

Full Title: Inadequate Mentoring in Undergraduate Research Experiences: Exploring Protective Factors

Short Title: Inadequate Mentoring

Author Names: Danielle X. Morales¹ (Corresponding Author), Sara E. Grineski², Timothy W. Collins³

Author Affiliations:

1. Department of Urban Studies, Worcester State University
2. Department of Sociology, University of Utah
3. Department of Geography, University of Utah

Corresponding Contact Information: Danielle X. Morales, Urban Studies Department, Worcester State University, 486 Chandler St, Worcester, MA 01602; email: dmorales@worchester.edu

Keywords: Faculty Mentoring, Undergraduate Research Experiences, Inadequate Mentoring, Protective Factors, STEM Education

ABSTRACT

This study examines instances of negative mentoring among undergraduate researchers within STEM education. Specifically, the common yet subtle issue of inadequate mentoring characterized by a faculty mentor's failure to provide their mentee with adequate research, educational, career-related, or emotional support. Using data from the Mentor-Relate survey of 514 NSF REU program participants, we identify prevalent patterns of inadequate mentoring and examine protective factors against it. Results indicate that inadequate research support is the least prevalent form, while inadequate educational/career guidance is more common, and inadequate emotional support is the most prevalent. Enhanced faculty mentoring skills emerge as a protective factor, with culturally responsive mentoring and gender concordance also playing significant protective roles. Less-hierarchical mentoring structures, such as multiple faculty mentors, offer better emotional support. These findings underscore the importance of comprehensive mentor training and culturally sensitive practices to mitigate inadequate mentoring in undergraduate research experiences. By promoting inclusive and supportive mentoring environments, institutions can maximize the transformative potential of undergraduate research experiences for all participants.

INTRODUCTION

Faculty and the mentoring support they provide play a crucial role in promoting student learning and development in science, technology, engineering, and mathematics (STEM) fields. In the context of undergraduate research experiences (UREs), which are recognized as a high-impact practice in higher education,¹ mentors are pivotal figures in students' personal and professional growth.²⁻⁴ Despite the overall positive impact of mentoring, it is essential to acknowledge that mentors can be a potential source of stressful or negative experiences for their mentees. Multiple studies have documented negative mentoring experiences in the workplace.⁵⁻⁷ Mentees who experience negative mentoring at work report decreased job satisfaction and increased turnover intentions and stress.⁸ Sometimes, negative mentoring can be so detrimental that mentees who experience it might be better off without a mentor at all.⁹

Researchers have noted that variation in the quality of faculty mentoring is a potential problematic aspect of UREs.^{4,10,11} Limeri et al. conducted the first systematic investigation of undergraduate researchers' negative experiences with their faculty mentors (e.g., absenteeism, abuse of power, interpersonal mismatch) based on interview data.¹² Their findings revealed that it was only in rare instances that faculty mentors actively harmed students. This is not surprising, as faculty members engaged in UREs are often individuals who are committed to undergraduate education and advocates for diversity and inclusion in STEM.^{13,14} Despite the good intentions of vast majority of these faculty members, many undergraduate researchers still reported insufficient research guidance, difficulties engaging mentors in discussions about education or career-related topics, and a need for greater approachability from their mentors.^{12,15} Therefore, we consider inadequate mentoring, characterized by a mentor's failure to provide their mentee

with adequate research, educational, career-related, or emotional support, to be a form of negative mentoring in UREs.

Although inadequate mentoring may not be as severe as more extreme negative mentor-mentee interactions—such as bullying or harassment—its impact should still be examined. Limeri et al. found that most undergraduate researchers who did not receive sufficient mentoring viewed their research experiences as poor investments of their time and as missed opportunities.¹² Therefore, it is imperative to gain a deeper understanding of inadequate mentoring and determine effective strategies for addressing this issue in the context of UREs. The current paper seeks to explore the relationships between inadequate mentoring and various features of mentoring relationships, such as quality, interactions, and relationship structure. We are particularly interested in clarifying the characteristics of mentoring relationships that can protect students from inadequate mentoring when participating in research. The concept of protective factors originates from epidemiology, where they are defined as factors that inhibit an outcome, typically a disease or health issue.¹⁶ Adapting this definition, we conceptualize protective factors as characteristics that reduce the likelihood of a student experiencing inadequate mentoring. In the next section, we review the literature to identify potential protective factors in the context of undergraduate research mentoring relationships.

REVIEW OF LITERATURE

Inadequate Mentoring in UREs

To gain a clearer understanding of inadequate mentoring, it is essential to revisit the concept of mentoring itself. Despite decades of research, the literature has been inconsistent and imprecise in defining mentoring. For example, in 2009, a comprehensive review of mentoring literature across disciplines highlighted the existence of 50 definitions of mentoring at that time.¹⁷ While

the definitions of mentoring vary, they often revolve around two primary functions: instrumental support, which involves the provision of challenging tasks for skill development, and psychosocial support, which encompasses role modeling and emotional support.¹⁸ More recently, the committee on effective mentoring in STEMM at the National Academies of Sciences, Engineering, and Medicine conducted a comprehensive examination of existing literature and concluded that “mentorship is a professional, working alliance in which individuals work together over time to support the personal and professional growth, development, and success of the relational partners through the provision of career and psychosocial support.”¹⁹ According to this definition, two key elements of mentoring are career support and psychosocial support. When applied to the context of UREs, we argue that education guidance is a critical element of career support. Additionally, faculty offer research support to help students develop their knowledge and research skills. Considering these elements, we conceptualize inadequate mentoring in UREs as a mentor's failure to provide their undergraduate mentee with: 1) sufficient knowledge/skill development, 2) educational/career guidance, or 3) psychosocial support.

Enhanced Mentoring Skills

The mentor's skills are a crucial aspect of a mentoring relationship, as they often determine the quality of the relationship. In a 2013 study, Fleming et al. examined 200 pairs of faculty mentors and undergraduate mentees across 16 universities, and identified six skills—maintaining effective communication, aligning expectations, assessing understanding, addressing diversity, promoting professional development, and fostering independence—that contribute to a mentor's effectiveness.²⁰ Subsequent research revealed a positive correlation between a mentor's enhanced skills and various positive outcomes for mentees, such as increased research program

satisfaction, a more developed science identity,²¹ and greater research gains.²² Following this line of research, we posit our first hypothesis (**H1**) that more skilled faculty mentors will reduce the likelihood of inadequate mentoring experiences for undergraduate researchers.

Culturally Responsive Mentoring

The second factor also relates to mentoring quality. Research on diversifying STEM fields asserts that faculty should be purposively inclusive, by fully recognizing the contexts and the lived experiences of their students and being culturally responsive.²³⁻²⁶ A study investigating undergraduate researchers in STEM revealed that those who reported receiving culturally responsive mentoring—characterized by mentors valuing students' cultural backgrounds and social identities—experienced various positive outcomes, such as increased confidence as researchers, refinement of academic and career goals, and a heightened commitment to graduate school.²⁷ Hence, we propose culturally responsive mentoring as the second protective factor against inadequate mentoring and offer the hypothesis that when undergraduate researchers have access to faculty mentors who prioritize cultural responsiveness, they are less likely to have inadequate mentoring experiences (**H2**).

Frequent Mentor-Mentee Interactions

The frequency of contact between mentors and mentees is another aspect of a mentoring relationship and plays a crucial role in shaping the dynamics between the mentor and mentee. More frequent interaction influences the effectiveness of mentoring processes by allowing more time for role-modeling, having developmental conversations, and acquiring skills.²⁸ It also strengthens the relationship as frequent contact enables mentors to provide guidance, encouragement, and support to their mentees.²⁹ In terms of mentoring in the context of higher education, the frequency of contact has consistently shown positive associations with mentees'

self-efficacy beliefs, academic success, and positive sense of identity.^{27,30-32} Recognizing these associations, we hypothesize that more frequent contact between mentors and mentees serves as a protective factor for undergraduate researchers, guarding against the experience of inadequate mentoring (**H3**).

