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Article

Navigating Barriers and Mentoring Support: The Career Goals of Women Doctoral Students in Chemistry

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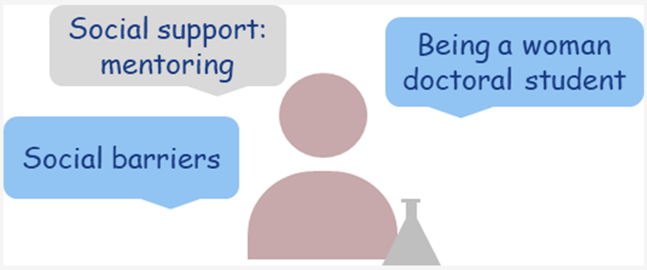
ABSTRACT: In chemistry, women are still underrepresented in the postbaccalaureate stages. However, there has been limited discussion in STEM education that treats chemistry as a singular discipline and explores doctoral students' experiences from a mentoring perspective. This qualitative research study investigated how contextual factors (i.e., social barriers and social support) and personal factors (i.e., being a female student) influence students' motivation and career goals in chemistry based on the Social Cognitive Career Theory, with an emphasis on mentoring experience as one of the contextual factors. Fourteen women doctoral students were interviewed. The findings revealed that women students rarely planned to stay in academia because of the barriers they experienced, such as the overwork norm. Women students faced microaggressions, such as others questioning their ability, a lack of sense of belonging, and unequal involvement in administration work. Mentoring support as a format of social support can mitigate these challenges. However, students' needs were nuanced depending on their developmental stages. The study concludes with nine action items for faculty members to support women students' success in chemistry, providing valuable information for future policy and mentoring training program designs.



KEYWORDS: *graduate education, qualitative research, women in chemistry, mentoring, chemistry education*

The exploration of gender issues in chemistry is a necessary move toward improving diversity and inclusion in the field. Despite the improvement in gender representation at the undergraduate level, a gap persists at the postbaccalaureate stages.[1] To illustrate, only 42.2% of the doctorate degrees are awarded to women.[1] Further, women account for only 32.1% of chemists and material scientists.[2] The most stubborn imbalance lies in academic research positions, where only 20% of the faculty members in the top-ranked U.S. universities are women.[3] Researchers have made substantial efforts to investigate the gender imbalance in science, technology, engineering, and mathematics (STEM).[4] However, the discussion has mainly focused on the most imbalanced fields (e.g., computer science)[5] or has treated STEM majors as a whole.[6] Less attention has been given to chemistry as a sole discipline. The potential risk of this is that the nuances among different disciplines were neglected.

Previous studies have suggested that mentoring is an important contextual factor influencing women students' learning experiences and career choices in STEM fields.[7,8] Nevertheless, most of these studies were conducted at the undergraduate level.[9,10] Graduate students' experience has been understudied. Therefore, there is a gap in the research on graduate students' experience in chemistry, especially from the mentoring perspective. Considering this, the purpose of this study is to qualitatively examine what and how contextual factors influence women students' motivation and career goals in chemistry at the graduate level, including the social barriers they face and the social support they receive. The Social Cognitive Career Theory (SCCT) was used as the theoretical framework for the design and conduct of this study. The mentoring experience was emphasized as a contextual factor within the framework.

■ THEORETICAL FRAMEWORK: SOCIAL COGNITIVE CAREER THEORY

In chemistry, several research instances have investigated the factors that influence students' learning experiences and career goals on the ground of the Social Cognitive Career Theory (SCCT).[11−13] SCCT proposes that personal factors (e.g., gender), contextual factors (e.g., social support and social barriers), and their interactions impact an individual's self-efficacy, outcome expectation, and personal goals (see Figure 1).[14] Self-efficacy refers to one's belief in their ability to perform a specific task. Outcome expectation refers to people's belief in the results of their behaviors. Personal goals refer to the objectives that people want to achieve.[14] Further, these three

