The Differential Impact of the COVID-19 Pandemic on Female Graduate Students and Postdocs in the Chemical Sciences

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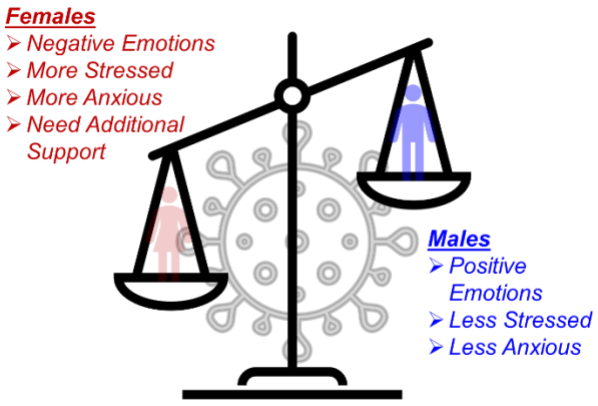
ABSTRACT

Over the past year and a half, the COVID-19 pandemic severely disrupted almost all aspects of life as people throughout the world were instructed to work-from-home. Scientific researchers, whose work is reliant on access to laboratory equipment, have been acutely impacted by these global changes. In this study, we surveyed graduate students and postdocs in the chemical sciences at a selected number of academic institutions in the United States. We found that many survey participants, especially women, experienced severely diminished research progress and increased anxiety levels during the COVID-19 pandemic. Through factor analysis and multiple regression modeling, we found that during this challenging time participants who reported greater levels of professional support also reported greater research progress and lower levels of anxiety. We also found that although advisors and departments provide some forms of professional support, there are other types of support that students and postdocs still desire. This phenomenon is magnified for female and underrepresented minority participants, as they need greater levels of professional support and place immense value on the quality of their work environments. Based on these results, we have identified some ways in which departments and advisors can provide the needed support for their graduate students and postdocs, thereby providing timeless advice that is applicable to improving academic work conditions not only during a global pandemic, but also in a post-pandemic world.

GRAPHICAL ABSTRACT



KEYWORDS

Graduate Education, Interdisciplinary, Collaborative, Career Counseling, Graduate Research, COVID-19.

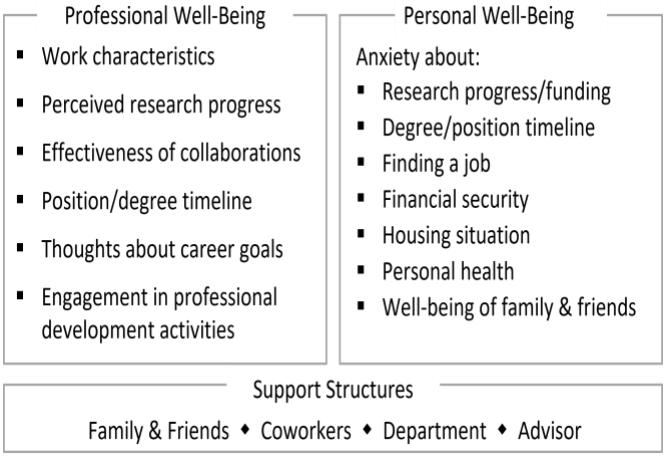
INTRODUCTION

Beginning in March 2020, many schools and academic research labs temporarily shut down to slow the spread of the novel coronavirus, SARS-CoV-2. The resulting COVID-19 pandemic has challenged many graduate students, postdocs, and faculty to continue pursuing their research at home without the resources that are often provided by university campuses. Although this disruption in research has affected everyone, it has not affected everyone equally.[1,2] Female scientists, scientists whose research primarily occurs at a lab bench, and scientists with children have experienced a substantial decline in their time devoted to research due to the stay-at-home orders.[3-5] These observations align with the broader body of literature highlighting the differential impact that the COVID-19 pandemic has had on women and caregivers.[6-11]

The pandemic-induced reduction in scientific research likely has a profound effect on the well-being of graduate students and postdocs, whose career progression is often predicated on experimental results. Furthermore, several studies have shown that students and young professionals (*ca.* 20–29 years old) are more susceptible to experiencing mental health challenges due to the COVID-19 pandemic than the general population.[7,9,10,12-15] Before the pandemic, stress and anxiety was already ubiquitous among students in graduate programs.[16-18] Female and underrepresented racial minority (URM)- broadly defined as non-White, non-Asian, students are more likely to experience these negative emotions and are more likely to experience mental health disorders than their male and non-URM peers.[19,20] One way to minimize the extent of mental health disorders among these minority groups is through a sturdy support structure from academic departments and advisors. Numerous studies have shown a correlation between graduate student anxiety and the strength of their relationship with their advisor; graduate students who report low anxiety levels also report strong relationships with their advisors and substantial support from their peers and friends.[21-26] In this way, advisors and departments have the opportunity to provide invaluable support to help graduate students and postdocs manage their anxiety. Notably, female and URM graduate students often report that they want more support from their advisor and department than their male and non-URM peers.[16,27] These support structures also help foster graduate students' and postdocs' sense of belonging, which is known to impact persistence and success in STEM fields.[28,29]