Mentor-Mentee Concordance

In terms of the mentoring relationship structure, recent studies have focused on the impact of concordance or discordance between undergraduates and their mentors. Emphasizing the "mirror effect" for undergraduate researchers in STEM, this research highlights the motivational factor of having mentors with shared social identities, such as race and gender.³³ Specifically examining gender concordance, research indicates that women students feel greater comfort,³⁴ receive more psychosocial support,^{22,35,36} and are more productive^{21,37} when paired with women mentors compared to men mentors. Since we focus on people's gender identities instead of binary biological sex, we use the terms woman, man, and transgender and gender non-confirming (TGNC) instead of female and male throughout this paper. Similarly, racial concordance emerges as influential, particularly for students from minoritized groups, as they report developing closer relationships and receiving better research, career and psychosocial support from racial/ethnic minority mentors than from White mentors.³⁸⁻⁴⁰ Therefore, we posit gender and racial concordance as essential protective factors against inadequate mentoring in UREs (**H4**). We hypothesize that when undergraduate researchers—especially women and students of color—have mentors who share their gender or racial background, they are less likely to encounter inadequate mentoring.

Less-dyadic Mentoring Environments

While research on mentorship in STEM primarily focuses on mentor-mentee dyads, more diverse mentoring configurations are used in practice. For example, it is common for an undergraduate researcher to engage in a mentoring triad, consisting of a graduate student or postdoctoral associate (postgraduate mentor) providing day-to-day research guidance and a faculty member heading the research group.⁴¹ Undergraduates may also participate in mentoring networks, where they are mentored by multiple faculty members.⁴² While the primary focus of this paper is on students' mentoring experiences with their primary faculty mentors, it is crucial to acknowledge that many students engage in less-dyadic mentoring relationships in UREs, and that the structure of mentoring relationships affects student outcomes.^{4,11,43} Although limited, existing research suggests that multiple mentors are positively associated with student outcomes.⁴¹⁻⁴⁶ Therefore, we hypothesize that involvement in less-dyadic mentoring environments serves as a protective factor, reducing the likelihood of students experiencing inadequate mentoring from their primary faculty mentors (**H5**).

Conceptual Framework

Figure 1 depicts the conceptual framework guiding this paper. In our conceptualization, inadequate mentoring has three facets: a deficiency in knowledge/skill development, educational/career guidance research, and psychosocial support. We propose five factors that characterize a mentoring relationship and can potentially provide students with protection against inadequate mentoring. To summarize, they are enhanced mentoring skills, culturally responsive mentoring, frequent mentor-mentee interactions, mentor-mentee concordance, and less-dyadic mentoring environments. As the first exploratory study on this topic, this paper utilizes national survey data to empirically test the protective effects of these five factors.

[Figure 1 about here]

DATA & METHODS

Data: *The Mentor-Relate Study*

The data used in this paper were obtained from the Mentor-Relate Study (hereafter referred to as “Mentor-Relate”), which is a longitudinal study focusing on mentorship among undergraduate researchers. The study was conducted by the authors and funded by the National Science Foundation (NSF). Specifically, Mentor-Relate centers on NSF REU Sites, which are established through multiyear awards to program directors and provide summer research experiences for undergraduate students. To facilitate research experiences, students participating in the REU Sites are assigned to faculty-led research projects, but they also have the opportunity to collaborate with postgraduate researchers, lab technicians, and other undergraduate students. The NSF provides support to the students during their participation at REU Sites, offering stipends, housing, meals, travel expenses, and professional development opportunities.

The inclusion criteria for our study were that the REU Sites had to be active during the Summer of 2022, not in their first year of operation, and expected to remain active in the Summer of 2023. According to the NSF REU webpage, there were a total of 957 active REU sites on February 4th 2022. Of these, 416 Sites met our inclusion criteria and were invited to participate. Based on our budget, our enrollment target was 87 sites. Ultimately, 78 sites agreed to participate. The 78 sites included in our sample exhibited a similar distribution of disciplines as the total 957 REU sites. Specifically, among the 957 sites, 26% were related to life sciences, compared to 29% of the 78 sampled sites. For engineering programs, 24% of the 957 sites and 26% of the 78 sampled sites were in this category. In math and computer science, 20% of the 957 sites and 19% of the sampled sites were represented. Physical sciences comprised 23% of the

957 sites and 21% of the sampled sites. Finally, social, behavioral, and educational sciences programs made up 8% of the 957 sites and 5% of the sampled sites.

On average, each participating Site had 9 students. Therefore, approximately 702 students were invited to participate in this study, representing 19% of the total students participating in the 416 eligible Sites. In total, 658 students clicked on the survey link, 518 students completed (or nearly completed) the survey. For the analysis in this paper, we excluded cases with 30% or more missing values for analysis variables, leaving us with a final sample size of $n=514$. These students were distributed across 36 U.S. states, Washington D.C., and Puerto Rico. These Sites represented various STEM disciplines, including 20 in biological and life sciences, 14 in math and computer science, 21 in the physical sciences, 21 in engineering, and 2 in the social sciences. Since there is no national database of REU student participants from which to draw a sample, this sampling approach was the only way to reach this population.

In September 2022, we requested that each participating program director send out an email script inviting their Summer 2022 REU students to participate in the study. Additionally, we provided scripted reminder emails to be sent after one and two weeks to encourage participation. The Qualtrics survey was made available to the participants on 28 September 2022 and remained open until 19 October 2022. To express our appreciation for their participation, students received a \$20 Amazon gift card. On average, it took participants approximately 29.8 minutes to complete the survey.

Measures

Dependent Variables: Inadequate Mentoring Experiences

Four questions related to inadequate mentoring were included in the Mentor-Relate structured survey: “did your primary faculty mentor help you with: 1, research guidance (e.g., literature

search, research techniques, topic selection, statistics, and instrumentation); 2, educational choices and strategies (e.g., coursework selection and further educational opportunities); 3, career planning (e.g., advice and assistance in finding opportunities); 4, emotional support (e.g., being a supportive listener for personal concerns)?” Students answered these questions by indicating whether (Yes/No) their primary faculty mentor provided support in each of these four areas.

We created three dichotomous variables to measure the three aspects of inadequate mentoring. The first variable was based on the first question and indicated inadequate research support from the faculty mentor (1=the faculty mentor did not provide research guidance to the student; 0=the faculty mentor provided such support). The second variable assessed inadequate educational/career guidance. We operationalized this variable based on responses to the second and third questions, coding as follows: 1=the faculty mentor helped the student with either educational choices/strategies or career planning; 0=the faculty mentor did not provide assistance with neither educational choices/strategies nor career planning. Similarly, the third variable was used to measure the lack of psychosocial support, with a value of 1 indicating inadequate emotional support.

Focal Independent Variables: Five Protective Factors

Mentoring Skills

We utilized the Mentor Competency Assessment (MCA) to evaluate the skills of faculty mentors. This validated measure was specifically designed for undergraduate researchers to assess their faculty mentors' proficiency in six areas: communication, managing expectations, gauging students' understanding, fostering students' independence, providing professional development opportunities, and addressing diversity.²⁰ The MCA comprises a total of 26 items.

During the survey, students were asked to complete all 26 items, rating their mentors' skills on a scale ranging from 1 ("not at all skilled") to 7 ("extremely skilled") for each item. We excluded the two "addressing diversity" items from this analysis to avoid issues of multicollinearity and conceptual overlap with culturally responsive mentoring. As a result, the total MCA score was derived by averaging responses across the remaining 24 items. The MCA scale demonstrates a high level of reliability, with a Cronbach's alpha of 0.983.

Culturally Responsive Mentoring

We utilized the validated Culturally Responsive Mentoring (CRM) scale.⁴⁷ It was designed to capture undergraduate mentees' perceptions of their mentors' engagement in culturally responsive mentoring behaviors related to race and ethnicity. The CRM scale consists of 5 items: 1) my mentor created opportunities for me to bring up issues of race/ethnicity as they arose; 2) my mentor encouraged me to think about how the research related to my own lived experience; 3) my mentor was willing to discuss race and ethnicity, even if it may have been uncomfortable for them; 4) my mentor raised the topic of race/ethnicity in our research mentoring relationship when it was relevant; 5) my mentor approached the topic of race/ethnicity with me in a respectful manner. Students were asked to rate each item on a scale of 1 to 5, with 1 indicating "never" and 5 indicating "all the time." The Cronbach's alpha for the CRM-race scale was 0.890, indicating high reliability.