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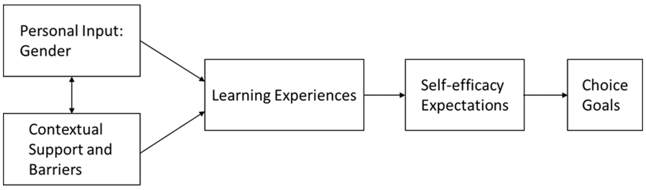

Figure 1. Adapted SCCT framework.[15]

factors influence one's motivation, interest, and choices in career development.[15]

In the context of STEM education, the review by Lent et al. that considered more than 100 studies over the past 30 years has provided evidence of the validity of this theoretical framework.[16] In other words, an individual's learning experiences and career goals in STEM majors are impacted by both personal factors and contextual factors. For example, mentoring support can be considered as one influential contextual factor that affects students' career goals.[9] In addition, underrepresented minority status such as gender interacts with contextual factors and significantly impacts students' learning experiences in STEM.[17] Thus, the present research aims to leverage the SCCT framework to examine how social barriers and social support (e.g., mentoring), confounded with personal factors (e.g., gender), influence students' motivation and career goals in chemistry. The SCCT framework was utilized to design the interview protocol and interpret the results.

LITERATURE REVIEW

Women in Chemistry

Past literature highlights that the barriers faced by women students in their graduate training go beyond numbers. Women students have reported perceptions of isolation and a lack of support in their academic journey.[18] They have experienced being taken less seriously (i.e., invisibility),[19] having a lower relationship satisfaction with advisors,[11] and having inadequate support in career preparation.[18] Overall, these findings suggest that women students face significant challenges that can impact their success in the field.

Additionally, women are less likely to enter academic careers when they graduate.[20,21] Two main reasons explain the low representation of women in faculty positions. First, women's career choices have been negatively influenced by unconscious bias experienced during their graduate studies.[22] Evidence has shown that microaggression negatively impacts women's psychological well-being and sense of belonging. Microaggression also puts pressure on women, as they feel the need to prove their competence in science.[23] Another factor that contributes to women's departure from research careers is the perceived difficulty of balancing family responsibility with the high intensity of a research career. Namely, women have low self-efficacy and high self-doubts in their ability to manage work–life balance.[24,25] These reasons at least partially explain why the decline in the intention to pursue a career in academia is most pronounced after completing a Ph.D. study.[20]

Mentoring as Social Support

Social support such as mentoring support serves as a source of contextual influence on students' learning experiences. Mentorship refers to the relationship between a less experienced person (protégé) and an experienced person (mentor), where the mentor is interested in supporting the protégé's career development.[7] Two types of mentoring support are differentiated based on previous literature: (1) instrumental support, which means that mentors provide tangible resources to protégés (e.g., funding), and (2) psychosocial support, which means that mentors provide emotional and mental support to protégés (e.g., encouragement).[7]

The important role of mentoring in the graduate school context has been well-documented.[26] Instrumental support influences students' productivity in their graduate training, and psychosocial support influences students' satisfaction with the student–advisor relationship.[27−29] Mentoring also impacts graduate students' acceptance of the norm and self-efficacy in science, particularly for underrepresented populations.[30,31] In chemistry, "mentoring is more important than ever."[32] Several retrospective studies from chemists have narratively supported the indispensable role of mentoring support on their way to success.[33−36] Conversely, negative mentoring experiences can harm graduate students' sense of belonging in chemistry, which is an important predictor of their interest and motivation in the field.[37]

Despite the significance of mentoring in graduate training, the mentoring support for women chemists of the next generation still has room for improvement. Women have reported a lack of access to mentoring resources during their graduate studies (e.g., constructive feedback from advisors),[11,17,18,38] which is challenging to the career development of women chemists.[27,39] More importantly, the underrepresentation of women in chemistry faculty positions perpetuates itself through the mentoring relationship between students and advisors.[36] In other words, the efforts to improve gender diversity in the chemistry community will not only benefit current students but also be carried over to future generations by mentoring relationships.