Understanding the ways in which departments and advisors can provide support for the needs of a diverse body of junior professionals, particularly as a result of a global crisis, is a valuable approach to mitigate the negative aspects of graduate school and thereby improve graduate student and postdoc well-being.[30,31] Towards this goal, we sought to understand how the COVID-19 pandemic has impacted graduate students and postdocs from different demographic groups within the chemical sciences. Given that anxiety is common among graduate students, we were interested in assessing participants' anxiety about their research, their finances (*e.g.*, job prospects), and their health before and during the COVID-19 pandemic. We refer to these collective measures of anxiety as participants' ***personal well-being***. We also assessed participants' ***professional well-being***, which we defined as participants' work

characteristics (*e.g.,* hours spent working), their perceived research progress, the effectiveness of research collaborations, and their thoughts on their degree/position timeline and their career goals. We were also interested in probing the ways in which participants' family and friends, coworkers, department, and advisors have supported them throughout the pandemic and how these support structures have impacted participants' personal and professional well-being (Scheme 1). By identifying the types of support participants want ,compared to the types of support they receive, we discovered that the types of support that received are not the ones they value most.[32] Notably, we found that female and URM participants want more support from their advisors and departments and have had higher anxiety levels than their male and non-URM peers throughout the pandemic. By analyzing the results of this study, we have recognized some ways in which departments and advisors can better assist their diverse population of graduate students. We believe this survey is a valuable resource to convey to graduate students and postdocs in the scientific community that they are not alone in dealing with anxieties about research progress, social isolation, and career progression as a result of this global crisis. Finally, much of the lessons learned from this survey can be extracted beyond COVID-19, improving graduate students' well-being in a post-pandemic world.



Scheme 1. Included items in the survey to examine professional well-being, personal well-being, and support structures.

MATERIALS AND METHODS

We surveyed graduate students and postdoctoral fellows within the Chemistry departments at fifteen academic institutions across the United States (Scheme 2). We sent out the survey to these institutions based on the selectivity of their Ph.D. program (ranked in the top 50 by U.S. News and World Reports) and their geographic location (*i.e.,* Northeast, South, Midwest, West Coast). The survey was emailed to chemistry departmental chairs and faculty to share with their graduate students and postdocs via email beginning October 1st and the survey was closed on December 2nd , 2020. Based upon the size of these departments, we estimated our survey response in each program to be on average 15%. A link to the survey can be found in the Supporting Information.

Scheme 2. Institutions Surveyed and participant demographics in this study.

At the beginning of the survey, participants were polled about the work-from-home period that occurred around March 2020. They were then asked a series of questions that probed their professional and personal well-being during the pandemic relative to their professional and personal well-being before the pandemic. Next, participants were presented with a series of questions about the ***extent of*** professional and personal support they have received from their advisor, coworkers, department, and family and friends before and during the pandemic. Furthermore, participants were queried about ***the type of*** support they have received from their advisor and their department and the importance of each support type. Next, participants were questioned about their thoughts and feelings about returning to lab after the work-from-home period. It is important to note that during this period of time, vaccines were still not available to the general public. Thus, even upon returning to lab, students were still unvaccinated and were required to socially distance, creating underlying additional stresses with a lack of social connection and collaboration. In the last section of the survey, we collected demographic data (gender and URM status) and other participant information including their academic status (graduate student vs. postdoc, year in Ph.D. program, completion of candidacy exam) and chemistry sub-field (organic, polymer, computational, physical, biological). We ended the survey with the following open response question: *"If you were to name a single thing that has been the most challenging for you since the start of the COVID-19 pandemic, what would it be?"* (See SI for details). The breakdown of participants who took the survey can be found in Scheme 2. The response rate from participants that considered themselves gender non-binary was too low to be included in the quantitative analysis, thus, our analysis

focused only on male and female genders. The demographic characteristics of our survey sample are in good agreement with the demographic characteristics of chemistry Ph.D. programs reported by the National Science Foundation.[33] Given the relatively small number of URM participants, it is possible that we may not observe statistically significant differences across URM status, but qualitatively there might well exist important differences.

All the analysis was conducted in R platform. For analyzing Likert scale questions, we used ordinal multivariable regression models as the dependent variables with categorical ordering (e.g. 5 level Likert scale from strongly agree to strongly disagree) . For analyzing binary questions (e.g. yes/no), we used logistic multivariable regression. We also used factor analysis and structural equation modeling to further explore the relationship between different variables. Given the small number of participants from each program, the data were analyzed all together without controlling for the institutions. In these quantitative analysis, gender and URM status were used as binary variables. We acknowledge the limitations of this approach to consider gender as a binary variable with only two levels of men and women and to group all racially marginalized students together. However, we did not have enough data points to include more nuance categorizations of these demographic variables in our analyses. For all the regression analyses, we used the simplest best fitting models to explore the data. To do so, we started with a basic additive model for each analysis that had gender and URM variables as well as other required predictors for a given analysis (e.g. time interval of during or before the work from home). Then to that model, we added the interaction terms of the included predictors one by one and tested whether the addition of each interaction term significantly improved the fit of the model. For the model comparison to examine the fit improvement, we used AIC values of models. To explore intersectionality, we tested whether the interaction between gender and URM would significantly improve the fit of a model. If the model fit improved significantly by including an interaction term, then we used that interactive model for our analysis. The details of the regression models are included in SI.