Based on the original scale, which was focused on race, we developed five parallel items to assess the faculty mentors' culturally responsive mentoring behaviors related to gender: 1) my mentor created opportunities for me to bring up issues of gender as they arose; 2) my mentor encouraged me to think about how the research related to my own lived experience; 3) my mentor was willing to discuss gender, even if it may have been uncomfortable for them; 4) my

mentor raised the topic of gender in our research mentoring relationship when it was relevant; and 5) my mentor approached the topic of gender with me in a respectful manner. Students also rated each item on a scale of 1 to 5, with 1 indicating “never” and 5 indicating “all the time.” The CRM-gender scale also demonstrated high reliability with a Cronbach's alpha of 0.923. Finally, we calculated the composite CRM score for each faculty-undergraduate pairing by averaging the responses from the 5 CRM-race items and the 5 CRM-gender items (Cronbach's alpha of 0.945). A higher CRM score indicates greater cultural responsiveness exhibited by the faculty mentor. For instance, this could mean that the faculty mentor frequently encouraged the undergraduate mentee to consider how their research relates to their lived experiences or consistently approached discussions engaging issues of gender or race with respect and sensitivity.

Mentor-Mentee Interactions

Students were asked to rate their communication frequency on a scale from 1 to 5, where 1 represented "less than once a month" and 5 indicated "daily" communication.

Mentor-Mentee Concordance

The Mentor-Relate structured survey collected information from students regarding their gender identities, which we categorized into three groups: men, women, and transgender or gender nonconforming (TGNC) individuals. Students also reported the gender identities of their faculty mentors. Utilizing these data, we developed a dichotomous variable to signify whether a student's gender identity aligns with that of their faculty mentor. A value of 1 denotes gender concordance, such as a TGNC faculty mentor paired with a TGNC student, while 0 signifies gender discordance, like a man faculty mentor matched with a TGNC student. Emphasizing our focus on gender identity rather than biological sex, we use "woman, man, and TGNC" instead of "female vs. male" throughout this paper.

Similarly, students reported both their own and their faculty mentors' race/ethnicity, and we coded the responses into five categories: non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic Asian, and other racial groups, which encompassed individuals identifying as Native American, Native Hawaiian, Pacific Islander, Multiracial, or belonging to other races. Then, we created a dichotomous variable to identify racial concordance between students and mentors, with 1 indicating such concordance (e.g., a Hispanic faculty mentor and a Hispanic student) and 0 representing racial discordance (e.g., a White faculty mentor and a Hispanic student).

In addition, to better understand whether mentor-mentee concordance is more protective for women, TGNC, or racial/ethnic minority students, we created eight additional dichotomous variables. Due to the small counts of TGNC faculty and students in our sample, we combined them with women, as they are all underrepresented gender groups in STEM. The first four dichotomous variables were based on the gender pairing of students and their faculty mentors: 1) man mentor and woman/TGNC mentee; 2) woman/TGNC mentor and man mentee; 3) man mentor and man mentee; 4) woman/TGNC mentor and woman/TGNC mentee. Similarly, the other four dichotomous variables were based on students and their faculty mentors' race/ethnicity: 1) White mentor and racial/ethnic minority mentee; 2) racial/ethnic minority mentor and White mentee; 3) White mentor and White mentee; 4) racial/ethnic minority mentor and racial/ethnic minority mentee.

Less-dyadic Mentoring Environments

Two variables were used to measure whether the students were involved in less-dyadic mentoring environments. First, students reported whether they were mentored by a postdoctoral fellow or graduate student (postgraduate mentor) (1=yes; 0=no). Students also reported if they worked with any other faculty members apart from their primary faculty mentor (1=yes; 0=no).

Control Variables

We adjusted for students' demographic and academic characteristics. Besides gender and race, we also considered LGBTQ+ status, distinguishing between individuals who identified as gay, bisexual, lesbian, pansexual, asexual, or another sexuality, and those who identified as straight. First-generation student status was operationalized to differentiate those who were the first in their family to pursue a Bachelor's degree from those whose parents had already earned a Bachelor's degree. In terms of students' academic characteristics, they reported their GPAs in spring 2022 on a 4-point scale. Students also provided information about their academic classification, which we recoded as junior/senior, freshman, or sophomore. Based on students' responses regarding their previous research experiences, we identified those who had not engaged in research before Summer 2022 as first-time undergraduate researchers. Finally, students reported their satisfaction with faculty mentors, and we recoded the variable as follows: 1=the student expressed satisfaction with the faculty mentor; 0=the student expressed dissatisfaction with the faculty mentor. This variable was used for descriptive analysis only. All the analysis variables are presented in Table 1.

[Table 1 about here]

Methods

First, we conducted descriptive statistics to measure the prevalence of inadequate mentoring among the 514 undergraduate researchers. Next, we used multivariable generalized estimating equation (GEE) models to investigate the five protective factors, using IBM SPSS Statistics 25. GEEs were chosen to account for the clustered data structure of our students within their REU programs.⁴⁸ Although we examined students in 78 REUs, some students provided a write-in response. In cases where these write-in responses were too general to be accurately coded into the correct REU, we treated each of these students as a separate cluster. For the GEE models, we specified an exchangeable intracluster correlation matrix, assuming constant intracluster dependency.⁴⁸ As the dependent variables were dichotomous variables, we chose the binomial distribution with a logarithmic (log) link function for all models.⁴⁸ We verified that multicollinearity did not affect the GEE results based on tolerance and variance inflation factor criteria.

To address missing data and account for uncertainty associated with missing values, we employed multiple imputation (MI) and reported pooled results from imputed datasets.⁴⁹ MI is particularly valuable when missingness is not completely random, as it helps preserve sample size, statistical power, precision, and minimizes bias. Missing observations were imputed using a regression-based approach, creating 20 multiply imputed datasets with each dataset having 200 iterations, and imputed values at the maximum iteration were retained for analysis.⁵⁰

Three initial GEE models were utilized to predict the occurrence of three forms of inadequate mentoring: inadequate research support (Model 1), inadequate educational/career guidance (Model 2), and inadequate emotional support (Model 3). These models included focal independent variables (five protective factors) along with control variables. In instances where gender or racial concordance variables exhibited significance, we employed a cross-classification

approach, a method frequently used in the literature.⁵¹⁻⁵⁴ Specifically, we cross-classified the gender identities of students and their faculty mentors by creating four mutually exclusive groups: 1) man mentor and woman/TGNC mentee; 2) woman/TGNC mentor and man mentee; 3) woman/TGNC mentor and woman/TGNC mentee; 4) man mentor and man mentee. Then, we re-estimated the model, substituting the concordance variable with the four groups.

RESULTS

Sample Characteristics

The participants in our study also represent a diverse group of college students, with 58% identifying as women, 36% as men, and 6% as TGNC. In terms of racial/ethnic breakdown, 47% are non-Hispanic White, 19% are Hispanic/Latino, 14% are Asian, 8% are Black, and the remaining 12% belong to other non-White racial backgrounds. About 35% identify as LGBTQ+. Further, approximately 28% of the participants are first-generation college students, and around 47% were first-time researchers when they participated in summer 2022 REU. Their academic standing reflects high achievement, with a median GPA of 3.7, ranging from 2.1 to 4.0. Only 10% of the participants are first-year students, while 28% are sophomores, and 63% are juniors and seniors. Their academic pursuits encompass a wide range of STEM majors: 29% major in life sciences, 22% in engineering, 19% in math or computer science, 23% in the physical sciences, and 7% in other fields.

Descriptive Results: *Prevalence of Inadequate Mentoring*

As shown in Figure 2, among the 514 participants, 5% (27 students) reported receiving inadequate research support from their faculty mentors. For 24% (125 students), their faculty mentor provided inadequate educational/career guidance. Additionally, 47% (235 students) reported receiving inadequate emotional support from their faculty mentors.