CURRENT STUDY

This study makes several contributions to the chemistry education literature. First, this study focuses on an understudied population: women students in doctoral study. Despite significant efforts and resources being invested in promoting diversity in the science community, most of the previous research has solely focused on the undergraduate population. The graduate stage, which serves as a link between the undergraduate study and the professional workforce, has been understudied.[40] Second, previous literature has mainly treated STEM majors as a whole or has treated chemistry as a gatekeeper course, rarely considering chemistry as an independent field. Even fewer studies have examined women students' motivation in chemistry from a mentoring perspective despite its significance in graduate training.[11,27,39] Last, the majority of previous research has been conducted at the institutional or program level to promote diversity in chemistry.[41−43] In contrast, this study focuses on smaller units in the learning environment. More specifically, this study forms empirical action items for faculty members and advisors aiming to improve the quality of mentoring support for women doctoral students from their near surroundings.

In short, this study aims to fill in the research gap by qualitatively examining how social barriers and social support experienced by women graduate students impact their career goals, with an emphasis on gender as a personal factor and mentoring as a contextual factor within the SCCT framework. The research questions are as follows:

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1. How do the perceived challenges that women face in doctoral studies in chemistry shape their career goals?
2. How does the mentoring support that women receive in their doctoral studies impact their career goals?

■ METHODS

The qualitative research method was used to gather extensive information about the unique experience of women students in the format of one-on-one interviews.[44] The qualitative research method is a constructivist way of thinking. It is inductive and interpretive of the meaning participants attribute to their experiences.[44] In the current study, the qualitative method provided in-depth insights and depicted individuals' stories with the support of the theoretical framework. All study procedures were approved by a university Institutional Review Board (IRB# IRB2021-1200D).

Participants

Participant recruitment for the project started in the spring of 2021. Students in chemistry from four universities were invited to participate in this project if they met the following criteria: they (1) were at least 18 years old, (2) self-identified as a woman, and (3) were currently enrolled as a graduate student in a chemistry major. Participants were recruited through a convenience sampling. Specifically, student organizations in four universities were contacted via email (e.g., chemistry graduate student organizations). If they agreed, the student organizations sent out a bulk email to their listserv with recruitment information. Interested graduate students contacted the author to express their interest in participating in the research. Additionally, snowball sampling was used to recruit participants. A $10 gift card was included as an incentive, funded by the Graduate Student Research Grant in the author's institution. Participants were given pseudonyms randomly.

In the end, 14 doctoral students from three universities participated in the research (mean age = 24.6, SD = 1.4). Thus, the current project focused on doctoral students' experiences and perceptions instead of the whole graduate student group. The majority of the participants were from overrepresented groups in chemistry (i.e., White and Asian). When interviewed, 50% of the participants were in their fourth year (see Table 1).

Table 1. Summary of Participant Demographics (*N* = 14; URM = Underrepresented Minority)

number	pseudonym	year in study	ethnicity
1	Sara	3	White
2	Natalie	4	White
3	Sophia	3	White
4	Emily	4	not reported
5	Jennifer	4	Asian
6	Taylor	4	Asian
7	Jessica	4	White
8	Megan	not reported	URM
9	Emma	4	White
10	Olivia	1	White
11	Grace	4	URM
12	Ashley	3	White
13	Anna	1	Asian
14	Megan	6	Asian

Data Collection and Data Analysis

The data were collected through one-on-one semi-structured interviews that lasted 30−150 min. Prior to each interview, a written consent form was obtained from each participant. The interviews were conducted over Zoom and were recorded with the participant's consent. Participants were asked open-ended questions following an interview protocol, which was developed based on the theoretical framework and the research questions. The interview protocol is available in the Supporting Information.

The interviews were transcribed by using the live transcript function in Zoom. After the interviews, the transcripts were manually checked and corrected for accuracy based on the recorded audio. The data were then analyzed using thematic analysis in Excel.[45] The first step in the analysis was to review the transcription several times and organize it into paragraphs based on the topic. Then, codes were created to summarize each paragraph, such as "difficult first year" and "favoritism". This procedure was conducted for all participants. Then, the codes were reviewed repeatedly. Grounded by the theoretical framework, the author summarized that the codes could form three main themes: general social barriers, social barriers specific to women, and mentoring support. After that, the codes were grouped under the corresponding themes. The frequency of each code was calculated. Finally, the most prominent codes were summarized as subthemes in the findings.