RESULTS AND DISCUSSION

Work Characteristics and Research Progress

We first asked survey participants to estimate the amount of time they spent working before the COVID-19 pandemic and during the work-from-home period. Due to the nature of research in the chemical sciences, we suspected that most participants would report a significant decrease in the amount of time working as a result of the COVID-19 pandemic. As expected, all participants reported working less during the work-from-home period ($b = -2.51$ (0.18), $p < 0.0001$, Figure 1) (SI,Table S1.1 and S1.2), and there was no difference based on gender ($p = 0.34$) or URM status ($p = 0.75$). Not surprisingly, most respondents also reported significantly less research progress during the work-from-home period (60% reported significantly less progress and 25% slightly less progress) with no difference based on gender ($p = 0.65$) or URM status ($p = 0.92$) (SI, Table S2.1 and S2.2, Figure S4). To better understand the challenges faced by graduate students and postdocs in their transition from working in a lab to working from home, we asked participants to rate the extent to which external factors (internet access, family living situation, health concerns, distractions, housing situation, time zone differences, quality of home office, childcare responsibilities, and family member care responsibilities) impacted their ability to work from home. Participants ranked the quality of their home office and distractions as the

greatest impediments to their work during the work-from-home period. Overall, female and URM participants believed that all listed external factors more negatively impacted their ability to work from home than their male and non-URM colleagues (b=0.19(0.06), p_{gender} = 0.001; b=0.39(0.04), p_{URM} <0.0001) (SI, Table S3.1 and S3.2).

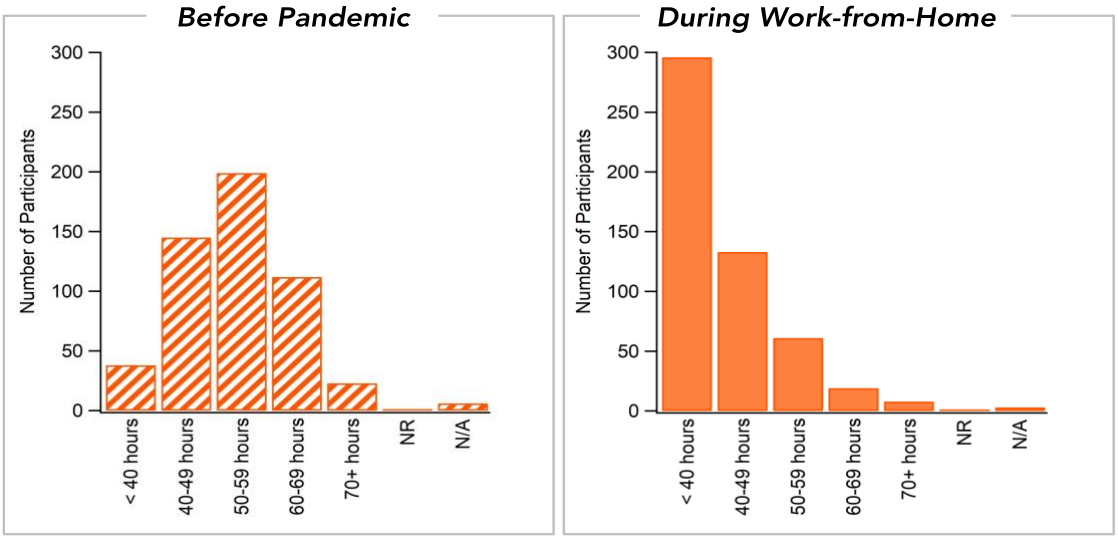


Figure 1. The number of hours worked by survey participants before the pandemic and during the work-from-home period.

We also asked participants to share their experiences returning to lab after the work-from-home period. Even when the majority of participants were allowed to return to lab, 82% reported that they were working less than they did before the pandemic. There was no difference in response based on gender (p = 0.99) or URM status (p = 0.81) (SI, Table S4.1 and S4.2). Many students expressed frustration with their inability to continue working like they did before the pandemic. One participant commented: *"[The pandemic] completely put a halt to any and all progress that I was making when we shifted to work-from-home schedules. Since the return to labs, I have been unable to truly accomplish 85% of the work that I would otherwise be doing because the instruments that I need are university-shared instruments, which means that the activation barrier to get anything done is astronomical compared to where it was pre-pandemic.*" Overall, respondents reported significantly less research progress after the work-from-home period and there was no difference based on gender (p = 0.71) or URM status (p = 0.29) (SI, Table S5.1 and S5.2).

Quality of Collaborations

As a natural result of social distancing and more difficulties in virtual communication during this time, we hypothesized that many graduate students would express that the quality of their collaborations decreased. When asked about the collaborations before and during the pandemic, respondents reported that the quality of research collaborations have decreased compared to pre-pandemic. This was the case during the work-from-home period (b= -2.52 (0.23), p <0.0001) as well as after the work-from-home period and returning to the lab (b= −1.72 (0.18), p < 0.0001). This finding is

particularly important as the majority of participants (65%) reported being involved in a collaborative project. Notably, URM participants reported a greater decrease in the effectiveness of research collaborations (b= −1.42 (0.65), p = 0.03), and furthermore these participants rated these collaborations as more effective pre-pandemic (b= 1.1 (0.45), p = 0.01). The effect that the pandemic has had on collaborations is exemplified by the comments we received at the end of the survey. For example, several students experienced "*reduced collaboration with other labs at my university and also labs at other universities*" and noted difficulties in "*the inability to work in the office with a normal flow of academic and non-academic communication. These more casual interactions really benefit new students to feel secure with their group and with their research.*" These results suggest that collaboration and communication about research is an essential aspect of professional well-being within graduate research programs which has been compromised due to the resulted constraints of the pandemic (SI, Table S6.1-S7.2).