[Figure 2 about here]

Multivariable Results: *Five Protective Factors*

Table 2 presents the results from the GEE models 1-3. Model 1 predicts students' likelihood of experiencing inadequate research support. Among the five protective factors, the MCA score and the frequency of mentor-mentee communication were statistically significant. Specifically, each point increase on the MCA score was associated with a 48.2% decrease in students' likelihood of experiencing inadequate research support ($p=0.003$). Similarly, each point increase in the frequency of mentor-mentee communication was associated with a 61.2% decrease in students' likelihood of experiencing inadequate research support ($p<0.001$).

Model 2 focuses on the experiences of inadequate educational/career guidance, and two protective factors were significant. Every one-point increase in the MCA score was associated with a 48.1% decrease in students' likelihood of experiencing inadequate educational/career guidance ($p<0.001$). A one-point increase in the CRM score was associated with a 33.1% decrease in students' likelihood of experiencing inadequate educational/career guidance ($p=0.002$). For the control variables, students who were first-time researchers, compared to those with previous research experience, were 80.1% more likely to experience inadequate educational/career guidance ($p=0.021$). As compared to seniors and juniors, sophomores were 76.9% more likely to experience inadequate educational/career guidance ($p=0.033$).

Model 3 revealed the significant predictors of experiencing inadequate emotional support. Among the five protective factors, every one-point increase in the MCA score was associated with a 58.4% decrease in the odds of students experiencing inadequate emotional support ($p<0.001$), and a one-point increase in the CRM score was associated with a 30.8% decrease in the odds of experiencing inadequate emotional support ($p=0.001$). Further, the

gender concordance variable was significant ($p=0.018$), indicating that students who had gender-matched faculty mentors were 84.0% less likely to experience inadequate emotional support than students paired with gender-unmatched faculty mentors. The racial concordance variable was not significant ($p=0.840$).

In terms of less-dyadic mentoring environments, students who had postgraduate mentors were 78.9% more likely to report experiencing inadequate emotional mentoring with their faculty mentors than those who did not work with postgraduate mentors ($p=0.011$). On the other hand, students who had multiple faculty mentors were 45.2% less likely to experience inadequate emotional support from their primary faculty mentors than students who only had one faculty mentor ($p=0.027$). For the control variables, for every one-point increase in students' GPA, their odds of experiencing inadequate emotional support increased by 188.8% ($p=0.021$).

[Table 2 about here]

Since gender concordance was a significant predictor of experiencing inadequate emotional support (Model 3), we proceeded to develop two additional models to test whether gender concordance protected women and TGNC students more than men students. As mentioned, in these models, we replaced the gender concordance indicator with the four groups based on the gender pairing of students and their faculty mentors. In Model 4, men mentors and woman/TGNC mentees were used as the reference group. In Model 5, the other gender discordance group, women/ TGNC mentors and men mentees, were used as the reference group. The dependent variable remained inadequate emotional support, and all other independent variables were consistent with Model 3, except that we took out student gender variables.

The findings from Models 4 and 5 are presented in Table 3. When compared to women/ TGNC students working with men faculty mentors (Model 4), both gender-matched groups—

women/TGNC students with women/TGNC faculty mentors and men students with men faculty mentors—exhibited a significantly lower likelihood of encountering inadequate emotional support with reductions of 49.2% ($p=0.036$) and 46.3% ($p=0.031$), respectively. However, when compared to women/TGNC faculty mentors and men students (Model 5), the two gender-matched groups were no less likely to experience inadequate emotional mentoring ($p>0.05$).

[Table 3 about here]

Hypotheses Testing

The results from the models provided support for our hypotheses, although some were only partially supported. Our first hypothesis (**H1**) was supported, as greater MCA was significantly associated with decreased odds of students experiencing all three forms of inadequate mentoring (Models 1-3). **H2** found partial support, with CRM being significantly associated with inadequate educational/career guidance (Model 2) and emotional support (Model 3), but not inadequate research support (Model 1). **H3** was also partially supported, as the frequency of mentor-mentee communication was significantly associated with decreased odds of inadequate research support (Model 1) but not the other two outcomes (Models 2-3). **H4** was partially supported; gender concordance was a significant predictor in Model 3, but racial concordance was not, while neither of them were significant in Models 1 and 2. **H5** received partial support; having multiple faculty mentors prevented students from experiencing inadequate emotional support (Model 3), as expected. Contrary to expectations, having a postgraduate mentor increased the likelihood of inadequate emotional support from faculty mentors (Model 3). But in Models 1 and 2, these two factors were not significant.

DISCUSSION

Investigating negative mentoring experiences among students is an emerging and expanding area of research within STEM education.^{4,10-12} While severe forms of negative mentoring—e.g., abuse of power and harassment—have rightfully garnered attention from researchers,^{12,55,56} we focus on a subtler yet more pervasive form, inadequate mentoring. We contend that negative mentoring is not just about what mentors have done wrong; it also encompasses what they have not done, but should have done.

Utilizing survey data from a national study, Mentor-Relate, we examined research and mentoring experiences of 514 undergraduate students who participated in NSF REU programs in summer 2022. Our findings revealed a concern: inadequate mentoring was prevalent among a large portion of these undergraduate researchers, with more than half of them reporting at least one form of inadequate mentoring. Distinct patterns emerged when comparing the three forms of inadequate mentoring: inadequate research support is the least prevalent form, while inadequate educational/career guidance is more common, and inadequate emotional support is the most prevalent. In the context of UREs, offering research support is frequently perceived as the primary responsibility of faculty mentors. However, this perspective on mentoring could result in faculty neglecting other vital aspects of mentorship. Additionally, it is possible that faculty members are insufficiently prepared or lack the necessary time and resources to provide a more comprehensive mentoring experience.

How can we best address inadequate mentoring in UREs? We developed a conceptual model encompassing five potential protective factors against inadequate mentoring, and then empirically tested these factors. Findings highlight the significance of faculty's enhanced mentoring skills as a protective factor across the three forms of inadequate mentoring. Existing research has consistently demonstrated the correlation between faculty mentoring skills and

effective mentoring.^{21,22} Our study builds upon this knowledge, emphasizing the universally protective nature of skillful faculty mentoring against various negative mentee experiences.

We also observed that culturally responsive mentoring protected students from receiving inadequate educational/career guidance and emotional support. The established importance of culturally responsive mentoring in previous studies laid the foundation for our exploration.²³⁻²⁷ Our research contributes nuanced insights by demonstrating that faculty members who exhibit greater cultural responsiveness in their mentoring practices, such as facilitating discussions on gender or race, encouraging mentees to reflect on how their research intersects with their lived experiences, and approaching sensitive topics with respect, are more adept at providing educational/career guidance and emotional support to their mentees. Interestingly, culturally responsive mentoring did not emerge as a protective factor against inadequate research support. This might suggest that faculty mastering conventional mentoring skills (e.g., communication) can ensure their provision of adequate research support; however, this does not ensure their provision satisfactory educational/career guidance or emotional support. Achieving the latter requires faculty to move beyond familiar and prescribed mentoring approaches, and to acknowledge that social identities shape their mentees' research experiences.¹⁹

While frequent interactions between mentors and mentees are often considered a hallmark of effective mentoring relationships,²⁷⁻³² our analysis indicates that this characteristic only shields students from inadequate research support. In other words, in the absence of additional protective factors, frequent interactions alone may not guarantee the fulfillment of students' desires for education/career guidance or emotional support.

Factors associated with relationship structure greatly impact students' experiences of inadequate emotional support. In particular, students with gender-matched mentors were less

likely to report receiving inadequate emotional support. This finding aligns with previous studies suggesting that having a gender-matched faculty mentor improves students' interpersonal comfort and confidence,^{21,22,39,57-60} a phenomenon known as the “mirror effect,” wherein students find motivation in seeing mentors who share their gender identity.³³ Among various mentor-mentee gender combinations, we found that women or TGNC students paired with men faculty mentors faced the highest risk of encountering inadequate emotional support. Women and TGNC students face underrepresentation and marginalization within STEM fields. Men mentors may have difficulties of providing guidance grounded in lived experiences specific to the unique challenges faced by women or TGNC students, potentially resulting in inadequate emotional support.^{61,62} Furthermore, societal norms and gender role stereotypes may influence men mentors' perceptions regarding the provision of emotional support to women or TGNC mentees,⁶³ coupled with concerns about overstepping boundaries or facing accusations of inappropriate conduct, potentially resulting in an oversight or undervaluation of these mentees' emotional needs.

