

Graduate Student Women's Perceptions of Faculty Careers: The Critical Role of Departmental Values and Support in Career Choice

Morgan E. Howe,* Melony M. Kim, and Samuel Pazicni*



Cite This: *JACS Au* 2022, 2, 1443–1456



Read Online

ACCESS |



Metrics & More



Article Recommendations



Supporting Information

ABSTRACT: While the number of women in undergraduate and graduate chemistry programs has increased in recent years, women remain under-represented and excluded in the ranks of faculty in chemistry higher education. This marginalization results from not only fewer women being offered faculty positions but also fewer women applying for these positions. To investigate the reasons why faculty positions are causing so many women to turn elsewhere for employment, a survey was designed based on the literature themes surrounding women's career choices, interviews with the current graduate student women in chemistry programs, and our previous work. The survey was grounded in social cognitive career theory (SCCT), and data were analyzed through a QuantCrit lens. Despite the existing literature focusing on the impact of having children on women's career decisions, the desire to have children did not appear among either the top priorities or the most important factors in predicting whether any of the 130 survey respondents were interested in a faculty career. Instead, faculty career interest was related to themes of overwork, high expectations from departments, and expected department emphasis on research despite an individual's interest in teaching and mentoring. Furthermore, women expressed a strong interest in maintaining work–life balance but low expectations for their ability to obtain a position that would allow it. They also reported a desire to work for a department that values mental health and diversity and supports its community members but similarly low expectations for their ability to find a department that shares these values. These themes suggest that chemistry departments must make fundamental changes regarding what is tangibly valued and rewarded within their systems if they wish to reduce the exclusion of women in faculty positions.

KEYWORDS: careers in chemistry, chemistry education research, gender equity, graduate education, women in chemistry



INTRODUCTION

Women's Career Choices in Chemistry

Despite the steady rise in women's representation in undergraduate and graduate training programs in chemistry, the number of women in faculty positions has not risen to match those numbers. While 39% of PhDs awarded in chemistry in 2018 went to women, only 25% of chemistry postdoctoral fellows were women in the same year.¹ In 2017, only 27% of assistant professors in chemistry at the top 75 universities were women, along with 27% of associate professors and 16% of full professors.² The large drop in the number of women participating in chemistry from PhD completion to postdoctoral positions suggests that somewhere during the graduate experience, women choose to steer away from postdoctoral paths that would lead them to faculty positions. The project reported here explores graduate student women's perceptions of faculty careers to gain greater insights into what may contribute to those choices. A more comprehensive quantitative review of the minoritization of women in chemistry and STEM faculty positions can be found in our previous work.³

There is a broad selection of work that has explored the exclusion and barriers women face during the hiring process to become a faculty member and the period after they earn the position; this work has been conducted at varying types of institutions with differing emphases on research. In STEM, more broadly, women face barriers including biases from hiring committees, lack of mentoring, social marginalization, inhospitable group cultures, lower salaries, fewer resources, less respect, lower likelihood of promotion, and even overt opposition to hiring female faculty.^{4–6}

Other work suggests that women's values, including an interest in caring for family and raising children, contribute strongly to their choice whether to pursue faculty positions. Work by Grunert and Bodner in chemistry suggests that

Received: March 16, 2022

Revised: May 27, 2022

Accepted: May 27, 2022

Published: June 7, 2022



Table 1. Item Stems and Definitions for Each SCCT Construct Queried in This Work

construct	definition in the context of this work	item stem(s) (example items)
learning experiences	experiences in graduate school that are sources of self-efficacy or outcome expectations	<p>(1) during your time as a graduate student in chemistry, to what extent have you witnessed the following in the people around you?</p> <p>women having successful careers as faculty members; faculty members holding a work–life balance you would be satisfied with; people you identify with in mentoring positions</p> <p>(2) during your time as a graduate student in chemistry, to what extent have you felt or experienced the following?</p> <p>success in formal teaching experiences; success proposing research questions; feeling the need to compare your success to your peers’</p> <p>(3) during your time as a graduate student, to what extent do you feel like others treat you in the following ways?</p> <p>your students in courses tell you (or have told you) that you are a good teacher; your PI recognizes your research accomplishments as important</p> <p>(4) during your time in graduate school, how often have you felt or experienced the following?</p> <p>feelings of anxiety or stress; microaggressions based on an aspect of your identity other than gender; having to participate in research projects you did not like or were uninterested in</p> <p>if you were to make the choice to pursue a faculty position, how confident are you in your ability to successfully do the following?</p> <p>propose research questions that would get funded; navigate the tenure process well enough to obtain tenure; maintain your overall mental health</p> <p>the following questions ask about what you would expect to be true of your work environment if you were to obtain a faculty position (whether this is your desired path or not). Based on your impressions and knowledge of faculty positions, if you were to obtain a faculty position, how likely do you think you would be to:</p> <p>earn a salary that is attractive to you; have a secure/stable job; have the freedom to choose what you research; be faced with high expectations</p> <p>in your future career, how important is it for you to:</p> <p>learn more about chemistry; propose original research questions; shape departmental policies; support others like you in pursuing chemistry</p> <p>if you were to pursue a faculty position (even if that’s not your current goal), how likely do you think it is that between now and starting that position, you would:</p> <p>get support from mentors other than your PI when applying for the position; have time to address stressors outside of work (e.g., family, children, housing, food, income)</p> <p>(1) do you plan to apply for faculty positions?</p> <p>(2) how much do you think that applying to a faculty position is a realistic goal for you? (regardless of whether you plan to apply)</p> <p>(3) how committed are you to being hired for a faculty position? (i.e., committed to getting hired, not whether you would feel committed to the job once you started it)</p> <p>(4) how exclusively do you plan to apply for faculty positions as compared to other positions? (all other positions, not just academic ones)</p> <p>(5) if you were accepted to multiple types of positions, would a faculty position be your first choice?</p> <p>(6) to what extent do you plan to pursue each of the following career goals after completing the required training? (see response options in Figure 2a)</p>
self-efficacy expectations	an individual’s belief in their ability to perform certain tasks to a particular degree of success as a faculty member	
outcome expectations	what graduate students expect to occur if they were to start a faculty position	
interests	tasks, values, and goals that graduate students want in their future career	
proximal environmental influences (supports and barriers)	people or systems surrounding a graduate student that they expect would help or hinder them between now and obtaining a faculty position	
choice goals	intent to pursue a career	

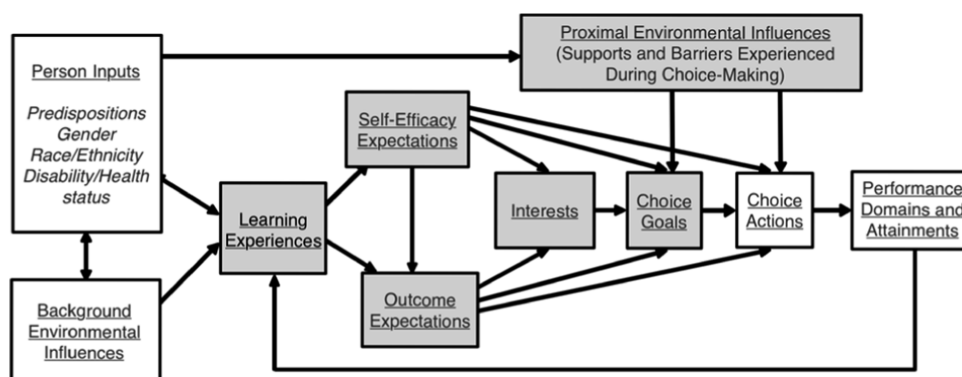


Figure 1. SCCT model;²¹ shaded constructs are queried in this work.

women find faculty positions incompatible with the traditional women's roles in childcare and familial responsibilities, as well as that women expect faculty work to be less intrinsically fulfilling and provide less work–life balance.^{7–9} This work also explores women's career interests through the lens of Markus and Nurius's "possible selves,"¹⁰ noting the disconnect between women's visions of themselves and who they felt they could be in faculty positions.⁷ Other work corroborates that women's disinterest in faculty positions in STEM was tied to their desire for work–life balance and an interest in caring for family.¹¹ Conclusions often link the importance of childcare in women's career choices to the exclusion of women who wish to have children and participate in their care. For some women, the choice to pursue a faculty position was also tied to the ability to contribute to societal health problems, the potential to positively impact students, and the desire to contribute to improving the world.¹²

The factors mentioned to this point are important to consider, but they primarily reflect the views and values of women who have already made the decision to pursue a faculty career. The degree to which these realities for current faculty affect the opinions and goals of graduate students, and specifically those in chemistry, is less well-explored. There is also literature exploring the development of factors that researchers posit affect the career choices of undergraduates, including chemistry identity, chemistry belonging, and other similar constructs.^{13–17} Less attention has been paid to graduate students and how the graduate school experience affects whether women choose to pursue a faculty path. The goal of this study is to bring together the themes from chemistry and STEM undergraduate literature and the themes from chemistry and STEM faculty literature to explore whether and how those themes extend to graduate student women.

Herein, we describe the design of a survey to explore the question: What experiences and values guide women's choices on whether to pursue faculty positions?