Career Aspirations

With respect to their career prospects, the majority of participants were either unsure how the COVID-19 pandemic impacted their degree/position timeline (41%) or reported that the COVID-19 pandemic prolonged their degree/position timeline (30%). We believed that a significant number of graduate students began to second-guess their career goals due to the COVID-19 pandemic and thus, we probed how students' career goals have changed. Although the majority of participants (85%) reported that their career goals have not changed during the pandemic, roughly half of these respondents (41%) reported that they were less certain of their career goal. Inconsequential of the COVID-19 pandemic, approximately 25% of graduate students change their initial career aspirations throughout the course of their graduate training.[22] However, we observe an even further increase in the percentage of students whose career aspirations have changed in the course of several months, with emphasis on COVID-19 as the result of this change. Notably, there was no difference in the rate at which participants changed their career goals based on gender (p = 0.48) or URM status (p = 0.81) (SI, Table S8). Regardless of their career goals, the majority of respondents were less excited about them during the pandemic than they were pre-pandemic, and this effect was marginally more pronounced for URM participants (p = 0.06); whereas 66% of non-URM participants were less excited about their career goals, 80% of URM participants were less excited about their career goals. Furthermore, we observed a gender difference with respect to participants' career goals (SI, Table S9.1 and S9.2). Compared to men, women were significantly less interested in a tenure track academic position at a research institution (p <0.001), which is in agreement with recent trends observed by other researchers (SI, Table S10.1 and S10.2).[16,34] This result suggests that the pandemic has exacerbated women's existing disinterest in academia.

Personal Well-Being

Aside from the negative effects the pandemic has had on graduate students' research progress and career aspirations, we believed that the toll of the pandemic severely impacted the personal well-being of our participants. In order to assess how participants' personal well-being changed during the pandemic, we asked them to rate how anxious they were about the following factors: their research progress, research funding, timeline of their degree/position, job prospects, financial security, housing situation, personal health, and well-being of their friends and family. In this context, emotions relating

to "anxiety" are based on the colloquial definition of "anxiety" and not the clinical definition. During the pandemic, participants' greatest sources of anxiety were related to their research progress and their job prospects. Notably, female participants reported greater anxiety levels than male participants across all factors ($p < 0.0001$). This gender difference was most pronounced on the factors related to job prospects and the well-being of their family and friends (Figure 2, left panel) (SI, Table S11.1 and S11.2).

Upon returning to lab following the work-from-home period, the most reported emotion was anxiety followed by stress and exhaustion. Although there was no difference in these emotions based on URM status ($p = 0.91$), there were significant differences in the emotions reported by male and female participants. Compared to men, women were more anxious ($p < 0.001$), less excited ($p < 0.001$), and felt less safe ($p < 0.001$) going back to lab (Figure 2, right panel) (SI, Table S12).

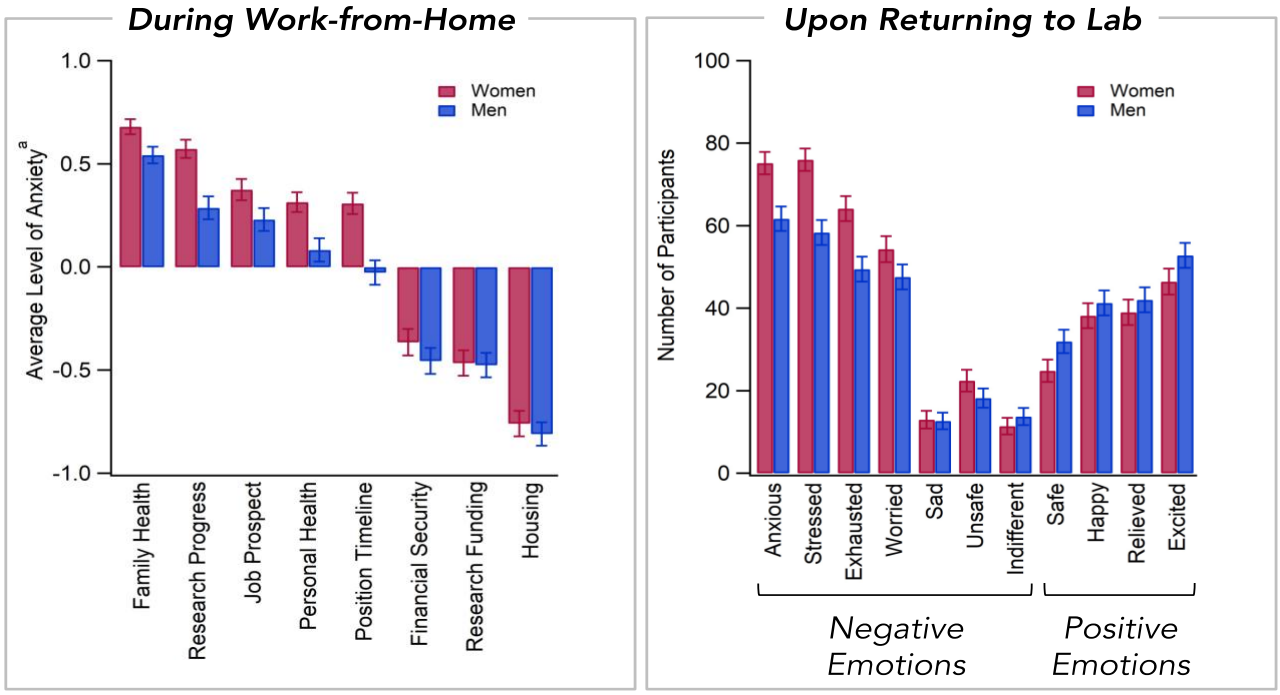


Figure 2. The personal well-being of women (red) and men (blue) during the work-from-home period normalized across all responses (left), positive values for an item across genders mean that the anxiety about that item is above average anxiety about all items, and negative values mean that anxiety about that item is lower than average anxiety about all items. The personal well-being of women (red) and men (blue) upon returning to lab (right): number of respondents from each gender who report feeling a given emotion, e.g, 61 male resoondents reported feeling anxious about returning to the lab. [a]Normalized across all responses.