As anticipated, the presence of multiple faculty mentors seems to safeguard students against inadequate emotional support. However, contrary to our expectations, having a postgraduate mentor seems to increase the likelihood of students experiencing inadequate emotional support from their faculty mentors. Previous research underscores that a multiple faculty mentoring structure may offer a less hierarchical, more relational, and reciprocal form of mentorship.^{42,45} This might explain why students perceived adequate emotional support from their primary faculty mentors when supported by more than one faculty member. Additionally, the distribution of mentoring responsibilities among multiple faculty might also afford the primary mentor greater availability to provide emotional support to the mentee. In terms of why

having a postgraduate mentor increased the odds of inadequate emotional support from faculty, it could be that since postgraduates offer day-to-day guidance and support to undergraduates, the faculty member, serving as the head of the team, may remain somewhat distant from the undergraduates, potentially impeding their ability to provide sufficient emotional support. This sort of hierarchal mentoring arrangement is prevalent in many STEM fields, with faculty at the top and postgraduate mentors providing a conduit to undergraduate mentees below.⁴¹

It is crucial to acknowledge other alternative forms of mentoring that are less dyadic, even though the students in our study were not directly engaged in them. For example, one such form is collective group mentoring, where a cohort of undergraduate mentees collaborates with one or more faculty mentors in a small network.⁶⁴ Within this framework, mentees exchange peer-to-peer advice, fostering a sense of community and shared experience. Another form of less-dyadic mentoring is cross-institutional mentoring, where students are mentored by multiple faculty members from different institutions, which exposes them to diverse expertise, perspectives, and networking opportunities.⁶⁵ Although these mentoring relationships are not the focus of this paper, our findings may extend to these contexts, as we found that students receive better emotional support in environments characterized as less hierarchical (multiple faculty mentors) compared to those that tend to be more hierarchical (a faculty mentor and a postgraduate mentor). Future research should investigate the relationships between different forms of less-dyadic mentoring and their potential protective effects against inadequate mentoring.

Table 4 provides a summary of our empirical findings in. It is clear that among the three forms of adequate mentoring, inadequate research support emerges as the least prevalent with

just two factors protecting against its occurrence. Conversely, inadequate emotional support is the most prevalent with a wider array of factors protecting against it.

[Table 4 about here]

Limitations

Several limitations should be noted about this study. For data collection, this study relies on a random cluster sample of student participants from a subset of REU Sites. Although our sample (n=514) provided sufficient statistical power for our models, a larger sample size would facilitate more nuanced analyses. Currently, no comprehensive data have been collected about all students participating in REU sites. Hence, we were unable to assess the representativeness of the 78 participating sites among the total 957 sites based on student, faculty, or institutional demographics. Future research should aim to collect more demographic information about the total REU sites to better understand the representativeness of the samples used in analyses.

Our analyses also relied solely on student-reported data. This means we did not include mentor perspectives, which would provide additional context for students' self-reported perceptions of the mentoring relationship. In terms of study design, this study was conducted cross-sectionally, meaning that we cannot really assess directionality and there could be bidirectionality between independent and dependent variables. Future longitudinal studies are needed to clarify directionality of the relationships we observed.

For the constructs we used in this study, we asked about inadequate mentoring using a binary (Yes/No) format rather than utilizing a scale, which might lead us to capture only the most serious instances for inadequate mentoring. Since no current scales exist to assess inadequate mentoring, future researchers could develop scales to more comprehensively assess students' experiences with inadequate mentoring. In addition, although students reported in the

survey that they did not receive mentoring in the three domains, they did not explicitly indicate a desire for each type of mentoring. Our premise in this paper is that students do not necessarily know their mentoring needs, and therefore that not receiving mentoring in these domains constitutes inadequate mentoring based on the established importance of each domain in the literature. Future qualitative work could help elucidate what inadequate mentoring means to students.

We also acknowledge that our findings regarding the effects of faculty mentoring skills on inadequate mentoring may be partially influenced by overlap in the constructs. For instance, there is a conceptual similarity between "promoting professional development" (one of the MCA subscales) and inadequate educational/career guidance. Although the correlations between MCA subscales and inadequate mentoring variables were all below 0.50 (Table 5 in supplemental materials), it is important to recognize the potential for overlap.

Finally, experiencing inadequate mentoring may lead to negative consequences, which we have not examined here, such as retention issues (e.g., changing major, dropping out), reduced science identity, and declining mental health. Future studies should investigate these potential consequences to better understand the broader implications of inadequate mentoring.

IMPLICATIONS AND CONCLUSIONS

UREs have been demonstrated as a high-impact practice in higher education, providing critical research experiences to undergraduate students, inspiring many of them to pursue research careers, and shaping the future of STEM.^{1,66,67} While broadening participation in UREs is important,⁶⁸ it is equally important to ensure that current participants fully capitalize on the benefits offered by UREs, and that the significant investments of time, money, and effort are not

wasted due to inadequate mentoring practices. Drawing from our findings, we present the following practical implications.

First, the findings suggest the importance of enhanced mentoring skills and culturally responsive mentoring as protective factors against inadequate mentoring. Mentoring skills can be enhanced through systematic and formal training programs.⁶⁹⁻⁷³ Mentor training can also augment faculty's cultural awareness and responsiveness, thereby enabling more culturally responsive mentoring practices.^{74,75} Therefore, institutions and undergraduate research programs should consider implementing effective and evidence-based mentor training curricula, such as the Entering Mentoring training,^{76,77} to address inadequate mentoring.

Second, our results indicate that gender concordance was associated with substantially reduced odds of inadequate emotional support (i.e., 84% less). Academic institutions and URE programs should be cognizant of gender dynamics and, as opportunities arise, consider matching students with mentors who share gender identities. Since ensuring access to mentors of the same gender can foster a more supportive and inclusive environment,^{22,35,36,78} URE programs should also make efforts to recruit mentors from all gender identities. Future mentor training should emphasize the significance of providing adequate emotional support to all students, regardless of gender. However, special attention and sensitivity may be necessary when men faculty members mentor women or TGNC students (as this combination had a greater likelihood of inadequate emotional support as compared to all other gender combinations) to address potential gaps in emotional support and ensure a positive mentorship experience.

Our results also indicate that when students conducted research for the first time, they were more likely to experience inadequate educational and career guidance. Several studies suggest that students with more prior undergraduate research experience tend to have more

positive perceptions and ratings of their mentors, compared to first-time undergraduate researchers.⁷⁹⁻⁸² In light of this evidence, we recommend that URE programs prioritize matching first-time student researchers with skilled, culturally responsive mentors to ensure comprehensive mentoring, as well as providing mentee training^{83,84} to equip these novice researchers with the necessary skills to maximize the benefits of the mentorship. Curriculum developers for mentorship programs could also consider incorporating components on best practices for mentoring first-time undergraduate researchers, specifically addressing their unique needs and potential challenges.

Finally, institutions and research programs should explore and endorse mentoring structures that foster a less hierarchical and more team-based approach. Rather than relying solely on the traditional model of a single faculty mentor overseeing a student's research experience, distributing mentoring responsibilities among multiple faculty members can potentially enhance accessibility to emotional support and cultivate a more supportive mentoring environment.⁸⁵ This team-based mentoring approach allows students to benefit from the diverse perspectives, expertise, and interpersonal styles of various mentors. By intentionally cultivating supportive mentoring environments, institutions can empower students to thrive in their research endeavors. Together, these efforts can pave the way for a more inclusive, nurturing, and impactful landscape in undergraduate research experiences.