Positionality Statements

The author acknowledges her positionality, as her perspective may influence the research process. The author has study experience in chemistry for her bachelor's and master's degrees. She left the field due to the perception of a difficult work−family balance in chemistry and entered an administration position after graduation. Then, she returned to university and is currently a doctoral student in educational psychology. The author believes that women face inequality when pursuing a STEM career due to stereotypes and unequal family responsibilities. The author also believes that although promoting diversity in STEM has caught significant attention, the majority of such promotion has been conducted at the institutional or program level. Action items for professors and advisors are necessary to improve the microenvironment for women students.

■ FINDINGS

After analyzing the data, three themes were formed based on the theoretical framework: (1) general social barriers and career goals, (2) social barriers unique to women students, and (3) mentoring as social support. Mainly, the results revealed that most of the women doctoral students planned to stay in chemistry but did not intend to pursue an academic career. Specifically, contextual barriers and support were found to interact with gender, influencing not only the students' self-efficacy in chemistry research but also their self-efficacy in keeping a work−life balance. Mentoring support was nuanced for students at different developmental stages. The themes and subthemes are summarized in Table 2 and are discussed in each section below.

Theme 1: Social Barriers and Career Goals

In the present study, although 13 out of 14 participants expressed their intention to stay in chemistry, only one participant planned to pursue an academic career after

Table 2. Summary of Findings

themes	subthemes
1. social barriers and career goals	
	1.1 the difficult first year
	1.2 the overwork norm
	1.3 favoritism
2. social barriers unique to women	
	2.1 ability questioned
	2.2 lack of sense of belonging
	2.3 unequal involvement in administration work
3. mentoring as social support	
	3.1 spontaneous support from peer mentors
	3.2 support for soft skills
	3.3 accessibility and patience

graduation. The others indicated career plans to enter the industry or that they "do not want to be a professor anymore". Interestingly, most of the participants had started their studies with an aspiration of becoming a professor. However, the high pressure in doctoral training redirected their career goals. As Jessica mentioned, "Grad school took away my love of science because it's just so stressful." Their motivation decreased primarily because the overwork norm in chemistry harms their self-efficacy in keeping a work−life balance and their outcome expectations for an academic position. As Megan mentioned, "My biggest challenge is getting confidence in myself as a chemist over time. I'm not the person who I was when I first joined the program."

The Difficult First Year. The first year of a graduate program can be particularly overwhelming in the field because the need to adjust to a new environment, leaving family and friends, the heavy course load, and the intense graduate assistantship work all happened at the same time (6/14: Taylor, Jessica, Emma, Anna, Sara, and Ashley). For example, the following is how Jessica summed up her experience of the first year:

> *Look, it is just workload. We have a full teaching load, which is three sections of 24 students each. It is a total of 72 students. And we have to do the grading each week too. That alone is a lot of work. On top of it, we have full-time classwork as well. I had two classes, neither of which I was particularly strong in. Plus, the graduate-level classes. It is my first-time taking graduate-level classes. That was just an adjustment there.*

Additionally, the process of familiarizing oneself with a new research area and even proposing research topics can also be a significant challenge for self-efficacy in chemistry research for first-year students. Sara expressed, "It was like reading 50−60 papers about something I have never done before. Just trying to figure out where to start is very overwhelming, especially when you're new to a field." Considering the fact that science innovation in the format of lab experiments involves more failures than successes, it is not surprising that students perceived it difficult to maintain a high self-efficacy in chemistry research (5/14: Emma, Megan, Natalie, Sophia, and Grace). As Emma described, "Especially in synthesis, not everything works. It's going to be a lot of failures before you get something to work."

The Overwork Norm. The overwork norm experienced in graduate school led to a low self-efficacy in keeping a work−life balance in chemistry, contributing to students' career goals (8/14: Jessica, Anna, Megan, Sara, Natalie, Sophia, Olivia, and Grace). Students perceived it to be difficult to draw a clear boundary between work and life. As Anna said, "I do not feel safe about taking off my mask. I feel like I still don't know how to balance life, how to organize my task." Natalie mentioned, "I think work−life balance in chemistry is tough and maybe tougher compared to some other career paths that are out there. I definitely think that there are careers out there for chemists where you can have a work−life balance. But I think it's hard."