The effect that the pandemic has had on participants' personal well-being is exemplified by the comments we received at the end of the survey. Many participants in their free-response to the pandemic challenges disclosed that they have suffered from chronic feelings of anxiety, depression, isolation, and loneliness, all of which have impacted their ability to work effectively. As one respondent reported:

> *"my anxiety has been harder to manage than ever because of the stressors of my environment, the lack of regular social contact at work, loss of access to my social networks and destressing activities, and pressure of being productive from home."*

Another respondent similarly stated:

"limited social interactions both professionally and personally [have been challenging]. They both help build moral and group dynamic as well as preserve mental health. Talking is limited at work currently due to shifts and social distancing. In addition, social gatherings at work are not as common as they were before the pandemic."

Thus, it can be seen that the pandemic has led to increased anxiety among graduate students and postdocs, thereby exacerbating the negative impact that the pandemic has had on their professional well-being.

It is clear from these survey results that the COVID-19 pandemic has negatively impacted the professional and personal well-being of graduate students and postdocs within the chemical science. Most strikingly, participants reported a substantial decrease in their research progress, which is the key metric of professional success for most Ph.D. and postdoctoral positions. There was no gender and URM difference in research progress changes. However, while everyone was anxious about the effect of the COVID-19 pandemic, women have been more impacted by the stress, and reported higher anxiety levels overall, and particularly related to anxieties about research and health.

Support Structures

A strong support network helps mitigate the stress and anxiety that accompanies a crisis.[23,35] Consequently, we were interested in examining participants' support network throughout the COVID-19 pandemic. We theorized that students who reported higher levels of professional and personal support would report less anxiety and stress during this time. Specifically, we assessed how participants' family and friends, coworkers, departments, and advisors supported their professional and personal well-being before and during the pandemic.

Professional Support: Before the pandemic, participants reported receiving the least professional support from their departments and then their coworkers ($p_{department} < 0.0001$, $p_{coworkers} = 0.01$) and the most professional support from their family and friends and their advisor. During the pandemic, participants reported a decrease in professional support from their coworkers ($p_{coworkers} = 0.001$) and their departments ($p_{department} = 0.03$) and no change in professional support from family and friends and advisors. Overall, URM participants reported receiving more professional support than their non-URM colleagues ($p = 0.04$) (Figure 3) (SI, Table S13.1 and S13.2).

Personal Support: Before the pandemic, participants reported receiving the most personal support from their family/friends, followed by their coworkers ($p < 0.0001$), then their advisor ($p < 0.0001$), and finally their department ($p < 0.0001$). During the pandemic, participants reported marginal increase in personal support from their family and friends ($p = 0.09$), significantly less personal support from their coworkers ($p < 0.0001$), and marginally less support from their departments ($p = 0.05$) (Figure 3). Notably, female participants reported receiving significantly more personal support from their family and friends than their male coworkers both before and during the pandemic ($p < 0.0001$) (SI, Table S14.1 and S14.2).