Acknowledgments:

Research reported in this publication was supported by the National Science Foundation under the linked Award Numbers 1930558 and 2055379. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation.

We would like to extend our sincere gratitude to Yolanda Chavez for her invaluable assistance in cleaning survey data for this paper. Her meticulous work and dedication have greatly contributed to the quality of our research.

IRB Statement:

This study was approved by IRB boards at the University of Utah and Worcester State University (#152679; # 2223-0034)

Author Contributions:

D.X.M., S.E.G., and T.W.C. collaborated on the conception and design of the study, and data analyses. D.X.M. developed the initial draft and collaborated with S.E.G and T.W.C. on revising the manuscript. All authors read and approved the final manuscript.

Competing Interests:

The authors declare no competing interests.

References:

1. Kuh, G.D. (2008). *Student Success in College: The Promise of High Impact Practices*; Association of American Colleges and Universities: Washington, DC.
2. Byars-Winston, A. M., Branchaw, J., Pfund, C., Leverett, P., & Newton, J. (2015). Culturally diverse undergraduate researchers' academic outcomes and perceptions of their research mentoring relationships. *International Journal of Science Education*, 37(15), 2533-2554.
3. Estrada, M., Hernandez, P. R., & Schultz, P. W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE—Life Sciences Education*, 17(1), ar9.
4. Thiry, H., & Laursen, S. L. (2011). The role of student-advisor interactions in apprenticing undergraduate researchers into a scientific community of practice. *Journal of Science Education and Technology*, 20(6), 771–784.
5. Eby, L., McManus, S. E., Simon, S. A., & Russell, J. E. A. (2000). The protege's perspective regarding negative mentoring experiences: The development of a taxonomy. *Journal of Vocational Behavior*, 57(1), 1–21.
6. Scandura, T. A. (1998). Dysfunctional mentoring relationships and outcomes. *Journal of Management*, 24(3), 449–467.
7. Tepper, B. J. (2000). Consequences of abusive supervision. *Academy of Management Journal*, 43(2), 178–190.
8. Eby, L. T., & Allen, T. D. (2002). Further investigation of protégés' negative mentoring experiences: Patterns and outcomes. *Group & Organization Management*, 27(4), 456–479.

9. Ragins, B. R., Cotton, J. L., & Miller, J. S. (2000). Marginal mentoring: The effects of type of mentor, quality of relationship, and program design on work and career attitudes. *Academy of Management Journal*, 43(6), 1177–1194.
10. Bernier, A., Larose, S., & Soucy, N. (2005). Academic mentoring in college: The interactive role of student's and mentor's interpersonal dispositions. *Research in Higher Education*, 46(1), 29–51.
11. Dolan, E., & Johnson, D. (2010). The undergraduate–postgraduate–faculty triad: Unique functions and tensions associated with undergraduate research experiences at research universities. *CBE—Life Sciences Education*, 9(4), 543–553.
12. Limeri, L. B., Asif, M. Z., Bridges, B. H., Esparza, D., Tuma, T. T., Sanders, D., ... & Dolan, E. L. (2019). “Where’s my mentor?!” Characterizing negative mentoring experiences in undergraduate life science research. *CBE—Life Sciences Education*, 18(4), ar61.
13. Morales, D. X., Grineski, S. E., & Collins, T. W. (2016). Influences on faculty willingness to mentor undergraduate students from another university as part of an interinstitutional research training program. *CBE—Life Sciences Education*, 15(3), ar35.
14. Morales, D. X., Grineski, S. E., & Collins, T. W. (2017). Faculty motivation to mentor students through undergraduate research programs: A study of enabling and constraining factors. *Research in Higher Education*, 58, 520–544.
15. Behar-Horenstein, L. S., Roberts, K. W., & Dix, A. C. (2010). Mentoring undergraduate researchers: An exploratory study of students' and professors' perceptions. *Mentoring & Tutoring: Partnership in Learning*, 18(3), 269–291.
16. Patel, V., & Goodman, A. (2007). Researching protective and promotive factors in mental health. *International Journal of Epidemiology*, 36(4), 703–707.

17. Crisp, G., & Cruz, I. (2009). Mentoring college students: A critical review of the literature between 1990 and 2007. *Research in Higher Education*, 50(6), 525-545.
18. Kram, K. E. (1983). Phases of the mentor relationship. *Academy of Management Journal*, 26(4), 608–625.
19. National Academies of Sciences, Engineering, and Medicine (2019). *The Science of Effective Mentorship in STEMM*. Washington, DC: The National Academies Press.
20. Fleming, M., House, M. S., Shewakramani, M. V., Yu, L., Garbutt, J., McGee, R., ... & Rubio, D. M. (2013). The mentoring competency assessment: validation of a new instrument to evaluate skills of research mentors. *Academic medicine: Journal of the Association of American Medical Colleges*, 88(7), 1002.
21. Morales, D. X., Grineski, S. E., & Collins, T. W. (2021). Effects of mentoring relationship heterogeneity on student outcomes in summer undergraduate research. *Studies in Higher Education*, 46(3), 423-436.
22. Morales, D. X., Grineski, S. E., & Collins, T. W. (2018). Effects of gender concordance in mentoring relationships on summer research experience outcomes for undergraduate students. *Science Education*, 102(5), 1029-1050.
23. Cropps, T., & Esters, L. (2018). Sisters, other-mothers and aunties: The importance of informal mentors for Black women graduate students at predominantly White institutions. *Diverse: Issues in Higher Education*. <https://diverseeducation.com/article/119653/> (accessed January 24, 2024).
24. García, I. O., & Henderson, S. J. (2015). Mentoring experiences of Latina graduate students. *Multicultural Learning and Teaching*, 10(1), 91-109.

25. Rasheem, S., Alleman, A. S., Mushonga, D., Anderson, D., & Ofahengaue Vakalahi, H. F. (2018). Mentor-shape: Exploring the mentoring relationships of Black women in doctoral programs. *Mentoring & Tutoring: Partnership in Learning*, 26(1), 50-69.
26. San Miguel, A. M., & Kim, M. M. (2015). Successful Latina scientists and engineers: Their lived mentoring experiences and career development. *Journal of Career Development*, 42(2), 133-148.
27. Haeger, H., & Fresquez, C. (2016). Mentoring for inclusion: The impact of mentoring on undergraduate researchers in the sciences. *CBE—Life Sciences Education*, 15(3), ar36.
28. Rhodes, J. E. (2009). *Stand by Me: The Risks and Rewards of Mentoring Today's Youth*. Cambridge, MA: Harvard University Press.
29. Eby, L. T. D. T., Allen, T. D., Hoffman, B. J., Baranik, L. E., Sauer, J. B., Baldwin, S., ... & Evans, S. C. (2013). An interdisciplinary meta-analysis of the potential antecedents, correlates, and consequences of protégé perceptions of mentoring. *Psychological Bulletin*, 139(2), 441-476.
30. Campbell, T. A., & Campbell, D. E. (1997). Faculty/student mentor program: Effects on academic performance and retention. *Research in Higher Education*, 38 (6), 727-742.
31. Smith-Jentsch, K. A., Scielzo, S. A., Yarbrough, C. S., & Rosopa, P. J. (2008). A comparison of face-to-face and electronic peer-mentoring: Interactions with mentor gender. *Journal of Vocational Behavior*, 72(2), 193-206.
32. Santos, S. J., & Reigadas, E. T. (2004). Understanding the student-faculty mentoring process: Its effects on at-risk university students. *Journal of College Student Retention: Research, Theory & Practice*, 6(3), 337-357.