The skewed norm in work hours stemmed from students' contextual environment, such as professors' expectations and peer pressure (Jessica, Sara, and Olivia). Sara explained, "Other people in my group are working 12 hours a day. ... I heard that my PI is like: if you're not working 12 hours a day, we're not being productive." As a doctoral student, "you have so much pressure to perform the best." Currently, the rules regarding work hours "really depend on your PI, honestly, and your group culture." However, as Jessica noted, "I think some amount of flexibility is fine, but there should be rules."

For women doctoral students, pursuing an academic career can require additional years of postdoctoral training. This extends the work−life conflicts from personal life to family life (Sara). Sara said, "I really don't wanna have to push off because of school. I wanted to get a job. I want to make money. But I also want to have kids before I'm 30 and be able to fund them." This interaction between gender and contextual factors diminished students' confidence to balance family growth and the heavy workload in academic positions.

Favoritism. Favoritism can be toward a specific person (Emma, Sara, and Grace) or a certain research topic (Grace). Favoritism as a form of detrimental social comparison led to students' self-doubts about their abilities. Emma described, "[My advisor] has a favorite student. And, like, it is obvious to everyone but that student. But that person is the favorite in the group. And the student is essentially like a copy-and-paste type of person like our boss. Very similar personalities and similar interests." Another participant, Grace, mentioned that her advisor only scheduled subgroup meetings with students on a specific research topic:

> *It is a completely different case if you are the [field 1] student. If you are a [field 1] student, they have their own meeting, right after our group meeting, where they talk about the progress related to [field 1] stuff. And then also you will see him more frequently because you are in the [field 1] room. They might be in the room where they do that work. He might come down there and help or whatever. But if you are a [field 2] student, you rarely, you will probably sometimes only see him during the group meetings.*

Theme 2: Social Barriers Unique to Women Students

Women doctoral students faced gender bias that harmed their self-efficacy in chemistry studies and led to negative learning experiences, primarily in an implicit form. Among all participants, the majority (9 of 14) mentioned experiences of gender bias. Specifically, four of them used the word "implicit" to describe the experience (4/14: Jessica, Natalie, Sophia, and Olivia). Jessica described the implicit bias such that "if you point [it] out, people feel like you're being whiny. You are the one who was too sensitive." Participants reported their ability being questioned, a lack of sense of belonging, a tendency to hold back, and unequal involvement in administration work compared to their male peers.

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Ability Questioned. Women students reported that their ability and interest in chemistry were questioned, and they were taken less seriously by either peers or faculty members (4/14: Emily, Jessica, Sophia, and Ashley). For example, participants perceived that they received different course grading and feedback from faculty members compared to their male peers. It was in an implicit way that they could only notice when discussing grades or feedback with peers.

Although substantial policies had been implemented to help women flourish in STEM, this trend was sometimes used to undermine women's abilities and accomplishments. Emily mentioned that her colleagues attributed her success in fellowship application to her gender rather than her hard work and achievement:

> *I have worked really hard to publish papers, to get fellowships, to do all kinds of things. And sometimes I'll have a colleague of mine go, "Oh, you are successful because they want diversity." So, you are saying that you are a woman. It is not because of the merit of my work. It is because the agency that is looking to hire someone is looking for diversity. So, they'll just automatically assume that I do not have what it takes and that I'm being treated well because I'm a woman, despite the fact that my research is just better than theirs.*

Lack of Sense of Belonging. It is not surprising that some participants reported a lack of sense of belonging in the community considering the low representation of women faculty at universities (3/14: Emily, Sara, and Sophia). In particular, they perceived that they were often being talked over and that their opinions and ideas were often overlooked. These negative experiences led to them feeling pressure to prove themselves and their self-doubt regarding their potential for success in the field. In addition, they reported having difficulty connecting with their colleagues. One participant, Sara, depicted the following scenario:

> *In my group, there are not many girls, and I just feel like a lot of times the guys kind of stick together. Maybe they have more to talk about, more relatable. But then you feel that you are excluded. And if they're all like having conversations, you know they'll be talking about research and giving each other advice, and then you missed out on that. So that is how I feel the most about being a girl. Sometimes I get excluded, not intentionally. But it just happens that way.*

Unequal Involvement in Administration Work. Women students reported that they were involved in administration work to a larger extent compared to male peers (e.g., record keeping and event planning) (2/14: Natalie and Grace). This added pressure on time management and not only occupied their time but also had a further negative impact on their self-efficacy in maintaining a work−life balance. Natalie expressed:

> *I end up having to do a lot more, so that would involve jobs that require organization or record keeping. I find that I myself and other women in the group get those jobs, kind of disproportionately more than men in the group. Same with social event planning and things like that. I find that I generally tend to do that stuff, whereas men in our group do not.*

Theme 3: Mentoring as Social Support

High-quality mentoring support, as a format of social support, can increase students' self-efficacy in succeeding in chemistry and significantly improve students' learning experiences. The mentoring support women students received was examined from two aspects: instrumental support and emotional support. The instrumental support that women graduate students needed depends largely on their academic rank. In other words, women students at different developmental stages had nuanced needs for support to fulfill academic tasks and career development. When first entering a research lab or beginning to learn about an unfamiliar research topic, students required timely feedback from either faculty or senior students. As students became advanced in the research, they assumed a mentor role other than a protégé in terms of academic skills. At this stage, they looked for guidance in career development and planning.

In terms of emotional support, most of the participants indicated that they seek support from family, friends, and therapy. In addition, accessibility, flexibility, and equal treatment from advisors were on top of the factors mentioned to maintain motivation in generally challenging doctoral studies (Jessica, Megan, Emma, Anna, Megan, Sara, Natalie, Sophia, Olivia, and Ashley). Considering the focus of this study, the findings related to relationships within the university context are discussed.

Spontaneous Support from Peer Mentors. Although support from advisors was crucial, peer mentors, especially postdocs and senior graduate students, were exceptionally valuable in the development of technical skills for younger students. Specifically, advisors commonly met with participants once or twice a week in the format of one-on-one meetings, subgroup meetings, or lab meetings. Compared to advisors, postdocs and senior graduate students could provide more instant communication, which could promote young students' self-efficacy when they were fresh into the lab (Jessica, Emma, Megan, Sara, Natalie, Sophia, Olivia, and Ashley).

Students who successfully built connections with postdocs and senior students experienced more grounded mentorship and perceived less isolation (Jessica, Megan, Emma, Megan, Sara, Natalie, Sophia, Olivia, Grace, and Ashley). For example, Olivia mentioned that when the lab expanded, senior students and postdocs in the lab provided her with hands-on guidance in experiments. Moreover, they were more accessible because they shared the same workspace as the first-year students.

On the contrary, first-year students who did not successfully bond with peer mentors perceived isolation, anxiety, and challenges when learning technical skills (Anna and Grace). Anna described her stress of exploring on her own even though she got support from her advisor:

> *Although we're in the same group, we do not meet each other very often (postdocs). We only meet each other when we need to talk to each other. So, I feel like the group members do not have enough connections. I have to do everything by myself. Like last time, I had to carry 12 bottles of DCM solvent, which is a really dense liquid. I felt like I really needed some help.*

Support for Soft Skills. Students were well-supported in terms of soft skills. Academic presentation was practiced in the format of literature talks or research talks during group meetings (Taylor, Emma, Anna, Megan, Sara, Natalie, Olivia, Grace, and Ashley). As students grew familiar with their research topic and gained strength in research skills, networking, and career development became the focus of their needs in their senior years (Megan, Sara, Sophia, Olivia, and Grace). For example, Sophia mentioned that her advisor started to discuss career development in one-on-one meetings when she became a third year. A timeline was set up to explore career opportunities.

