the stigma attached to people who make use of flexibility policies (Villablanca, Beckett, Nettiksimmons & Howell, 2011). If both genders took advantage of family-friendly policies, however, normalization might counteract some of the legitimate concerns women have about using them. For example, the use of these policies by men and women may help erase the idea that individuals who use them are less dedicated to their careers. Therefore, promoting family-friendly policies is likely to have a beneficial effect on the careers of women STEM graduate students.

Creating a positive environment for women in STEM fields matters because it may lead to a more gender equal distribution in these fields, which could benefit women's economic situation, as these jobs tend to offer higher salaries (Harmon, Hopkins, Persky & Roy, 2018; Hegewisch & Tesfaselassie, 2019). The current state of academia due to the pandemic also shows how important these recommendations are. Since the pandemic started, women have struggled to maintain a balance between family life and their academic careers, and universities have struggled to make policies that are understanding of this challenge (Zamarro & Prados, 2020; Kramer, 2020). If women held positions of power responsible for making work-family balance decisions, it is possible that these decisions would be more helpful to the family needs of women scientists, and also men scientists. Following recommendations like these may help women scientists, men scientists, and society more broadly as all qualified personnel can bring their skills to the scientific arena.

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APPENDIX A

Interview Schedule

1. What is the aim of the study? The aim of the study is to learn about the experiences of women in various STEM fields, specifically Chemistry and Biological/Biomedical Sciences. Through this study, I aim to understand why Biological/Biomedical Sciences has a more equal gender representation compared to other STEM Ph.D. programs. The reasons behind the difference in gender representation in Biology compared to other fields is important to understand in order to determine how to achieve gender equality in STEM fields. Gender equity and fair treatment of students is essential to developing better STEM programs and equal fields.
2. What will be involved in participating? The main component will be the interview today which will last approximately forty-five minutes.
3. Who will know what I say? Only my faculty director and I will have access to your tape and transcriptions. My faculty director is Dr. Irene Padavic, a professor in the Sociology Department at FSU. Your answers will be completely anonymous. In my Thesis, your name and any other information that could identify you will be changed.
4. What risks and benefits are associated with participation? It is likely there are no risks for this study, unless perhaps upsetting experiences occurred over your course of studies. You may end the interview at any time, and if you want me to turn off the recorder at any time, I can do that. The benefit is that I hope to add to the literature on what works well for women in STEM and what works less well, so it may help future women in the field.
5. What are my rights as a respondent? Your participation in the study is voluntary and you may end your participation at any point. You have the right to ask questions at any time, and I will answer them.

If I want more information, whom can I contact about the study? You can contact my advisor, Irene Padavic, at ipadavic@fsu.edu. May I use my phone's recorder to tape this interview?

1. Is there anything about the study you'd like to ask me or anything about the subject you'd like to tell me before we begin?

I am going to start by asking you about your interactions with professors in classes for your major.

1. Can you tell me about a time you may have felt your professors perceived you differently from your other peers? (Probe: What was that like? How did this make you feel? Did you ever wonder if it was because you were a woman?)
2. Can you tell me about a time when a professor encouraged you or took an interest in you? (Probe: What was the best part of this? Did it change your orientation to the program? Can you tell me about what the professor did to show interest in you? Did you meet often, and if so, what did you discuss? What did you like best about this experience? What effect did this relationship have on you and your career goals?)
3. Can you tell me about a time when you felt a professor discouraged you? (Probe: Did it make you doubt yourself or your ability, even if unintentionally? How did you react? Did the professor treat others in a similar way? Do you think this treatment had anything to do with the student being a man or a woman?)

Now I'd like to ask you about your classroom experiences.

1. Do you ever hold back on making comments in class? Can you tell me about a time this happened? (Probe: Have you ever been interrupted or ignored when you spoke? If so, can you tell me what happened, starting from the beginning? Have you noticed a difference in

the ratio of men to women who speak aloud in class? (If yes, can you tell me about what happened? Does either group get interrupted or ignored more?)

2. What about group projects? Think about your most recent project. There is usually someone who takes the organizing lead, someone who records, and someone who reports. Did you notice whether men and women took on different roles in that project? What role did you take? How did you feel about it? Can you tell me what happened during the project, starting from the beginning?

Now I'd like to turn to more informal situations.

1. What are your relationships like with fellow students in your program? (Probe: Are you in a study group? Do you get together socially?)
2. Would you say you have a close bond with them? Can you tell me about something you did with them recently and how it went? (Probe: What did you talk about?)
3. Who do you turn to for support when you need to talk to someone about what's going on for you in the program? Can you tell me about the last time you turned to someone for support? (Probe: What was the issue? How did they respond when you asked for support? Were they helpful?)
4. Do you ever talk about what it's like to be a woman in the program? Can you tell me about a time when you discussed this and who it was with?
5. Can you tell me about the last social event you attended for your program? Did you feel welcome and included? (If not, what made you feel that way? If yes, can you identify what it was that made you feel part of the group?)
6. Have you ever felt that women and men acted differently from each other in these social situations?

Now I'd like to ask about your experience of research and publishing.

1. Have you had the opportunity to gain research experience? How did that come about?
How long did it last; is it on-going? What was the best part about your research experience? What was the worst part of your research experience?
2. Do you feel like your chances for gaining research opportunities are as good as a man's?
3. Are you working on any publications? (If not, why not. If yes, how is that experience going?)

Now I'd like to ask about possible future family plans.

1. Has anyone ever expressed that having a career in your field and managing family life may be difficult? How did that conversation come about? Did you find it helpful?
2. Have you seen any examples of women in your field balancing a career and motherhood?

I'd now like to ask about your career plans.

1. What is your career goal once you have your PhD? Do you think that being a woman will affect your ability to attain this goal? Do you feel that you have equal resources and opportunities compared to the men in your academic program that will allow you meet your goal?

Conclusion

1. I'd like to conclude by asking if there is anything I failed to ask about being a woman in this program that you would like to share.
2. Are there any women in your program you could refer to me to for future interviews?
Would it be possible for you to contact her and ask if she would be willing, and perhaps give her my phone number? Would it be okay for me to call if I need to clarify or follow up on a question? Is there a number that would be best to reach you at?