Theoretical Framework: Social Cognitive Career Theory

This work is grounded in social cognitive career theory (SCCT), a framework developed by Lent et al.^{18–21} based on Bandura's social cognitive theory.²² SCCT uses both personal factors (like interests and identities) and proximal factors (like learning experiences, supports, and barriers) to understand how individuals make career choices. It has previously been used to model choices at multiple points in a career path (e.g., undergraduate major choice,^{23,24} graduate career choice,^{25,26} overall career choice^{23,24,27,28}) and in multiple disciplines (e.g., chemistry,^{3,23} physics,²⁷ sustainability,²⁸ sports science,²⁹

biomedical sciences,¹² geoscience,²⁴ and STEM in general^{30,31}). SCCT is appropriate for this work because it considers both women's personal interests and the experiences they collect during graduate school, both of which are likely to affect how a person's career choice goals develop. A description of each construct follows below, and more in-depth information about the constructs and considerations in measuring each can be found in ref 21. For a greater context, the item stems for each SCCT construct of the survey detailed here are provided in Table 1.

Starting on the left side of Figure 1, since we situated this study in the context of graduate education, experiences prior to graduate school are grouped together into "background environmental influences" and are not included in our work. Next, learning experiences encompass any graduate school experience that informs an individual's expectations about their own abilities or faculty positions in general. These are broken into four categories: vicarious learning, performance accomplishments, social persuasion, and emotional arousal. Vicarious learning includes observations of others' behaviors and how those people are treated. Performance accomplishments are instances of an individual's successes or failures in tasks related to the future job (e.g., teaching, research, ability to navigate departmental politics). Social persuasion incorporates instances of others communicating a sense of belonging or success to the individual making a career choice. These instances could include students telling a graduate student they are a good teacher, family and friends viewing science as an attainable career for this person, or an advisor praising them for their research accomplishments. Finally, instances of emotional arousal include times where the individual experiences an emotional response to their environment: feelings of exclusion, discomfort, belonging, enjoyment, anxiety, and anything else they may feel.

Next, self-efficacy expectations capture an individual's current belief about their ability to do something in the future. For instance, while a graduate student may not currently feel capable of writing a grant, they may still believe that by the time they achieve a faculty position, they will have the skills to do so. Outcome expectations reflect what an individual expects to happen if they were to obtain a faculty position. This could include what they expect the department environment to be like or what they expect their life to be like.

Progressing to the right in Figure 1 again, both self-efficacy and outcome expectations inform a person's interests, which reflect the tasks, values, and goals they want to be incorporated into their future career. For graduate students, this means

things like their desire to teach, participate in research, contribute to their community, and have time outside of work for families and hobbies.

In addition to the path traced from learning experiences to interests, SCCT posits that graduate students would have proximal environmental influences in the form of supports and barriers from their environment that would affect their choices. These might be professional development resources from their current institution, networking help from an advisor, emotional support from peers, or biases in the hiring process.

Finally, all aforementioned SCCT factors come together to influence an individual's choice goals: what they want to pursue. As we are exploring graduate students' perceptions of whether they are interested in pursuing faculty positions, not their eventual actions, our work stops short of the choice actions construct, which would include which path they follow through on, and performance domains and attainments, which would include their success in pursuing that path.

Analytical Framework: QuantCrit

The analysis presented here is based on QuantCrit,^{32–34} a theory that merges the foundations of critical race theory³⁵ with quantitative data analysis. While this work explores gender as its primary focus rather than race, many of the same principles can be applied. For instance, while this work does not focus on the centrality of racism, it does center the oppressive and inequitable policies and systems within academia. With this in mind, we situate the results and implications of this study in how systemic structures, beliefs, and values result in the exclusion of women, not how women fail to meet the standards set by that inherently exclusionary system. This exclusion is interpreted as the result of a series of values, beliefs, and choices made in constructing the system of academia, not an inherent “natural property” of women. As such, participants were included based on their self-identification with the term “woman,” not based on their sex assigned at birth. This addresses another tenet of QuantCrit: that categories are neither “natural” nor given, and so this categorization needs to be critically evaluated.

Additionally, QuantCrit asserts that voice and insights are essential to understanding the experiences of marginalized individuals. Therefore, a section of the results will be dedicated to the known experiences of marginalized groups that were not reflected in our data, and those experiences will be shared in the words of interview participants who hold marginalized identities. The reasons for why these narratives were not elicited by our methods are discussed along with those narratives in the section titled “theme 6: this survey is not an appropriate tool to highlight the stories of all women.”

Finally, this study's expressed focus on the experiences of marginalized individuals renders comparison to majority groups inappropriate. That is, rather than comparing women to men, our goal is to uncover those factors with strong predictive relationships to the faculty career interests of women, akin to a within-group comparison. Between-group comparisons to the dominant group (men) imply that equity will come by making women more like men, while a focus exclusively on the narratives and needs of women leads to conclusions that highlight opportunities for systemic changes that better support them. As such, all participants in this study are women, and all conclusions are made about women. Many of the themes that arise during data analysis are likely to be shared by individuals of other genders, and implementing

policy changes suggested by this work may also benefit people who are not women. The goal of this work is not to propose changes that help only women but rather to highlight the changes that would make faculty positions a more equitable space for women by addressing their needs.

Personal Context and Positionality

In recognition of the fact that all science, and especially all research about people, is affected by the identities and perspectives of the researchers conducting the study, we wish to elaborate on the roles of the study team and the identities that we feel impact our respective understandings of gender and academia. The design of the study was primarily carried out by author M. E. H., who is a white, cisgender, asexual, heteroromantic woman who was born in the United States. As such, her experiences as a woman in STEM are not compounded by other minoritized identities, and care was taken to seek out the narratives of women with different identities both in the literature and during interviews.

Interviews were conducted by M. E. H. and M. M. K., who identifies as an Asian, cisgender, heteroromantic woman who immigrated to the United States during her teens. As an undergraduate woman, she did not have graduate school experience, so time was dedicated to discussing graduate school experiences before and after the interviews to compensate for this lack of experience. We believe that having two women lead the interviews contributed to trust between participants and the research team, but recognize that, especially for women of color, it is possible that being interviewed by two women who self-identify as majority racial identities could make them uncomfortable or unwilling to share sensitive topics. This was explicitly recognized at the beginning of each interview, and the study team took time to allow each participant to become familiar with the work and ask questions about how their stories would affect future stages of the project. The study team also made it explicitly clear that participants did not need to share or elaborate on anything they were uncomfortable discussing.

The crafting and revision of this manuscript were carried out by M. E. H. and S. P., both of whom identify as cisgender, white, and raised in the United States. M. E. H. is a woman in a postdoctoral research position, and S. P. is a homoromantic man in a faculty position. Our cultural backgrounds mean that our personal experiences with gender roles are limited to those experienced by cisgender individuals in the culture of the United States. Furthermore, both have found success within the existing structure of academia and, therefore, are likely to overlook aspects of that system that have benefitted them in the past. Both authors took care to examine the conclusions being made to ensure that they focused on change at a system level rather than framing graduate students who struggled or expressed negative opinions with deficit language.

METHODS

This study and the methods described herein were determined by the UW–Madison Education and Social/Behavioral Science IRB to meet the criteria for exempt human subjects research (2020-0164).

Survey Development

The survey went through five primary stages of development: a literature review, interviews, consolidation, expert review, and cognitive interviews. During the literature review, existing work surrounding women's careers in STEM was collected. This literature included work focusing not only on graduate women in chemistry but also on undergraduates, faculty, adjacent fields such as physics and

engineering, and STEM more broadly. This corpus of work was viewed through the lens of SCCT, and the conclusions and experiences reported therein were categorized according to specific SCCT constructs (e.g., learning experiences, outcome expectations, etc.).

Next, an interview protocol was designed based on previous work by Lent et al.³⁶ and the themes that emerged from the literature analysis. Since much of the previous literature focused on outcome expectations, self-efficacy, interests, and learning experiences, special care was taken to explore the barriers and supports women expected to face between now and achieving a faculty position, including those during the application and hiring processes. Interview subjects were recruited by email from the UW–Madison graduate student body and the Center for Sustainable Nanotechnology (CSN) member institutions. Volunteers were specifically recruited to ensure that women who identified as Black and women who identified as Hispanic or Latinx were included in the sample. This was done to ensure that narratives and items specific to their intersectional experiences were included in the survey.^{37,38} The final group of participants included 9 women, 5 of whom identified as white, 3 of whom identified as Hispanic or Latinx, 3 of whom identified as Black or African American, and 1 of whom identified as Asian. Interview participants were compensated for their time with \$25 Amazon gift cards. Interviews were carried out using Zoom during the summer of 2021, and audio recordings were transcribed using Otter. The transcripts were coded to consensus using NVivo to identify all new themes and narratives, which were categorized into SCCT constructs.

The literature items and interview items were then combined, duplicates were removed, and the differing language was resolved. For instance, the literature often discussed an “unspoken culture” of academia regarding unspoken rules that one was expected to follow and burdens that one was assumed to take on. When interview participants mentioned these topics and interviewers suggested the phrase “unspoken culture” to describe them, participants actively revised the language to “departmental politics.” Therefore, the survey items were revised to use language that was used by interview participants and was most likely to be interpreted as intended by the survey participants.

While both interviews and our previous work³ suggested that women view R1 and PUI faculty positions differently, we elected not to add additional survey items that would differentiate between these two settings. As such, some survey items may be more applicable to one type of position over another (e.g., forming relationships with students you teach). However, including items that can be applied broadly to any type of faculty position allowed us to identify salient themes pertaining to graduate women’s overall interest in faculty positions.