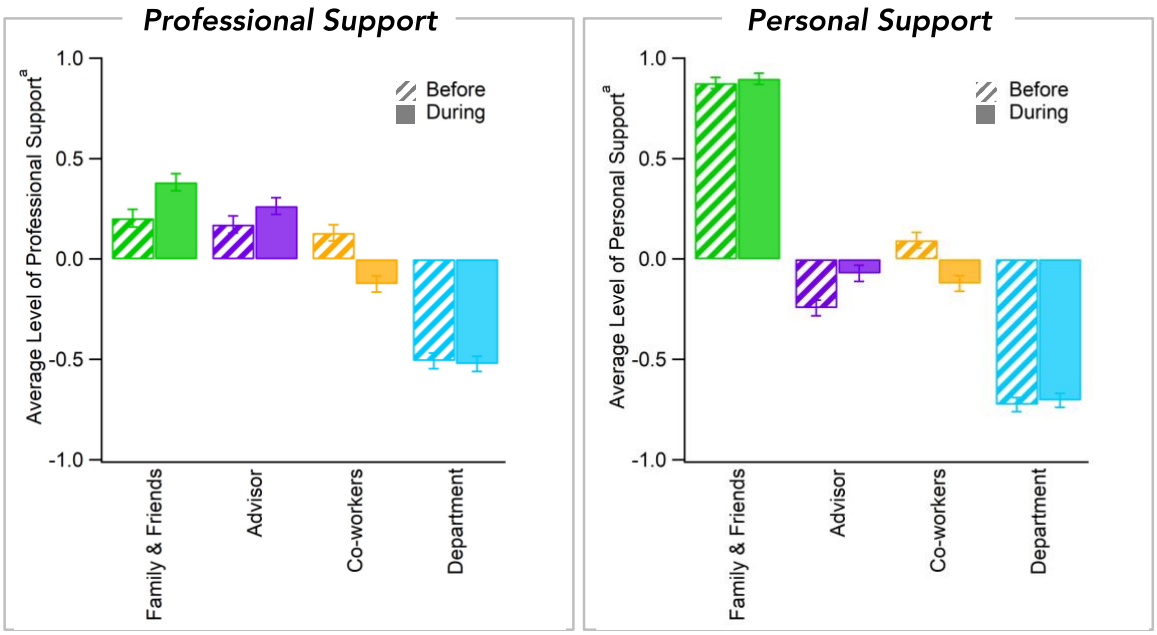
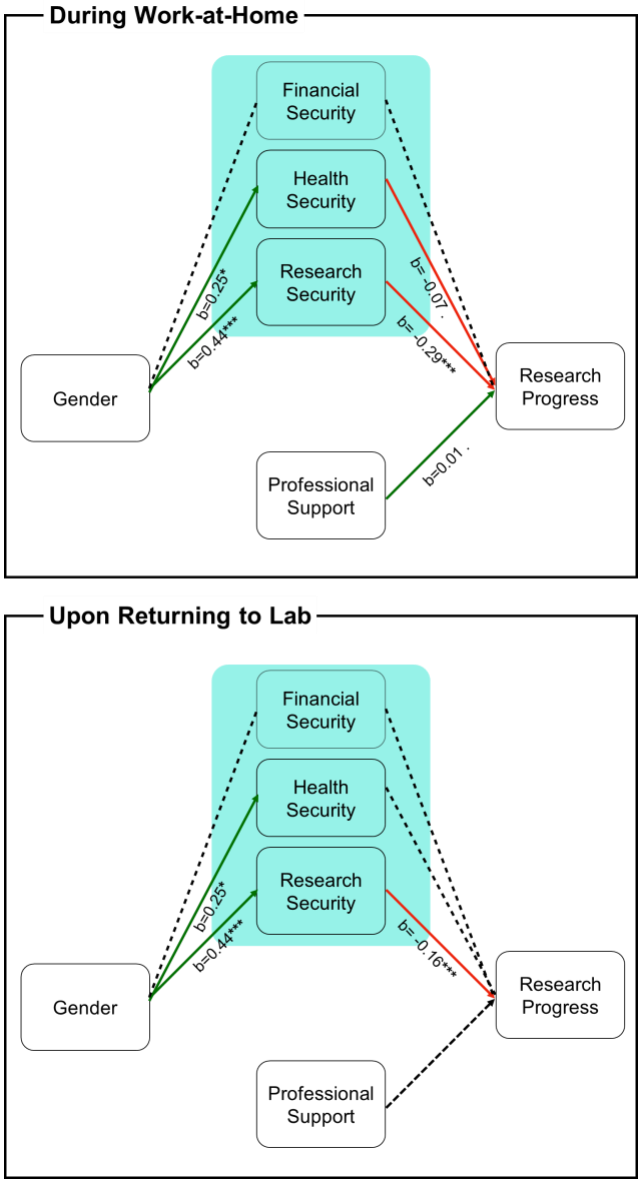


Figure 3. Professional (left) and personal (right) support participants received from family and friends (green), advisor (purple), co-workers (orange), and their department (blue) before (dashed) and during (solid) the COVID-19 pandemic. [a]Normalized across all responses.

Relationship between research progress, professional support, and personal well-being

To further assess how participants' research progress has been impacted by their personal well-being and professional support structures, we performed factor analysis (see Supporting Information for the details of factor analysis SI Table S15.1 – S17.2). We found that personal well-being could be categorized by three factors: anxiety about research security, anxiety about health security, and anxiety about financial security. "Research security" describes participants' anxieties about their research progress and degree timeline. Anxiety about "Health Security" describes participants' anxieties about the health of themselves, their family, and their friends. Anxiety about "Financial Security" describes participants' anxieties about their job prospects and their current financial situation. Similarly, the four sources of professional support (family/friends, coworkers, departments, and advisors) could be categorized into one variable called professional support and the same four sources of personal support (family/friends, coworkers, departments, and advisors) could be categorized into one variable called personal support. We ran structural equation modeling to further explore the relationship between professional, personal support, and research progress. The SEM model used for this analysis was a good fit for the data, and all the fit indices fell within an acceptable range (CFI=1.00, RMSEA= 0.004, SRMR=0.023). We found that participants' anxieties about research security and health security strongly correlated with their research progress during the work-from-home period ($b_{research}$ = –0.29 (0.05), p<0.0001; b_{health} = –0.07 (0.04), p =0.10) and upon returning to lab ($b_{research}$ = –0.16 (0.05), p=0.001); students' who were more anxious about their research or health security during the work from home reported less research progress. Similarly, students who were more anxious about their research progress upon returning to lab reported less research progress. Notably, women are significantly more anxious than men about both their research and health security ($b_{research}$= 0.44 (0.11), p<0.0001;

b_{health}=0.25 (0.13), p=0.05). Additionally, professional support during work from home was also marginally correlated with research progress (b=0.011 (0.06), p=0.06); participants' who reported receiving more professional support throughout the pandemic also reported more research progress (Scheme 3)) (SI, Table S18.1-18.4).



Scheme 3. Factors impacting participants' research during the work-at-home period (top) and upon returning to lab (bottom).