33. Morales, D. X., Grineski, S. E., & Collins, T. W. (2023). Advancing understanding of discordant mentoring relationships in STEMM: A method and framework. *Annals of the New York Academy of Sciences*, 1526(1), 8-15.
34. Allen, T. D., Day, R., & Lentz, E. (2005). The role of interpersonal comfort in mentoring relationships. *Journal of Career Development*, 31, 155-169.
35. Lockwood, P. (2006). “Someone like me can be successful”: Do college students need same-gender role models?. *Psychology of Women Quarterly*, 30(1), 36-46.
36. Kark, R. & R. Shilo-Dubnov. (2007). The effects of gender on prot’eg’es’ perceptions of mentoring relationships in Israeli academia. *Megamot*, 44: 707–735.
37. Goldstein, E. (1979). Effect of same-sex and cross-sex role models on the subsequent academic productivity of scholars. *American Psychologist*, 34(5), 407-410.
38. Barker, M. J. (2011). Racial context, currency and connections: Black doctoral student and white advisor perspectives on cross-race advising. *Innovations in Education and Teaching International*, 48(4), 387-400.
39. Blake-Beard, S., M. L. Bayne, F. J. Crosby, and C. B. Muller. (2011). Matching by race and gender in mentoring relationships: Keeping our eyes on the prize. *Journal of Social Issues*, 67(3):622–643.
40. Byars-Winston, A., Rogers, J., Branchaw, J., Pribbenow, C., Hanke, R., & Pfund, C. (2016). New measures assessing predictors of academic persistence for historically underrepresented racial/ethnic undergraduates in science. *CBE—Life Sciences Education*, 15(3), ar32.
41. Aikens, M. L., S. Sadselia, K. Watkins, M. Evans, L. T. Eby, and E. L. Dolan. (2016). A social capital perspective on the mentoring of undergraduate life science researchers: An

- empirical study of undergraduate–postgraduate–faculty triads. *CBE—Life Sciences Education*, 15(2):ar16.
42. Hernandez, P. R., B. Bloodhart, R. T. Barnes, A. S. Adams, S. M. Clinton, I. Pollack, E. Godfrey, M. Burt, and E. V. Fischer. (2017). Promoting professional identity, motivation, and persistence: Benefits of an informal mentoring program for female undergraduate students. *PLOS ONE*, 12(11):e0187531–e0187531.
43. Behar-Horenstein, L. S., & Prikhidko, A. (2017). Exploring mentoring in the context of team science. *Mentoring & Tutoring: Partnership in Learning*, 25(4), 430-454.
44. Aikens, M. L., M. M. Robertson, S. Sadselia, K. Watkins, M. Evans, C. R. Runyon, L. T. Eby, and E. L. Dolan. (2017). Race and gender differences in undergraduate research mentoring structures and research outcomes. *CBE—Life Sciences Education*, 16(2):ar34.
45. Yun, J., B. Baldi, and M. Sorcinelli. (2016). Mutual mentoring for early-career and underrepresented faculty: Model, research, and practice. *Innovative Higher Education*, 41(5):441–451.
46. Joshi, M., Aikens, M. L., & Dolan, E. L. (2019). Direct ties to a faculty mentor related to positive outcomes for undergraduate researchers. *BioScience*, 69(5), 389-397.
47. Byars-Winston, A., & Butz, A. R. (2021). Measuring research mentors' cultural diversity awareness for race/ethnicity in STEM: Validity evidence for a new scale. *CBE—Life Sciences Education*, 20(2), ar15.
48. Garson, G., (2012). *Generalized Linear Models and Generalized Estimating Equations*. Statistical Associates Publishing, Asheboro, NC.

49. Rubin, D. B. (1988). An overview of multiple imputation. In *Proceedings of the survey research methods section of the American statistical association* (Vol. 79, p. 84). Princeton, NJ, USA: Citeseer.
50. Enders, C. K., & Gottschall, A. C. (2011). Multiple imputation strategies for multiple group structural equation models. *Structural Equation Modeling*, 18(1), 35-54.
51. Bauer, G. R., Churchill, S. M., Mahendran, M., Walwyn, C., Lizotte, D., & Villa-Rueda, A. A. (2021). Intersectionality in quantitative research: A systematic review of its emergence and applications of theory and methods. *SSM-population Health*, 14, 100798.
52. Bauer, G. R., & Scheim, A. I. (2019). Advancing quantitative intersectionality research methods: Intracategorical and intercategory approaches to shared and differential constructs. *Social Science & Medicine*, 226, 260-262.
53. Gustafsson, P. E., Fonseca-Rodríguez, O., Nilsson, I., & San Sebastián, M. (2022). Intersectional inequalities in loneliness among older adults before and during the early phase of the COVID-19 pandemic: a total population survey in the Swedish eldercare setting. *Social Science & Medicine*, 314, 115447.
54. Liu, Y., Zhong, L., Puram, S. V., & Mazul, A. L. (2023). Neighborhood socioeconomic status and racial and ethnic survival disparities in oral cavity and laryngeal cancer. *Cancer Epidemiology, Biomarkers & Prevention*, 32(5), 642-652.
55. Al Makhamreh, M., & Stockley, D. (2020). Mentorship and well-being: Examining doctoral students' lived experiences in doctoral supervision context. *International Journal of Mentoring and Coaching in Education*, 9(1), 1-20.

56. Tuma, T. T., Adams, J. D., Hultquist, B. C., & Dolan, E. L. (2021). The dark side of development: A systems characterization of the negative mentoring experiences of doctoral students. *CBE—Life Sciences Education*, 20(2), ar16.
57. Baker, V. L., and K. A. Griffin. (2010). Beyond mentoring and advising: Toward understanding the role of faculty “developers” in student success. *About Campus*, 14(6):2–8.
58. Felder, P. P., and M. J. Barker. (2013). Extending Bell’s concept of interest convergence: A framework for understanding the African American doctoral student experience. *International Journal of Doctoral Studies*, 8(1):1–20.
59. Gonzáles-Figueroa, E., & Young, A. M. (2005). Ethnic identity and mentoring among Latinas in professional roles. *Cultural Diversity and Ethnic Minority Psychology*, 11(3), 213–226.
60. Patton, L. D., and S. Bondi. (2015). Nice white men or social justice allies? Using critical race theory to examine how white male faculty and administrators engage in ally work. *Race Ethnicity and Education*, 18(4):488–514.
61. Ensher, E. A., and S. E. Murphy. (2011). The mentoring relationship challenges scale: The impact of mentoring stage, type, and gender. *Journal of Vocational Behavior*, 79(1):253–266.
62. Woolnough, H. M., and S. L. Fielden. (2014). The impact of a career development and mentoring programme on female mental health nurses: A longitudinal, qualitative study. *Gender in Management: An International Journal*, 29(2):108–122.
63. McKenzie, S. K., Collings, S., Jenkin, G., & River, J. (2018). Masculinity, social connectedness, and mental health: Men’s diverse patterns of practice. *American Journal of Men's Health*, 12(5), 1247–1261.

64. Kobulnicky, H. A., & Dale, D. A. (2016). A community mentoring model for STEM undergraduate research experiences. *Journal of College Science Teaching*, 45(6), 17-23.
65. Petersen, S., Pearson, B. Z., & Moriarty, M. A. (2020). Amplifying voices: Investigating a cross-institutional, mutual mentoring program for URM women in STEM. *Innovative Higher Education*, 45(4), 317-332.
66. Fischer, A. E., Immel, K. R., Wilkum, K., & Lee, L. (2021). A Taxonomy for Developing Undergraduate Research Experiences as High-Impact Practices. *Journal of the Scholarship of Teaching and Learning*, 21(1), 84-106.
67. Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Undergraduate research experiences: Impacts and opportunities. *Science*, 347(6222), 1261757.
68. Prunuske, A., Wilson, J., Walls, M., Marrin, H., & Clarke, B. (2016). Efforts at broadening participation in the sciences: An examination of the mentoring experiences of students from underrepresented groups. *CBE—Life Sciences Education*, 15(3), ar26.
69. Behar-Horenstein, L. S., Feng, X., Prikhidko, A., Su, Y., Kuang, H., & Fillingim, R. B. (2019). Assessing mentor academy program effectiveness using mixed methods. *Mentoring & Tutoring: Partnership in Learning*, 27(1), 109-125.
70. Behar-Horenstein, L. S., & Kuang, H. (2019). Efficacy of a mentor academy program: A case study. *Mentoring & Tutoring: Partnership in Learning*, 27(2), 144-163.
71. Pfund, C., House, S. C., Asquith, P., Fleming, M. F., Buhr, K. A., Burnham, E. L., ... & Sorkness, C. A. (2014). Training mentors of clinical and translational research scholars: a randomized controlled trial. *Academic Medicine*, 89(5), 774-782.