Validation Approach and Evidence of Validity

Evidence of validity provides assurance that the survey does, in fact, measure what we intend it to—this is crucial for establishing the quality of evidence elicited from survey instruments.^{39,40} Here, we build a validity argument⁴¹ using evidence based on the survey content and response processes.

Two of the initial interview participants (one who identified as white and one who identified as Black) were asked to participate in cognitive interviews to elicit validity evidence based on response processes. During these interviews, participants read over the survey items with members of the study team and were asked to point out items whose meaning they thought was unclear. The study team also asked specific questions regarding items that had been reworded from the interviewee’s initial language to ensure that the interviewees felt the questions continued to represent their initial intent. At the end of the cognitive interview, participants were asked whether they thought that their experiences as women in graduate school were fully represented by the questions on the survey or if they thought any important aspects of their experience had been omitted. Both participants agreed that their experiences were fully represented.

Finally, the survey was reviewed by three scholars with experience in SCCT or gender equity in STEM to elicit validity evidence based

on survey content. These scholars were asked to evaluate items for completeness (i.e., whether they were aware of any significant themes that were missing), unclear wording, misalignment with SCCT, and general comments. The revisions suggested by these experts largely focused on details of item wording in ways that made language consistent and did not affect item meanings.

It is critical to note that we specifically chose to design a survey that could describe the “landscape” of women’s interests in faculty careers rather than “essence.” That is, the choice to pursue a “landscape” view motivated the inclusion of items that are not important to every respondent but play a major role in the decisions of a small number of participants. Designing a survey that allows us to highlight the narratives of marginalized groups by including items that are relevant aligns with the QuantCrit analytical framework. Consequently, while this survey produced quantitative data aligned with the constructs of SCCT, its “landscape” nature prevents the acquisition of validity evidence based on internal structure via confirmatory factor analysis. Because items were meant to address a wide variety of experiences within each SCCT construct, each construct should not be expected to be unidimensional. For example, items probing self-efficacy about research ability should not be expected to factor together with items probing self-efficacy about teaching ability, and neither should factor together with items probing self-efficacy regarding finding a balance between their work and home life. Furthermore, we analyze survey data at the item level, not the SCCT construct level, and so the internal structure of the survey is not relevant to this work—an exception being the one group of survey items that was intended to measure interest in faculty careers, the analysis of which is detailed in the [Data Processing and Analysis](#) section.

Survey Deployment

The final survey featured 316 items, grouped into sections by the SCCT construct (although these were not labeled with the constructs). There were 16 items associated with choice goals, 44 with interests, 64 with outcome expectations, 27 with self-efficacy expectations, 89 with learning experiences, and 53 with supports and barriers (proximal environmental influences). An additional 23 items attended to demographics, or person inputs. More detailed descriptions of each construct can be found in the Theoretical Framework section, and the full survey can be found in the [Supporting Information](#).

The survey was deployed using Qualtrics via snowball sampling. Recruitment messages were sent to the UW–Madison chemistry graduate student body, all CSN member groups, the CER listserv hosted on the ChemEdX server (a mailing list that reaches many chemistry educators and chemistry education scholars), and the research team’s Twitter accounts with details about the study and requests to spread the recruitment message as broadly as possible. Requests were also sent specifically to the UW–Madison chapters of the Society for Advancing Chicanos/Hispanics and Native Americans in Science (SACNAS) and the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) to recruit more participation from women who identified as Hispanic/Latinx and Black. Survey participants were offered the choice to enter a raffle for one of 12 Amazon gift cards upon completion of the survey. The survey remained open for 4 weeks in November 2021, and anyone who had an unfinished response at that time was given 24 h to complete their survey. The median survey completion time was approximately 33 min.

Participants

Upon termination of the survey period, results were downloaded, and incomplete responses were removed, leaving 130 total responses. 108 participants identified as Caucasian (a term which the team now understands is harmful due to its origins as part of an effort to form a scientific basis for white supremacy,⁴² but this was the term used); 18 identified as Asian or Asian American; 4 as American Indian, Native American, indigenous, or Alaskan native; 2 as Black or African American; and 1 as native Hawaiian or Pacific Islander. Four people chose to self-identify as a white European immigrant, Middle Eastern, West Asian, and European. On a separate item about ethnicity, 18

respondents identified themselves as Hispanic or Latinx. Unfortunately, while particular attention was paid to recruiting women who identified as Hispanic, Latinx, and Black, the recruitment procedure appears to have excluded these women. It is possible that more targeted recruiting is necessary (e.g., by obtaining IRB approval to contact specific departments or programs), or that a different method of data collection will be more effective in reaching this group. This observation is elaborated on in “theme 6: This survey is not an appropriate tool to highlight the stories of all women.” The racial and ethnic identity distribution of study participants is summarized in Table 2 along with other demographic information.

Table 2. Summary of Selected Demographic Characteristics of Survey Respondents^a

identifier	number of participants	percent of sample (%)
Race ^b		
Caucasian	108	83
Asian/Asian-American	18	14
American Indian, Native American, Indigenous, or Alaskan Native	4	3
Black/African-American	2	2
Native Hawaiian/Pacific Islander	1	1
identity not listed (see text)	4	3
Ethnicity		
Hispanic or Latinx	16	12
not Hispanic or Latinx	114	88
Year in Graduate School		
1	8	6
2	23	18
3	36	28
4	26	20
5+	37	28
Chemistry Discipline ^b		
analytical	20	15
biochemistry	24	18
chemistry education research	33	25
chemical biology	19	14
computational	18	14
inorganic	22	17
materials	24	18
organic	27	21
physical	26	20
not yet established	1	1
discipline not listed (see the Supporting Information)	7	5
Bachelor's Institution Type		
university with research training up to Master's and/or Doctoral students	57	44
institution with research training up to the undergraduate level	64	49
college with little or no research component	9	7

^aFull demographic information is reported in the Supporting Information. ^bPercents within race and chemistry discipline categories exceed 100 because participants were allowed to select multiple responses.

Participants identified with a variety of different chemistry disciplines, but the researchers' connection to the chemistry education community did result in a sample that overrepresented that discipline. In addition, there were relatively few individuals who earned undergraduate degrees at institutions with no research component, and so themes in their experiences are unlikely to appear in the results of this study. While some participants chose not to identify their current institution, those who did answer indicated representation from over 40 different institutions. Complete demographics for the

sample can be found in the Supporting Information, and further limitations of the sample are discussed in the Limitations section.

Data Processing and Analysis

After downloading from Qualtrics, all data processing was performed in R version 4.0.3. First, the responses to all items were visualized and sorted by score within each SCCT construct. This was done to identify preliminarily which items appeared to be the most important and the least important, although no statistical tests were used to make inferences about this distinction.

Next, a factor score was computed to represent how much faculty career interest (FCI) each respondent held (see the Supporting Information). This factor score was used as a measure of participant FCI in all subsequent analyses. The numerical value of the FCI score does not have a meaning. Rather, the relative value indicates a low interest (a low FCI) or a high interest (a high FCI), and correlations between FCI and individual item responses can indicate what experiences and interests are most predictive of an interest in pursuing a faculty career. The distributions of FCI and career interests indicate that the sample included women with a variety of choice goals (Figure 2). Moreover, these distributions suggest that our participant recruitment methods did not give preference to those who hold only a strong interest in faculty positions.

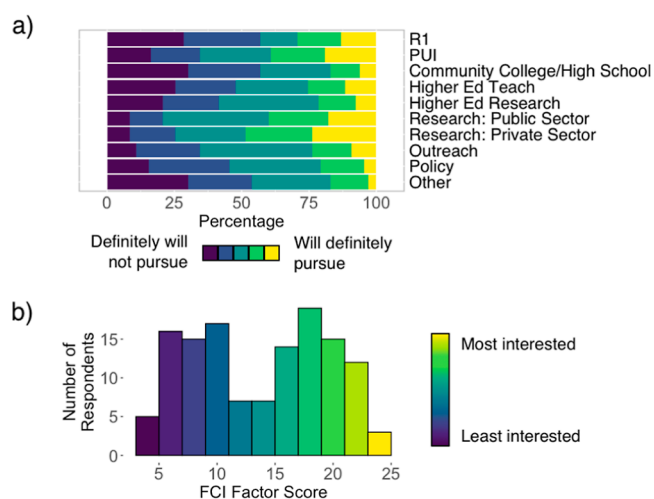


Figure 2. (a) Career interests of survey participants from a given list of possibilities. (b) Distribution of FCI factor scores.

Following the FCI factor construction, Spearman rho correlations were computed between FCI and every other survey item (excluding demographics). The Spearman rho correlation was chosen because it is a nonparametric statistic appropriate for the ordinal nature of Likert scale data. All correlations reported herein differ significantly (statistically) from zero ($\alpha = 0.022$, following a Benjamini–Hochberg correction, see the Supporting Information) unless otherwise noted and are expressed, herein, in terms of effect size: $\rho \leq 0.1$ is of a negligible size, $\rho = 0.1–0.3$ is small, $\rho = 0.3–0.5$ is medium, and $\rho \geq 0.5$ is large. As all survey items were worded affirmatively; meaningful correlations between an item and FCI (i.e., those statistically different than zero and of a medium/large effect size) indicate that respondents who score low on the item have low interest in faculty careers, and that respondents who score high on the item have a high interest. Finally, meaningful correlations were examined for themes in what respondents considered important, unimportant, attractive, and unattractive. The themes that resulted from this analysis are discussed below.