As previously highlighted, participants' advisors and departments contribute to their professional support.[33] To ensure the well-being of their graduate students and postdocs, advisors and departments need to provide the support that their graduate students and postdocs desire most. Our results indicated that professional support can mitigate the negative effect that the pandemic has had on research progress. We explored the types of support respondents have received and wish to receive

from their advisors and department. With respect to advisor support, participants reported that maintaining a respectful work environment, respecting commitment outside lab, and receiving advice on research projects and degree requirements were the most valuable types of support their advisor could provide. In contrast, the most common support that advisors provided was research group meetings. Importantly, the types of support advisors provided did not change despite the onset of a global pandemic, suggesting that this discrepancy is unrelated to the pandemic (Figure 4A). This observation is further validated in our analysis of participants' perception of their graduation timeline. As previously noted, 41% of participants reported being unsure about their timeline, suggesting that advisors are not properly communicating this information with their students and postdocs. With respect to department support, participants reported that maintaining a respectful work environment, supporting an inclusive work environment, and providing mental health resources were the most important types of support. Before the pandemic, however, the most common form of department support was hosting departmental seminars and symposia. During the pandemic, participants reported a decrease in almost all types of departmental support ($p < 0.0001$) except those related to departmental efforts to support an inclusive environment ($p<0.0001$) and solicit feedback ($p<0.0001$), which have increased during the pandemic (Figure 4C) (SI, Table S19.1-S22).

This difference in realized vs. valued support is magnified for researchers from traditionally underrepresented groups (women, URM). With respect to advisor support, female participants view respecting commitments outside of lab, providing mental health support, and maintaining a respectful work environment as more important than their male colleagues ($p = 0.03$, $p = 0.05$, $p = 0.06$, respectively) (Figure 4B). Additionally, female participants report receiving less professional support from their advisor than male participants. With respect to departmental support, female participants view almost all types of support as more important than their male colleagues ($p_{respectful}=0.004$, $p_{inclusive}<0.0001$, $p_{mentalhealth}=0.01$, $p_{careeropp}=0.005$, $p_{degree}=0.002$, $p_{feedback}=0.002$) (Figure 4D). Similarly, all departmental supports, regardless of type, were deemed more important to URM participants than non-URM participants ($p = 0.02$). Although many graduate students and postdocs value various types of support from their advisor and department, researchers from underrepresented groups (women, URM) find these supports to be significantly more important. Notably, the types of supports that these underrepresented groups value most have less to do with research and more to do with work environment. Overall, we observe that the types of support valued the most by graduate students and postdocs is not the type of support they receive the most from their advisors and departments (SI, Table S19.1-S22).