Accessibility and Patience. Advisors being accessible to students kept the students motivated and involved. Two main aspects that were mentioned that helped maintain a close connection between students and advisors were one-on-one meetings and being physically accessible. One-on-one meetings with advisors provided the opportunity to discuss research progress, plan career development, and provide spiritual support (Jessica, Emma, Anna, Megan, Sara, Natalie, Sophia, and Ashley). A supportive relationship was built up and deepened through the time invested. However, keeping one-on-one meetings became challenging as the lab expanded. Sophia described the benefits of one-on-one meetings as "it's sort of the most targeted feedback about how the project is going, and what we should prioritize next."

In addition, students greatly valued having advisors being physically accessible to them, as it provided opportunities for spontaneous feedback (Jessica, Anna, Natalie, Sophia, Grace, and Ashley). In-person small talk can surprisingly be motivating. For instance, Ashley mentioned that her advisor's office was right across from hers. And, having her advisor come into the office and seeing her advisor face-to-face often provided her with a strong sense of support. Conversely, Grace lacked the chance but expected this daily random talk with her advisor: "Something that motivates me to keep working is when I see them every day. They can come up to you at any time and say, 'How's it going?' And you're like, 'Look, I did this thing.' And it might just be a little bit of progress."

Furthermore, patience was an emergent suggestion to advisors (Jessica, Emma, Anna, Megan, Olivia, and Grace). When advisors have been away from the graduate experience, "they forget that things, like, take time to get." Megan mentioned:

> *I feel like he's very, very impatient when it comes to research results. It is a little bit difficult because he expects us to set up reactions right away and then tell the result the next day. But, it's hard because you need to take into consideration when the reaction is done. How are you gonna work it up? How are you going to purify exactly, that can take a couple of hours. And another thing is analyzing what you got from that reaction [could] take a day or two. But, he expects everything [to be] done in like a day.*

■ DISCUSSION

The present study interviewed 14 women doctoral students in chemistry majors and investigated how gender interacts with contextual factors and influences students' career goals. The results found that the social barriers experienced by women students led to a negative learning experience in chemistry. As a result, while the students planned to stay in the field, they rarely intended to pursue academic research careers. At this stage, mentoring support is insufficient to alleviate these negative experiences. There is a need to call for the improvement of mentoring support for women doctoral students, taking into account their nuanced needs.

The SCCT framework suggests that the barriers reported by these women may have effects on their learning experiences and self-efficacy and, therefore, their career choices.[16] Despite decades of effort by researchers and practitioners to promote equality and diversity in the STEM community,[19] women doctoral students in chemistry still experience microaggressions. Participants perceived different treatment from faculty and peers. Passively avoiding inequality seems to not be enough to neutralize the unconscious bias women students face. More proactive efforts are necessary to include them. Although most of the actions to date have been toward undergraduate populations,[43,46] graduate students have been gradually included in practitioners' sight. For example, at McMaster University, monthly discussion events have been organized to increase the awareness of equity, diversity, and inclusion among graduate students and faculty members.[42]

Furthermore, the struggle to maintain a work−life balance was one of the obstacles in the career development of women students. The highly intensive work in graduate training led to a decrease in motivation to continue the same lifestyle in the following years. This is consistent with previous research, where women students were found to perceive a higher level of difficulty in balancing personal life in faculty positions compared to male peers.[24,25] Women students also considered the conflicts between work and family obligations in the planning of their careers. According to the research by Chapman et al., women students do not see themselves as able to succeed in faculty positions while raising children at the same time.[20] More resources and support are needed to help women students achieve work−life balance.

Particularly, the participants in this study expressed difficulty during their first year. This finding can be grounded by Tinto's stages of graduate persistence,[47] which differentiate three stages in the graduate study: (1) transition and adjustment, (2) acquisition of knowledge and the development of competency, and (3) completion of the dissertation. First-year students are at the transition stage and, at the same time, are required to master the skills necessary for research. Spontaneous support can better support them in the transition and in skill acquisition. Considering the limited bandwidth of faculty to provide spontaneous mentoring,[18,48] peer mentors who spend more time in the lab may be able to provide more instant and informal feedback to students. To this end, the connection to peer mentors is crucial in supporting the positive experiences of first-year doctoral students and maintaining their high self-efficacy in the field of chemistry.