RESULTS AND DISCUSSION

The following section is organized as a series of themes that arose from viewing the results corpus through an SCCT lens rather than by an SCCT construct. Broadly, the themes

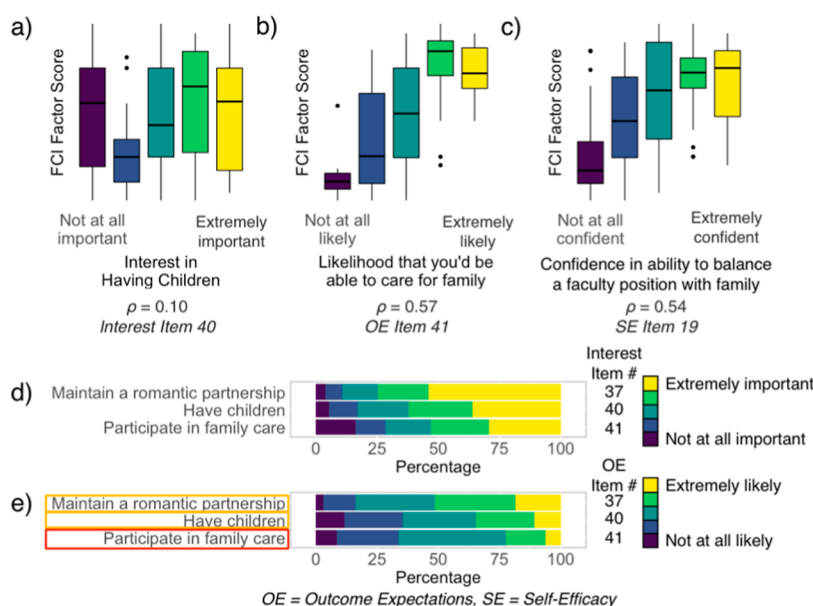


Figure 3. (a) Respondents' FCI based on their interest in having children during their career. (b) Respondents' FCI based on perceptions of the likelihood that they would be able to care for family if they were in a faculty position. (c) Respondents' FCI based on their confidence that they would be able to successfully balance a faculty position with the desire to spend time with family. (d) Respondents' interests in maintaining a romantic partnership, participating in family care, and having children during their careers. (e) Respondents' outcome expectations about the likelihood of each item if they were to pursue a faculty position. Orange boxes indicate a Spearman rho correlation of a medium effect size with FCI; a red box indicates a correlation of a large effect size.

discussed here follow similar patterns wherein we explore correlations with FCI that arose, trace the correlations to interests that our respondents hold, compare those interests to what self-efficacy and outcome expectations they hold, and hypothesize about learning experiences that may have shaped those beliefs. While many studies based on SCCT use the framework in a quantitative fashion to build structural equation models, there are also several that use SCCT to make sense of qualitative themes in the same way that this work does.^{25,43,44}

Theme 1

Respondents who want to have children and families are still interested in faculty positions; ones who feel they will not have time to care for those children and families are not.

One prominent theme in discussions around women in faculty positions is family, including care for children and partners. We certainly found a high interest in those themes, but there is less of a correlation with FCI than expected. Certainly, 36% of respondents indicated that they were "extremely interested" in having children, with an additional 26% indicating they were "very interested" (Figure 3d). However, there was no meaningful correlation between interest in having children and FCI, $\rho(130) = 0.10$, $p = 0.26$ (Figure 3a). If women were choosing not to pursue faculty positions due to an interest in having children, we would expect a large, negative correlation, but this was not the case. Items more meaningfully correlated with FCI (i.e., those of a large effect size) included whether respondents believed it was likely that they would be able to care for family if they got a faculty position (Figure 3b) and how confident they were that they would be able to balance a faculty position with time for family to their satisfaction (Figure 3c). Additionally, outcome expectations about the likelihood that participants would be able to have children and maintain a romantic relationship correlated with FCI with medium effect sizes (Figure 3e). To map these trends back onto Figure 1, strong negative outcome

expectations combined with a large positive interest in family care are reflected in a low FCI (intent to pursue a faculty career choice goal).

The correlations between FCI and outcome expectations about support and a lack of correlation between FCI and interest in having children suggest that the women being excluded from faculty positions are not the ones interested in having children. Rather, the women being excluded are those who hold the lowest expectations for the support and flexibility that they will receive from their departments. Furthermore, the support of family and maintenance of romantic relationships appear to be just as important as having children (if not more so). This applies both in terms of general interest in each item and in terms of each item's relationship to FCI (Figure 3d).

The important distinction between women who have an interest in having children being excluded versus women who feel they will be supported in caring for their children or family has several implications. First and foremost, it means the onus for fewer women applying to faculty positions should not be placed on women for wanting to have children: rather, departments should be responsible for having policies that will support women once they get there. Second, it helps to clarify which women are currently being excluded: they are the ones who do not expect support and the ones who expect that they will have little time, money, or resources to care for family. There is ample evidence that women with intersecting marginalized identities, and especially women of color, are particularly unsupported by academic departments.^{45–48} This marginalization due to their intersectional identity is sometimes referred to as the "double bind," reflecting the particular exclusion of those individuals.^{44,49} Therefore, it is likely that this group of excluded women disproportionately contains women of color, queer women,^{50,51} women with disabilities,^{52,53} and other women with multiple marginalized identities. Finally, the women in our study are focused on

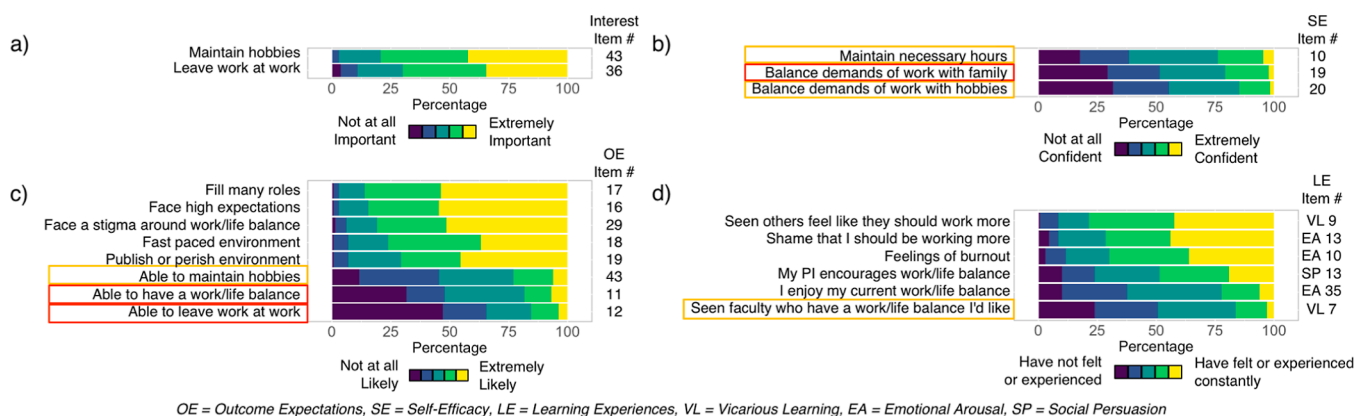


Figure 4. For all items, red boxes indicate Spearman rho correlations of a large effect size with FCI, and orange boxes indicate those of a medium effect size. (a) Respondents' interests in each item during their career. (b) Respondents' confidence that they would be able to do each task successfully if they were in a faculty position. (c) Respondents' expectations that they would encounter or experience each item if they were in a faculty position. (d) How frequently respondents have experienced each item during graduate school.

caring for their significant others and extended families as much or more than they are focused on having children. Therefore, it is important to provide not only support for childcare and similar programs but also flexibility in ways that allow women to maintain relationships.

Theme 2

Respondents want balance and do not expect it; also, they have not experienced it.

Another theme that arose was a perception of faculty positions being associated with a culture of overwork and high expectations, accompanied by a parallel theme of a desire for a balance between life and work. Roughly half of the respondents report that they believe it would be "extremely likely" for them to be expected to fill many roles, face high expectations, encounter a stigma (the word used by interview participants) favoring the work side of work–life balance, and face a fast-paced, publish-or-perish culture (Figure 4c). These expectations seem to come from vicarious learning experiences: almost half of women report that they "constantly" witness other graduate students feeling like they should work more, and 24% of respondents report never seeing a faculty member with a work–life balance that they would be content with (Figure 4d). Furthermore, women indicated that they had relatively low expectations for the potential to participate in hobbies, have a satisfactory work–life balance, and leave work at work if they were to enter a faculty position (Figure 4c). Half of the women expected that it was "not at all likely" they would be able to leave work at work. They also expressed that they were not very confident that they would be able to maintain a balance between their work and family or work and hobbies, reflecting the structural barriers that they would have to overcome to do so (Figure 4b). All these low expectations are in stark contrast to the strong interest women express in leaving their work at work and maintaining hobbies in their future careers (Figure 4a). As was the case for theme 1, theme 2 findings map back onto Figure 1 as negative outcome expectations, a low self-efficacy, and a high interest in work–life balance resulting in a low FCI (choice goal).