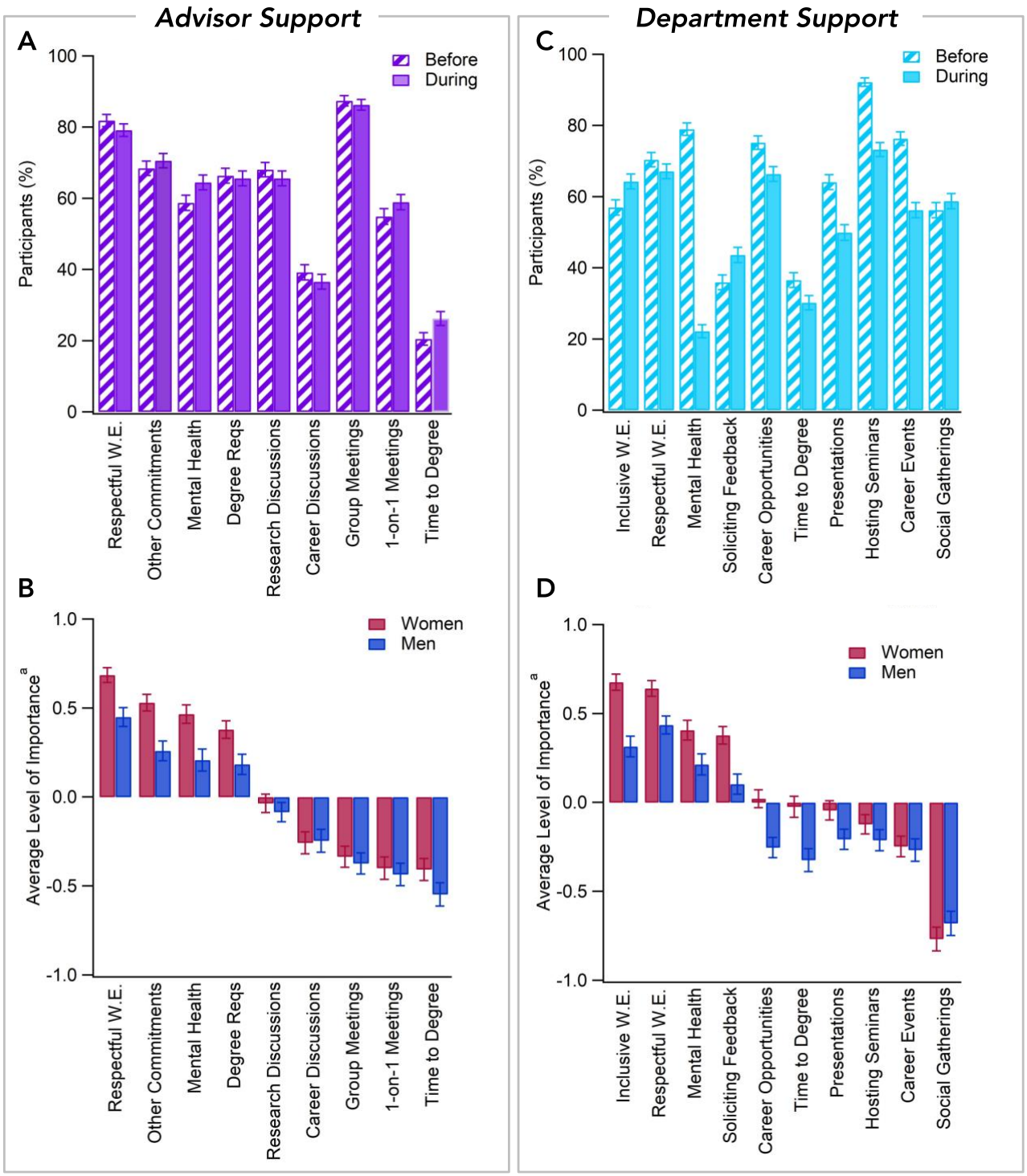

Advisor Support
Department Support
A
B
C
D
Before
During
Participants (%)
Women
Men
Average Level of Importance[a]
Respectful W.E.
Other Commitments
Mental Health
Degree Reqs
Research Discussions
Career Discussions
Group Meetings
1-on-1 Meetings
Time to Degree
Inclusive W.E.
Soliciting Feedback
Career Opportunities
Presentations
Hosting Seminars
Career Events
Social Gatherings

Figure 4. (**A**) Types of support participants received from their advisors before (purple dash) and during (purple solid) the pandemic (**B**) Importance of advisor support type depends on participant gender (women = red, men = blue) (**C**) Types of support participants received from their departments before (blue dash) and during (blue solid) the pandemic (**D**) Importance of department support type depends on participant gender (women = blue, men = purple). [a]Normalized across all responses.

It is important to emphasize that the support desired by participants is independent of the COVID-19 pandemic. While it is essential to provide extra compassion and support during a global crisis, our survey results reveal the ways in which chemistry advisors and departments can generally improve regardless of the pandemic. Based on our data, we have identified tangible steps that advisors and departments can take to better support their graduate students and postdocs, particularly those from underrepresented groups. Advisors should focus on creating and maintaining a respectful environment within their lab and respecting students' and post-docs' commitments outside of lab. For example, advisors could actively discourage poor lab citizenship practices, and they could schedule meetings on days/times that enable students and post-docs to fulfill their out-of-lab roles and responsibilities. Similarly, departments could reallocate some of the time they spend coordinating seminars to coordinating events that promote an inclusive work environment and providing mental health resources. For example, departments can organize workshops that discuss stress management techniques, host forums to solicit feedback from graduate students and postdocs, and place greater emphasis on inviting guest speakers that identify with underrepresented groups.[36] As stated by one participant: *"I would say the best thing advisors can do for us now would be the same as before the pandemic: a commitment to good mentoring. I think departments should be more proactive in encouraging their training in this regard."* Improved communication and empathy from advisors and departments would greatly assist in supporting the professional and personal well-being of graduate students and postdocs, especially those from underrepresented groups. More importantly, creating an inclusive and supportive environment for students of all backgrounds is more valuable than ever for promoting a more equitable working environment for graduate students. Notably, these recommendations are timeless; they will enable graduate students and postdocs to thrive in the best of times and the worst of times.

CONCLUSION

In surveying graduate students and postdocs in chemistry programs across top schools in United States, we observed that a majority of students have been extremely anxious about their research progress during the COVID-19 pandemic. Of these respondents, women have reported feeling more anxious overall. Furthermore, our survey revealed that many graduate students, particularly women and URM students, desire more support from advisors and departments in topics related to graduation timeline and research progress. A recent ACS Survey analyzing the graduate student experience has also noted that students who identify as URM and/or female have been less likely to receive desired support from their advisors.[37] Thus, the importance of one's advisor and department during graduate school, especially for women and URM students. By identifying the types of support participants value

and receive, we discovered that what participants typically receive from their advisor and department is not what they value most. Participants report that research group meetings are the most common type of aid that they receive from their advisor. Notably, advice on research projects and efforts to maintain a respectful work environment are the types of advisor assistance that participants, especially female and URM students, value most. Similarly, participants report that seminars and symposia are most commonly hosted by their departments. However, efforts to promote an inclusive work environment and provide mental health resources are the types of support that participants, especially female and URM students, value most. Such results provide insight into ways in which advisors and departments can best mitigate stress and anxiety during a global crisis as well as in general. Advisors and departments should more explicitly: 1) guide advisees in their degree progress, 2) provide feedback on their research progress, 3) aid in helping students achieve their career goals, 4) promote inclusive work environment. While COVID-19 provided a global scale experiment that allowed us to gain insight into the well-being of graduate students, the results from this survey are not limited to the COVID-19 era; the insights derived from this survey can be used irrespective of a global pandemic to create a more inclusive, equitable, and supportive scientific community.

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ACKNOWLEDGMENTS

This work was supported by the National Science Foundation Center for Sustainable Polymers at the University of Minnesota, a Center for Chemical Innovation (CHE-1901635). B. P. F. thanks the Alfred P. Sloan foundation for a Sloan Research Fellowship We would like to thank Professor Natasha Holmes and her group for all her assistance with the initial survey logistics and planning. Finally, we would also like to acknowledge all the individuals that helped us distribute the survey and collect this data.

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