Additionally, favoritism is a new emergent obstacle lying in the way of women students. Although prior work has indicated that inaccurate social comparisons undermine students' self-efficacy,[49] the negative influence of favoritism in chemistry has been minimally discussed. The current study provides evidence that favoritism as a format of social comparison contributes to a negative mentoring experience and negatively influences student−advisor relationship satisfaction.

Although significant challenges exist, mentoring support, including instrumental support and psychosocial support, can buffer the negative influence of these barriers. Previous research has shown that timely feedback enhances domain-specific self-efficacy for college students.[50] In the current study, it turns out that timely communication is also needed to help doctoral students grow their self-efficacy in chemistry.

As previously discussed, most of the current practices in chemistry aim to promote women students' motivation and enhance their learning experiences by implementing interventions, such as redesigning courses.[46] Less attention has been focused on changing the daily routine of social relationships, particularly mentoring relationships. Informed by the findings of this study, institutions can take action from a different perspective to support women students. For instance, institutions can offer mentoring training programs that are tailored to women students' needs based on the findings. To this end, nine suggestions toward building an inclusive environment

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for women students are summarized below with a focus on mentoring relationships:

1. Formally assign a peer mentor to first-year graduate students to provide more timely support in learning technical skills.
2. Provide guidance or direct resources in career development for senior students.
3. Promote discussion on maintaining a healthy work−life balance. Foster a proactive attitude toward ensuring it.
4. Minimize favoritism toward any specific student or subfield.
5. Assign lab administration work equally to lab members.
6. Consciously include women students in lab discussions.
7. Be physically accessible to students.
8. If possible, schedule a one-on-one meeting with each student.
9. Be patient about the experimental progress.

LIMITATIONS

This study has several caveats, but each points toward a direction for future studies. First, the author stayed close to the struggles experienced by women in chemistry, but future research can extend to embrace those with other gender identities. In addition, gender was the only considered minority identity in this study. Other minority identities, such as disability and ethnicity, were not discussed. Those are potential areas that warrant future investigations. For example, the study by Hamers et al. that examined the experiences of women of color in graduate school in chemistry revealed that underrepresented students face a lack of research experience and a lack of mentors with the same identities.[41] In fact, the participants of the current study were mainly from overrepresented ethnic groups in STEM (i.e., White and Asian). The experiences of doctoral students with other minority identities may be distinct from the sample in this study because of the intersectionality of several minority identities. This limitation constrains the transferability of the findings of the current work. Future work can delve into the experience of populations with other or multiple minority identities and examine how their stories are the same or different from those of this study. Last, because the data analysis was conducted by the author, trustworthiness cannot be evaluated by measures such as inter-rater reliability. The findings from this study are open to verification by future research.

CONCLUSION

This study investigated how contextual barriers and support influence women doctoral students' career goals based on the Social Cognitive Career Theory. Women students planned to stay in chemistry but rarely intended to stay in academia. The transition and heavy workload in the first year and the overwork norm in chemistry contributed to their compromised self-efficacy in chemistry research and low self-efficacy in maintaining a work−life balance. In addition, implicit bias still exists and harms women students. Women students perceived being questioned in their ability, a lack of sense of belonging, and an overinvolvement in administration work.

Social support, particularly mentoring support, can antidote these negative learning experiences. However, the needs are nuanced for students at different developmental stages. For example, spontaneous support from peer mentors is invaluable, especially during the first year, as they can provide spontaneous and timely feedback. Throughout the multiyear training, students mainly seek emotional support from family and friends. At the same time, advisors' accessibility and patience can also be helpful in maintaining students' motivation. Mentoring support should be tailored to the nuanced needs of doctoral women at different developmental stages. As one of the few research studies focusing on the mentoring relationship for women doctoral students in chemistry, the findings of the current study contribute to our knowledge about women students' perceived barriers on their way to success and the support they need. The results provide rich information that facilitates the design of policy and intervention programs by chemistry departments, such as mentoring training programs.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.3c00197.

Semi-structured interview protocol (PDF, DOCX)

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Notes

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