Like the trends with respect to family, the graduate women most likely to leave academic career paths are not those who are especially interested in work–life balance: the correlations between interest in leaving work at work and maintaining hobbies are not meaningful. Rather, the women who seek other

careers are the ones who are not confident that the structural barriers in academia will allow them to have any sense of balance in their lives. This is shown by the correlations of large effect size between FCI and both the expectation that a faculty position would allow for work–life balance, self-efficacy in one's ability to balance family with that position, and the expectation that work could be left at work. Again, the excluded women are those who expect faculty positions to not be compatible with other life goals.

Our results also illuminate what may have contributed to these expectations of graduate student women: many of the things they expect are also reported as common learning experiences. For instance, almost half report constantly seeing others feeling that they should work more and a similar number constantly experience burnout and shame that they should be working more (Figure 4d). There are a wide variety of experiences with whether PIs explicitly encourage women to maintain work–life balance, and a similarly wide range of experiences with how satisfied women are with their current work–life balance (Figure 4d). There are negative correlations of small effect size between these learning experiences and FCI (see Tables S7–S10 in the Supporting Information) that may have contributed to outcome expectations and interest in faculty positions, which also suggests that these experiences impact women's interests in faculty careers.

The key to this discussion about balance is that women are not trying to avoid hard work. That is, there is no correlation between wanting to have hobbies or leave work at work and interest in a faculty position. Instead, women who express less interest in a faculty position have less confidence that they will be able to do those things in a faculty position. Like the discussion about children, it is important to highlight here that the problem is not women wanting balance: rather, it is how departments respond to that desire. The implication is that departments must adopt a more holistic set of values related to success (i.e., hiring, promotion, and tenure) so that it becomes explicit that those requirements can be met even if faculty decide to spend time on the "life" side of work–life balance. This also includes implicit elements of department culture, such as the expectation to attend evening meetings and activities and the expectation that individuals respond to communications on weekends and in the evenings.

Furthermore, these expectations begin before women become faculty, as demonstrated by the prevalent learning

experiences surrounding high expectations and burnout. Therefore, the expectations of graduate students must also change. Guidelines, administrators, advisors, and co-workers that continue to normalize an unbalanced working schedule and stigmatize spending time on hobbies will solidify these expectations for graduate women and influence them to pursue careers outside of academia.

Theme 3

Women do not expect to be able to maintain their mental and physical health during their path to a faculty position or after they attain one.

Another trend of particular concern is that women reported relatively low self-efficacy in their ability to maintain both physical and mental health if they were to enter faculty positions. As with the expectations present regarding work–life balance, these expectations are informed by their learning experiences from graduate school. Namely, women frequently reported experiences of stress, anxiety, burnout, depression, a lack of belonging, and social isolation (Figure 5a), many of

Given how little time the women in our study feel they would have outside of work, it is unsurprising to see that they believe a faculty position would have a negative impact on their health. In a continuing trend from the previous two sections, this is not about women who have health concerns leaving academia: it is about women's concerns that the process of applying for faculty positions will cause them mental and physical harm. This concern is informed by their learning experiences in graduate school, and so those experiences need to change if more women are to enter faculty positions. The more that women experience and witness poor mental and physical health outcomes as graduate students, the less likely they will be to want to continue participating in an academic environment.

Theme 4

The women interested in faculty positions are the ones who want to teach and have had positive teaching experiences.

The next theme emerges from comparing responses regarding research, teaching, and mentoring. Kruskal–Wallis tests indicated statistically significant differences between the response distributions for those three topics in terms of interest [$H(2) = 11.21, p = 3.68 \times 10^{-3}, \epsilon^2 = 0.09$], outcome expectations about training [$H(2) = 26.91, p = 1.43 \times 10^{-6}, \epsilon^2 = 0.21$], and self-efficacy [$H(5) = 69.13, p = 1.55 \times 10^{-13}, \epsilon^2 = 0.54$] (Figure 6). Post-hoc Mann–Whitney tests with Bonferroni correction for multiple comparisons were used to compare all pairs of groups. Roughly half of the women were either “very” or “extremely” interested in all three topics (left panel); only mentoring and teaching appeared to differ meaningfully in response distribution (with a medium effect size). However, their outcome expectations regarding training indicate that they expect more training in research than in mentoring and teaching (with a medium effect size, middle panel). Oddly, this still left women with lower self-efficacy regarding research than either mentoring or teaching (with a strong effect size, right panel).

Also of note is that 4 of the 10 correlations between a survey item and FCI of a large effect size concerned teaching, mentoring, and students. Namely, these items were an interest in mentoring, an interest in teaching in a classroom, an interest in forming relationships with students, and confidence in one's ability to form relationships with students (Table S4, Supporting Information). There were also correlations of a medium effect size between FCI and whether a person has had enjoyable or exciting teaching experiences. These all suggest that women who are considering moving away from academia are also those who have less interest in teaching (which is understandable) and those who have had poor teaching experiences.

Interestingly, low expectations for sufficient mentoring and teaching training do not translate to a lower self-efficacy. However, this does not capture how graduate students currently feel about their abilities. For instance, if a student were particularly confident in their current teaching abilities, they may feel that they will meet teaching expectations without additional training. Since the mitigation of the effects of future training depends on past experiences, it is reasonable that positive teaching experiences during graduate school have a strong effect on whether an individual has an interest in teaching and, therefore, whether they wish to continue to a faculty position. Putting time and resources into making sure women have successful and enjoyable teaching experiences

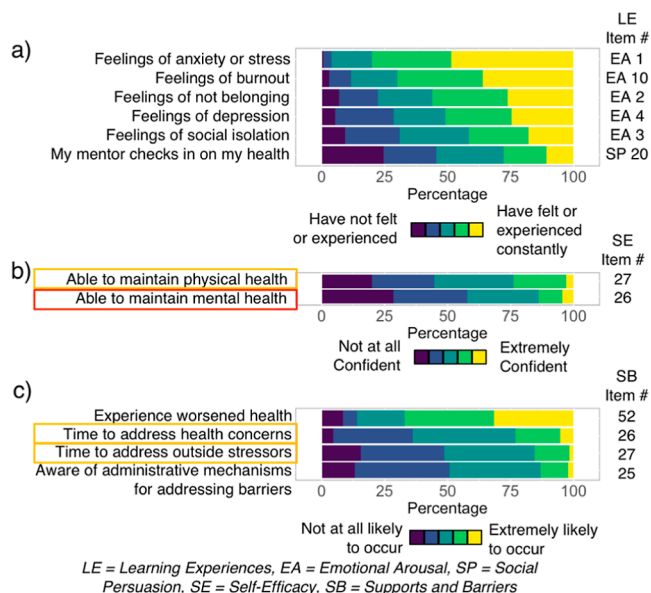


Figure 5. For all items, red boxes indicate a Spearman rho correlation of a large effect size with FCI, and orange boxes indicate those of a medium effect size. (a) How frequently respondents have experienced each item during graduate school. (b) Respondents' confidence that they would be able to do each task successfully if they were in a faculty position. (c) How much respondents expect they would face each support or barrier between now and earning a faculty position.

which had negative correlations of a small effect size with FCI. Many other sources have also reported on these mental health trends among graduate students in recent years^{54,55} and the effects it has on women's persistence in STEM.⁵⁶

Equally relevant to the question of why women choose to avoid academic positions is the correlation of a medium effect size between FCI and how much respondents predicted they would have time to deal with health or outside stressors (Figure 5b). An alarming number of graduate women also predicted they would experience worsened health if they were to pursue a faculty position—even if they believed a future position would support their health, they believe they would need to sacrifice health to get there (Figure 5c).

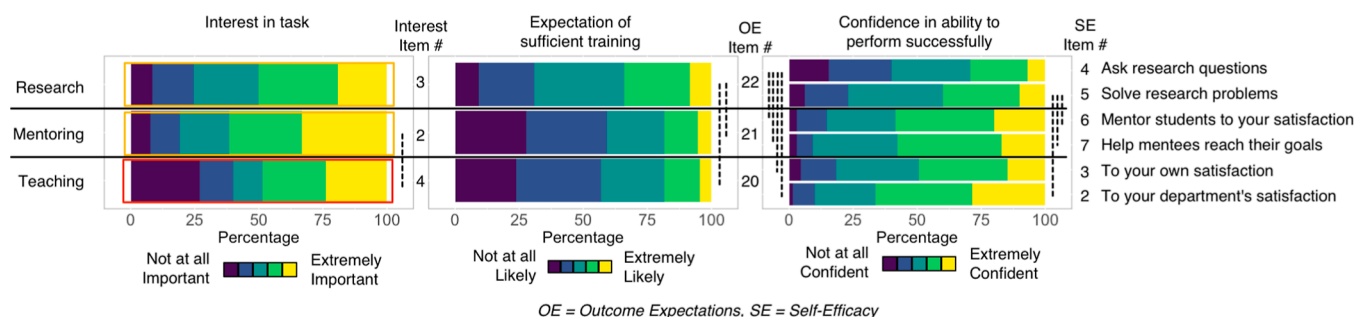


Figure 6. For all items, red boxes indicate a Spearman rho correlation of a large effect size with FCI, and orange boxes indicate those of a medium effect size. Dashed lines indicate statistically significant pairwise differences according to post-hoc Mann–Whitney tests with appropriate Bonferroni corrections. Left panel: respondents' interests in each item during their career. Middle panel: whether respondents expect they would receive sufficient training in each category if they were to enter a faculty position. Right panel: how confident respondents are that they would be able to complete each responsibility if they were to enter a faculty position.

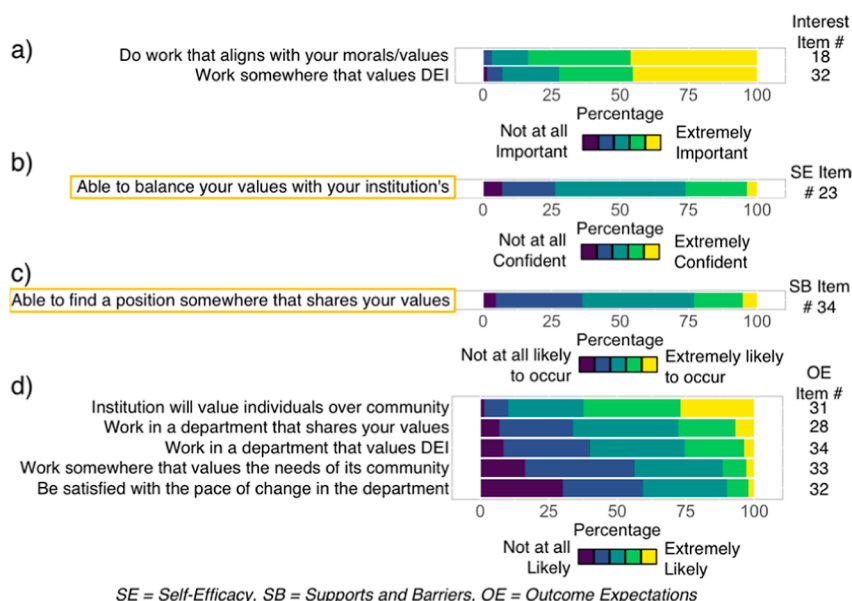


Figure 7. Orange boxes indicate a Spearman rho correlation of medium effect size between the indicated item and FCI. (a) Respondents' interests in each item during their career. (b) Respondents' confidence that they would be able to do each task successfully if they were in a faculty position. (c) Respondents' expectation that the item would occur between now and obtaining a faculty position (d) Respondents' expectations that they would encounter or experience each item if they were in a faculty position.

may, therefore, help promote interest in faculty positions by improving women's self-efficacy toward teaching. Furthermore, the high confidence in teaching ability despite low expectations of training may reflect that women perceive their departments to place a low value on teaching responsibilities and that their teaching does not have to be high quality to meet expectations. The disconnect between how respondents value teaching and how they perceive institutions to value teaching may also contribute to a low interest in faculty positions.

Theme 5

Women want to work with a department that shares their morals and values but do not expect that to be achievable.

Additional interests that women reported as principal to their future careers were working for an institution that shared their morals and values as well as working for a department that valued and took steps to improve diversity, equity, and inclusion (Figure 7a). For both interests, 45% of women reported these as "extremely important," with an additional 38% ranking an alignment of morals as "very important" and 27% ranking a focus on DEI as "very important."

However, similar to previous themes, the expectations for these desires to become a reality were relatively low. Most pointedly, women had very low outcome expectations that they would be satisfied by the pace of change in their departments, and likewise, low expectations that a department they worked for would change to meet the needs of its faculty, staff, and students (Figure 7d). There is a distinct contrast between these low expectations about department policy shifting to meet the needs of a community and the correlation of a medium effect size between interest in shaping department policy and FCI. Specifically, it indicates that women who express an interest in faculty positions are likely to have an interest in changing department policy, and yet they expect their efforts to yield little change. Similar to other themes, the women who do not believe departments will meet the needs of their communities are the ones who will likely be excluded by a slow-moving change.

Respondents also reported low outcome expectations that they would be able to work for a department that aligns with their values and morals if they were to start a faculty position,

with similar results regarding expectations that the department they worked for would value and take steps to support diversity, equity, and inclusion (Figure 7d). Women also reported a low confidence in their ability to balance their values with those of their institution if they were to be in a faculty position (Figure 7b). Finally, two-thirds of respondents indicated that they thought it was “very” or “extremely” likely that the institution they worked for would value individual achievements and progress over those of the community, which was a drawback that several participants mentioned during interviews. These results support the idea that women do not believe that departments value a sense of community and support.

As noted in Figure 7, there are also several correlations of a medium effect size between FCI and the items mentioned above: outcome expectations regarding whether a department would change to meet the needs of its community, support DEI efforts, and align with an individual’s morals and values, as well as self-efficacy regarding one’s ability to maintain a satisfactory balance with their department’s values. All of these reiterate the tenor of the results presented thus far: the women leaving are not the ones with differing morals and values or even strong morals and values, but rather the ones who do not feel their departments will support them going forward according to their own morals and values. This aligns with the SCCT framework wherein interests and outcome expectations for whether those interests will be achievable both influence choice goals.

It is worth noting that these correlations do not specify which values or morals respondents feel are unlikely to be shared by their departments. However, the other prominent findings of this work are likely candidates for what women feel would be lacking: support for people caring for families, support for a balanced life, care for mental and physical health, and on a more academic note, and the recognition and training of teaching skills instead of just research. Additionally, women indicate that they expect the pace of change to be slow. While this is expected within academic behemoths (particularly ones controlled by the government), departments can work to streamline the processes of ascertaining the needs and values of their communities and then shifting departmental policies to match those needs and values.

Theme 6

This survey is not an appropriate tool to highlight the stories of all women.

Alongside the validation of this survey as a tool for connecting women’s experiences, goals, and observations to their career choices, it is important to highlight where it falls short. As detailed in the “Survey Development and Deployment” section, care was taken to ensure that the survey included items that reflected the experiences of women who identified as Black, Hispanic, or Latinx because there is evidence that those women face unique challenges as a result of their intersecting marginalized identities.^{43–47} These women were explicitly included in the interview processes, and all experiences they shared were included in the survey questions (none were cut for not being shared by other participants). Furthermore, one of the two cognitive interview participants also identified as Black, and she indicated that she felt the survey accurately captured her experiences. Finally, survey participants were recruited from the same student group whose members participated in interviews with the hope that those

who interviewed would convey the trust built with the study team to other potential survey participants.

However, only three survey participants identified as Black, which means that the items important to reflecting their unique stories were not common enough to appear in the overall analysis, and there were too few responses to report or analyze those responses separately. Commonly, this would be reported in a limitations section as a limitation of the sample population. However, we argue that this is a limitation of the study design: because of the chosen study design, important stories are missing from the quantitative survey results or hidden within broader themes. For instance, one interview participant shared her experience with an orientation training:

“We had a microaggressions training that was just kind of a, not as effective as it should have been. Um or I think it was more harmful to the students of color who were in the room versus like educational and impactful. Um so that’s definitely a tough experience that has always kind of snuck up on me.”

She then described the departmental response to the staff member in whom she confided: “I know that she did talk to, um, I think to people who kind of like organize it, and to see if maybe, there’s any way we can change it. But, um, when she got back to me, it seemed like, uh, they were kind of like things are already set in stone, and we can’t make too many changes. Um, so kind of like, we’ve done this for years, so why change it now?”

Through the lens of the SCCT model shown in Figure 1, this experience shows an emotional arousal learning experience (a harmful TA training and departmental reluctance to change to protect her) that could feed into the participant holding outcome expectations that future departments would be similar. The themes of slow change and impact on mental health both showed up in our results, but this manifests in a unique way for women of color that is not apparent in the survey analysis. This is further apparent in another moment with a different interview participant, who shared the following:

“I think the whole thing about my like Black face, white space is kind of the, the people before you will be suffering somehow in my specific group of people, um, Black people, to be specific, um, you know, people had to go to those protests and get hosed down. I mean, they didn’t have to, but like they did, you know, and they did that sacrifice. And it costs a lot of people a lot of things. And I think for me, my protest, it kind of, it kind of aims at a department that is toxic to me, like, I will put a lot on the line, and just being in academic spaces is already hard enough, you know, um, I just say that is my sacrifice. And I am not going to just be hardcore and go like, at the very front of the protest line, or whatever, like right in front of the SWAT team, or, you know, I’m giving kind of a parallel story here. But I, I have a limit on where I’m going to stay independent in that crowd.”

Again, this likely ended up as part of theme 3, centered on mental health, and theme 5, working for a department that shares an individual’s morals and values. However, the degree to which it manifests and the specific feelings encompassed in that theme are hidden because the survey item “Feeling like grad school is like a fight” did not resonate with as many participants as “mental health.”

Theme 6 emphasizes that even though the survey may have the ability to capture the experiences of Black, Hispanic, and Latinx women, that becomes irrelevant if the structure of the study itself keeps their responses in the minority. Moreover,

this discussion highlights the need for future qualitative work to explore those narratives more deeply.

■ IMPLICATIONS

The overarching message communicated by this work is that largely, graduate women's interests in leaving academia are not due to a trait or interest that they hold. Rather, a low FCI is more closely tied to the outcome expectations and self-efficacy that women hold about faculty positions. The learning experiences recounted above suggest that women feel they do not receive the support they need in graduate school and, therefore, expect to receive little support as faculty members. Overall, this work highlights the ways in which learning experiences inform graduate students' outcome expectations and, therefore, inform their interests and career choice goals (Figure 1). The connection between graduate school experiences and outcome expectations about faculty positions suggested by our findings means that changes need to be made at both the graduate student and faculty levels.

First, graduate programs need to shift to support women better in the areas mentioned above. This would include clear policies around family, time off, and health that normalize women taking time to address these concerns and standardize the policies for doing so in ways that do not put women at a disadvantage for needing to address other priorities. This may include adjusting timelines for graduation or shifting the requirements for graduation from a program to make them more accommodating of disruptions. Additionally, while changes in individual research group policies are a step in the correct direction, these changes ultimately need to be codified at the department or institution level for the protection of graduate students. Results also suggest that curating positive teaching experiences may encourage more women to pursue faculty positions.

Second, graduate students' perceptions of faculty positions are based on the reality of faculty positions, so that reality needs to change if women are to become more interested. Therefore, in addition to policies that allow graduate students flexibility, compassion, and understanding when they encounter outside stressors, these results suggest that similar policies need to be implemented for faculty. Again, these would include shifting requirements for hiring and tenure that do not penalize women for taking time to address family, mental and physical health, and other concerns. The vicarious learning that women experience during graduate school by observing their advisors has an important influence on their beliefs and eliminating the exclusion of women at all levels is important if women are to be invited into academia.

It is also important to acknowledge that policy change at either level likely will not be sufficient on its own: there will need to be an accompanying culture shift to support people in taking advantage of those policies. In places where flexibility does exist, people may still choose not to take advantage of that flexibility (e.g., family leave) for a fear that others around them may perceive them as weak or unsuccessful. Even when that support exists, the current competitive culture of academia leads to scenarios where 42% of women report constantly feeling the need to compare their success to the success of others (Figure 8). A more community-focused culture would likely help mitigate this pressure.

Cultural and policy shifts at the department level will also need to be supported by corresponding shifts by funding agencies and metrics used for national and global recognition.

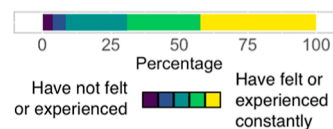


Figure 8. Responses to performance accomplishment item #12: The extent to which respondents report experiencing the need to compare their success to those of their peers.

Just as graduate students operate within a department-level system, departments operate within a greater context that values certain metrics. Along with departments giving women support in upholding their values, both departments and funding agencies will need to place a higher value on activities that women pursue, such as mentoring, outreach, science communication, and departmental service work. This would mean giving those activities a greater weight in decisions about admissions, hiring, funding, tenure, and awards. We also recognize that these shifts will need to be tailored to local environments and invite others to use and adapt the methods shared herein to explore the needs of their particular environments.

■ LIMITATIONS

One major limitation of this work has been discussed at length in theme 6. Namely, this was not an appropriate study design to elicit the stories of women with intersecting marginalized identities. Furthermore, similar to our previous survey work,³ this survey also was not designed to address the experiences of women who hold many other marginalized identities, including indigenous women, queer women, trans women, and disabled women. All these groups face unique struggles in graduate school, but there was not sufficient literature regarding those narratives as they apply specifically to the experiences of people holding each intersectional identity in chemistry faculty positions to incorporate them into this study. Additionally, the experiences of those individuals would require a different set of questions targeted specifically at their experiences and, therefore, would be best addressed in a separate and targeted study. We strongly encourage researchers interested in furthering this work to explore the barriers and supports present for any of those groups of women.

■ CONCLUSIONS

The conclusion that women feel unsupported in academia and STEM is not a new one. What this work does is emphasize the connection between the feelings of chemistry graduate students and the low number of women applying to faculty positions in chemistry. This suggests that to bring more women into those positions, departments need to support not only their faculty but also the graduate students that are in the process of choosing career paths. The academic community does not consist only of faculty, and fostering growth requires care for all participants. Finally, when considering the implications of this work, it is important to consider that when women indicate that they want a department or institution to share their values, those values must manifest not only as performative acts of support but also as policy changes that adjust the distribution of money, awards, admission, hiring, and promotion in ways that tangibly value the skills and ideals that women find most important.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at <https://pubs.acs.org/doi/10.1021/jacsau.2c00175>.

Additional data and figures referred to in the manuscript text (response distributions of survey items, FCI factor computation, and correlation analyses for all hypothesized item-FCI relationships); full text of survey instrument; and interview protocol (PDF)

■ AUTHOR INFORMATION

Corresponding Authors

Morgan E. Howe – Department of Chemistry, University of Wisconsin, Madison, Wisconsin 53706, United States;

orcid.org/0000-0001-7274-6379; Email: mhowe4@wisc.edu

Samuel Pazicni – Department of Chemistry, University of Wisconsin, Madison, Wisconsin 53706, United States;

orcid.org/0000-0002-4775-7794; Email: sam.pazicni@chem.wisc.edu

Author

Melony M. Kim – Department of Chemistry, University of Wisconsin, Madison, Wisconsin 53706, United States

Complete contact information is available at:

<https://pubs.acs.org/doi/10.1021/jacsau.2c00175>

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

Support for this research was provided by the University of Wisconsin–Madison, Office of the Vice Chancellor for Research and Graduate Education with funding from the Wisconsin Alumni Research Foundation. Contributions by M.M.K. were supported by the National Science Foundation under grant no. CHE-2001611, the NSF Center for Sustainable Nanotechnology. Finally, the authors wish to thank Drs. Ramón Barthelemy, Rebecca Gibbons, and Megan Grunert Kowalske for critical and thoughtful feedback on survey development.

■ ABBREVIATIONS

STEM science, technology, engineering, and mathematics
SCCT social cognitive career theory
FCI faculty career interest
OE outcome expectations
SE self-efficacy
LE learning experiences
SB supports and barriers

■ REFERENCES

- (1) National Center for Science and Engineering Statistics: Women, Minorities, and Persons with Disabilities in Science and Engineering. <https://nces.gov/pubs/nsf21321/data-tables> (accessed March 12, 2022).
- (2) Open Chemistry Collaborative in Diversity Equity: Oxide 2019 Faculty Demographics Survey. http://oxide.jhu.edu/src/data/gender/OXIDE_AY16-17_gender_demographics_data_by_alpha.pdf (accessed March 12, 2022).
- (3) Howe, M. E.; Schaffer, L. V.; Styles, M. J.; Pazicni, S. Exploring Factors Affecting Interest in Chemistry Faculty Careers Among Graduate Student Women: Results from a Local Pilot Study. *J. Chem. Educ.* **2021**, *99*, 92–103.
- (4) National Academies of Sciences, Engineering, and Medicine. *Promising Practices for Addressing the Underrepresentation of Women in Science, Engineering, and Medicine: Opening Doors*; The National Academies Press: Washington, DC, 2020.
- (5) Newsome, J. L. *The Chemistry PhD: The Impact on Women's Retention*; Royal Society of Chemistry: London, U.K., 2008; p 40.
- (6) Greene, J.; Stockard, J.; Lewis, P.; Richmond, G. Is the Academic Climate Chilly? The Views of Women Academic Chemists. *J. Chem. Educ.* **2010**, *87*, 381–385.
- (7) Grunert, M.; Dissertation, Ph.D. *Women's Career Choices in Chemistry: Motivations, Perceptions, and a Conceptual Model*; Purdue University: West Lafayette, 2010.
- (8) Grunert, M. L.; Bodner, G. M. Underneath it all: gender role identification and women chemists' career choices. *Sci. Educ. Int.* **2011**, *22*, 292–301.
- (9) Grunert, M. L.; Bodner, G. M. Finding fulfillment: women's self-efficacy beliefs and career choices in chemistry. *Chem. Educ. Res. Pract.* **2011**, *12*, 420–426.
- (10) Markus, H.; Nurius, P. Possible Selves. *Am. Psychol.* **1986**, *41*, 954–969.
- (11) Sears, A. L. W. Image Problems Deplete the Number of Women in Academic Applicant Pools. *J. Women Minorities Sci. Eng.* **2003**, *9*, 169–182.
- (12) Gibbs, K. D., Jr.; Griffin, K. A. What Do I Want to Be with My PhD? The Roles of Personal Values and Structural Dynamics in Shaping the Career Interests of Recent Biomedical Science PhD Graduates. *CBE-Life Sci. Educ.* **2013**, *12*, 711–723.
- (13) Vincent-Ruz, P.; Schunn, C. D. The nature of science identity and its role as the driver of student choices. *Int. J. STEM Educ.* **2018**, *5*, 48.
- (14) Hosbein, K. N.; Barbera, J. Development and evaluation of novel science and chemistry identity measures. *Chem. Educ. Res. Pract.* **2020**, *21*, 852–877.
- (15) Hosbein, K. N.; Barbera, J. Alignment of theoretically grounded constructs for the measurement of science and chemistry identity. *Chem. Educ. Res. Pract.* **2020**, *21*, 371–386.
- (16) Rüschenpöhler, L.; Markic, S. Secondary school students' acquisition of science capital in the field of chemistry. *Chem. Educ. Res. Pract.* **2020**, *21*, 220–236.
- (17) Sabella, M. S.; Mardis, K. L.; Sanders, N.; Little, A. The Chi-Sci Scholars Program: Developing Community and Challenging Racially Inequitable Measures of Success at a Minority-Serving Institution on Chicago's Southside. *Phys. Teach.* **2017**, *55*, 350–355.
- (18) Lent, R. W.; Lopez, F. G.; Bieschke, K. J. Mathematics Self-Efficacy: Sources and Relation to Science-Based Career Choice. *J. Couns. Psychol.* **1991**, *38*, 424–430.
- (19) Lent, R. W.; Brown, S. D.; Hackett, G. Toward a Unifying Social Cognitive Theory of Career and Academic Interest, Choice, and Performance. *J. Vocat. Behav.* **1994**, *45*, 79–122.
- (20) Lent, R. W.; Brown, S. D.; Sheu, H.-B.; Schmidt, J.; Brenner, B. R.; Gloster, C. S.; Wilkins, G.; Schmidt, L. C.; Lyons, H.; Treistman, D. Social Cognitive Predictors of Academic Interests and Goals in Engineering: Utility for Women and Students at Historically Black Universities. *J. Couns. Psychol.* **2005**, *52*, 84–92.
- (21) Lent, R. W.; Brown, S. D. On Conceptualizing and Assessing Social Cognitive Constructs in Career Research: A Measurement Guide. *J. Career Assess.* **2006**, *14*, 12–35.
- (22) Bandura, A.; National Institute of Mental Health. *Social Foundations of Thought and Action: A Social Cognitive Theory*; Prentice-Hall, 1986.

- (23) Avargil, S.; Kohen, Z.; Dori, Y. J. Trends and perceptions of choosing chemistry as a major and a career. *Chem. Educ. Res. Pract.* **2020**, *21*, 668–684.
- (24) Pugh, K. J.; Paek, S. H.; Phillips, M. M.; Sexton, J. M.; Bergstrom, C. M.; Flores, S. D.; Riggs, E. M. Predicting academic and career choice: The role of transformative experience, connection to instructor, and gender accounting for interest/identity and contextual factors. *J. Res. Sci. Teach.* **2021**, *58*, 822–851.
- (25) Borders, L. D.; Wester, K. L.; Driscoll, K. H. Researcher Development of Doctoral Students: Supports and Barriers Across Time. *Couns. Educ. Superv.* **2020**, *59*, 297–315.
- (26) Seo, G.; Ahn, J.; Huang, W.-H.; Makela, J. P.; Yeo, H. T. Pursuing Careers Inside or Outside Academia? Factors Associated With Doctoral Students' Career Decision Making. *J. Career Dev.* **2020**, *48*, 957–972.
- (27) Sax, L. J.; Lehman, K. J.; Barthelemy, R. S.; Lim, G. Women in physics: A comparison to science, technology, engineering, and math education over four decades. *Phys. Rev. Phys. Educ. Res.* **2016**, *12*, 020108.
- (28) Medugorac, V.; Sverko, I.; Babarovic, T. Careers in sustainability: an application of Social Cognitive Career Theory. *Int. J. Educ. Vocat. Guid.* **2020**, *20*, 477–499.
- (29) Chan, C.-C. Factors Affecting Career Goals of Taiwanese College Athletes From Perspective of Social Cognitive Career Theory. *J. Career Dev.* **2020**, *47*, 193–206.
- (30) Estrada, M.; Hernandez, P. R.; Schultz, P. W. A Longitudinal Study of How Quality Mentorship and Research Experience Integrate Underrepresented Minorities into STEM Careers. *CBE-Life Sci. Educ.* **2018**, *17*, ar9.
- (31) Connolly, M. R.; Lee, Y.-G.; Savoy, J. N. The Effects of Doctoral Teaching Development on Early-Career STEM Scholars' College Teaching Self-Efficacy. *CBE-Life Sci. Educ.* **2018**, *17*, ar14.
- (32) Garcia, N. M.; López, N.; Vélez, V. N. QuantCrit : rectifying quantitative methods through critical race theory. *Race Ethn. Educ.* **2018**, *21*, 149–157.
- (33) Gillborn, D.; Warmington, P.; Demack, S. QuantCrit: education, policy, 'Big Data' and principles for a critical race theory of statistics. *Race Ethn. Educ.* **2018**, *21*, 158–179.
- (34) López, N.; Erwin, C.; Binder, M.; Chavez, M. J. Making the invisible visible: advancing quantitative methods in higher education using critical race theory and intersectionality. *Race Ethn. Educ.* **2018**, *21*, 180–207.
- (35) Ladson-Billings, G.; Tate, W. F. Toward a Critical Race Theory of Education. *Teach. Coll. Rec.* **1995**, *97*, 47–68.
- (36) Lent, R. W.; Brown, S. D.; Talleyrand, R.; McPartland, E. B.; Davis, T.; Chopra, S. B.; Alexander, M. S.; Suthakaran, V.; Chai, C.-M. Career Choice Barriers, Supports, and Coping Strategies: College Students' Experiences. *J. Vocat. Behav.* **2002**, *60*, 61–72.
- (37) Crenshaw, K. Demarginalizing the Intersection of Race and Sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory, and Antiracist Politics. *Univ. Chic. Leg. Forum* **1989**, *1989*, 139–167.
- (38) Museus, S. D.; Griffin, K. A. Mapping the Margins in Higher Education: On the Promise of Intersectionality Frameworks in Research and Discourse. *N. Dir. Inst. Res.* **2011**, *2011*, 5–13.
- (39) *Standards for Educational and Psychological Testing*; American Educational Research Association, American Psychological Association, and National Council for Measurement in Education: Washington, DC, 2014.
- (40) Arjoon, J. A.; Xu, X.; Lewis, J. E. Understanding the State of the Art for Measurement in Chemistry Education Research: Examining the Psychometric Evidence. *J. Chem. Educ.* **2013**, *90*, 536–545.
- (41) Reeves, T. D.; Marbach-Ad, G. Contemporary Test Validity in Theory and Practice: A Primer for Discipline-Based Education Researchers. *CBE-Life Sci. Educ.* **2016**, *15*, rm1.
- (42) Freedman, B. J. For Debate... Caucasian. *Br. Med. J.* **1984**, *288*, 696–698.
- (43) Newton, N.; Hunter-Johnson, Y.; Niu, Y. Exploring the Influence of Job Satisfaction Upon the Retention of Bahamian Special Educators. *J. Educ.* **2022**, *202*, 58–68.
- (44) Li, J.; Mau, W.-C. J.; Chen, S.-J.; Lin, T.-C.; Lin, T.-Y. A Qualitative Exploration of STEM Career Development of High School Students in Taiwan. *J. Career Dev.* **2021**, *48*, 120–134.
- (45) Eaton, A. A.; Saunders, J. F.; Jacobson, R. K.; West, K. How Gender and Race Stereotypes Impact the Advancement of Scholars in STEM: Professors' Biased Evaluations of Physics and Biology Post-Doctoral Candidates. *Sex. Roles* **2020**, *82*, 127–141.
- (46) Ong, M.; Wright, C.; Espinosa, L.; Orfield, G. Inside the Double Bind: A Synthesis of Empirical Research on Undergraduate and Graduate Women of Color in Science, Technology, Engineering, and Mathematics. *Harv. Educ. Rev.* **2011**, *81*, 172–209.
- (47) Kachchaf, R.; Ko, L.; Hodari, A.; Ong, M. Career-life balance for women of color: Experiences in science and engineering academia. *J. Divers. High. Educ.* **2015**, *8*, 175–191.
- (48) Turner, C. S. V. Women of Color in Academe: Living with Multiple Marginality. *J. High. Educ.* **2002**, *73*, 74–93.
- (49) Malcom, S. M.; Hall, P. Q.; Brown, J. W. *The Double Bind: The Price of Being a Minority Woman in Science*; American Association for the Advancement of Science: Washington, DC, 1976.
- (50) Mattheis, A.; De Arellano, D. C.-R.; Yoder, J. B. A Model of Queer STEM Identity in the Workplace. *J. Homosex.* **2020**, *67*, 1839–1863.
- (51) Yoder, J. B.; Mattheis, A. Queer in STEM: Workplace Experiences Reported in a National Survey of LGBTQA Individuals in Science, Technology, Engineering, and Mathematics Careers. *J. Homosex.* **2016**, *63*, 1–27.
- (52) Shingledecker, C.; Duerstock, B. From college to careers: Fostering inclusion of persons with disabilities in STEM. *Science* **2014**, *344*, 765.
- (53) Moriarty, M. A. Inclusive Pedagogy: Teaching Methodologies to Reach Diverse Learners in Science Instruction. *Equity & Excell. Educ.* **2007**, *40*, 252–265.
- (54) Gin, L. E.; Wiesensthal, N. J.; Ferreira, I.; Cooper, K. M. PhD Depression: Examining How Graduate Research and Teaching Affect Depression in Life Sciences PhD Students. *CBE-Life Sci. Educ.* **2021**, *20*, ar41.
- (55) Evans, T. M.; Bira, L.; Gastelum, J. B.; Weiss, L. T.; Vanderford, N. L. Evidence for a mental health crisis in graduate education. *Nat. Biotechnol.* **2018**, *36*, 282–284.
- (56) Wilkins-Yel, K. G.; Arnold, A.; Bekki, J.; Natarajan, M.; Bernstein, B.; Randall, A. K. "I can't push off my own Mental Health": Chilly STEM Climates, Mental Health, and STEM Persistence among Black, Latina, and White Graduate Women. *Sex. Roles* **2022**, *86*, 208–232.