72. Sorkness, C. A., Pfund, C., Ofili, E. O., Okuyemi, K. S., Vishwanatha, J. K., NRMN team, ... & Womack, V. (2017). A new approach to mentoring for research careers: the National Research Mentoring Network. In *BMC proceedings* (Vol. 11, pp. 171-182). BioMed Central.
73. Stelter, R. L., Kupersmidt, J. B., & Stump, K. N. (2021). Establishing effective STEM mentoring relationships through mentor training. *Annals of the New York Academy of Sciences*, 1483(1), 224-243.
74. Han, I., & Onchwari, A. J. (2018). Development and implementation of a culturally responsive mentoring program for faculty and staff of color. *Interdisciplinary Journal of Partnership Studies*, 5(2), 3-3.
75. Pfund, C., Sancheznieto, F., Byars-Winston, A., Zárate, S., Black, S., Birren, B., ... & Asai, D. J. (2022). Evaluation of a culturally responsive mentorship education program for the advisers of Howard Hughes Medical Institute Gilliam Program graduate students. *CBE—Life Sciences Education*, 21(3), ar50.
76. Pfund, C., Maidl Pribbenow, C., Branchaw, J., Miller Lauffer, S., & Handelsman, J. (2006). The merits of training mentors. *Science*, 311(5760), 473-474.
77. Rogers, J., Branchaw, J., Weber-Main, A. M., Spencer, K., & Pfund, C. (2020). How much is enough? The impact of training dosage and previous mentoring experience on the effectiveness of a research mentor training intervention. *Understanding Interventions*, 11(1).
78. Casper, A. A., Rebolledo, N., Lane, A. K., Jude, L., & Eddy, S. L. (2022). “It’s completely erasure”: a qualitative exploration of experiences of transgender, nonbinary, gender nonconforming, and questioning students in biology courses. *CBE—Life Sciences Education*, 21(4), ar69.

79. Haeger, H., & Fresquez, C. (2016). Mentoring for inclusion: The impact of mentoring on undergraduate researchers in the sciences. *CBE—Life Sciences Education*, 15(3), ar36.
80. Leavitt, A. S., Nelson, K. L., & Cutucache, C. E. (2022). The effect of mentoring on undergraduate mentors: A systematic review of the literature. In *Frontiers in Education* (Vol. 6, p. 731657). Frontiers Media SA.
81. Limeri, L. B., Asif, M. Z., Bridges, B. H., Esparza, D., Tuma, T. T., Sanders, D., ... & Dolan, E. L. (2019). “Where’s my mentor?!” Characterizing negative mentoring experiences in undergraduate life science research. *CBE—Life Sciences Education*, 18(4), ar61.
82. Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education*, 3(4), 270-277.
83. Manuel, S. P., & Poorsattar, S. P. (2021). Mentoring up: Twelve tips for successfully employing a mentee-driven approach to mentoring relationships. *Medical Teacher*, 43(4), 384-387.
84. Han, A. Y., Gentle, C. K., Stefanopoulos, S., Burneikis, T., Lipman, J. M., & French, J. C. (2022). Managing Up: Approaching Mentoring From a Mentee's Perspective. *Journal of Surgical Education*, 79(6), e161-e165.
85. Hunter, A.-B., Laursen, S. L., & Seymour, E.. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education*, 91, 36–74.

Table 1. Descriptive Statistics (n=514)

	Min.	Max.	Mean	SD	Freq.
Dependent Variables					
Inadequate research support					27
Inadequate educational/career guidance					125
Inadequate emotional support					235
Independent Variables					
<i>Protective Factors:</i>					
Faculty mentor competency assessment (MCA)	1	7	5.72	1.313	
Culturally responsive mentoring (CRM)	1	5	3.00	1.191	
Mentor-mentee communication frequency	1	6	4.81	1.059	
Gender Concordance					282
Racial Concordance					257
Man mentor & woman/ TGNC mentee					181
Woman/TGNC mentor & man mentee					39
Woman/TGNC mentor & woman/TGNC mentee					142
Man mentor & man mentee					137
Having a postgraduate mentor					228
Having multiple faculty mentors					108
<i>Control Variables:</i>					
Gender:					
Man [reference]					181
Woman					294
TGNC					32
LBGQ+ status:					
Yes					176
No [reference]					331
Race/ethnicity:					
White [reference]					239
Black					40
Hispanic					96
Asian					73
Other racial groups					60
First-generation college student status:					144
GPA	2	4	3.69	0.325	
Academic Classification:					
Freshman					49
Sophomore					141
Junior/senior [reference]					324
First-time undergraduate researcher:					239

Table 2. Pooled results of GEEs predicting students' experiences of inadequate mentoring (n=514)

	Model 1: Inadequate research support				Model 2: Inadequate educational/career guidance				Model 3: Inadequate emotional support			
	b	Lower CI	Upper CI	p	b	Lower CI	Upper CI	p	b	Lower CI	Upper CI	p
<i>Intercept</i>	2.09	-4.50	8.69	0.53	3.24	-0.69	7.17	0.11	3.42	-0.45	7.29	0.08
<i>Protective Factors:</i>												
Faculty mentor competency assessment (MCA)	-0.66***	-1.10	-0.22	<0.0001	-0.66***	-0.89	-0.43	<0.0001	-0.88***	-1.13	-0.62	<0.0001
Culturally responsive mentoring (CRM)	0.18	-0.19	0.54	0.35	-0.40***	-0.65	-0.15	<0.0001	-0.37***	-0.58	-0.16	<0.0001
Mentor-mentee communication frequency	-0.95***	-1.30	-0.59	<0.0001	-0.16	-0.45	0.13	0.27	-0.21	-0.48	0.07	0.14
Gender Concordance	0.18	-0.79	1.15	0.72	-0.05	-0.62	0.51	0.85	-0.61*	-1.11	-0.11	0.02
Racial Concordance	0.73	-0.25	1.71	0.14	0.31	-0.36	0.99	0.36	-0.05	-0.58	0.47	0.84
Having a postgraduate mentor	-0.60	-1.58	0.38	0.23	0.16	-0.40	0.71	0.58	0.58*	0.13	1.03	0.01
Having multiple faculty mentors	0.17	-0.85	1.18	0.75	-0.04	-0.65	0.57	0.89	-0.60*	-1.13	-0.07	0.03
<i>Control Variables:</i>												
Gender:												
Man	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Woman	0.24	-0.88	1.35	0.68	0.37	-0.24	0.98	0.23	-0.03	-0.56	0.50	0.91
TGNC	-0.70	-3.61	2.22	0.64	0.02	-1.00	1.04	0.98	-0.02	-1.09	1.04	0.96
LBGQ+ status:												
Yes	1.11	-0.09	2.31	0.07	0.05	-0.50	0.60	0.86	0.02	-0.41	0.46	0.92
No	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Race/ethnicity:												
White	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref	ref
Black	0.06	-2.17	2.29	0.96	-0.59	-1.69	0.50	0.29	-0.42	-1.60	0.76	0.49
Hispanic	0.99	-0.38	2.35	0.16	-0.11	-0.88	0.65	0.77	0.11	-0.58	0.81	0.75
Asian	-0.07	-1.34	1.19	0.91	-0.36	-1.15	0.42	0.36	-0.27	-0.97	0.44	0.46
Other racial groups	1.29	0.01	2.57	0.05	-0.26	-1.10	0.57	0.54	-0.21	-0.99	0.56	0.59

First-generation college student status:													
	Yes	0.75	-0.27	1.76	0.15	-0.36	-0.98	0.25	0.25	-0.33	-0.88	0.23	0.25
	No	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
GPA													
		0.29	-1.17	1.76	0.69	0.14	-0.78	1.07	0.76	1.06*	0.16	1.96	0.02
Academic Classification:													
	Freshman	0.49	-0.80	1.79	0.46	0.57	-0.37	1.50	0.24	-0.16	-0.95	0.64	0.70
	Sophomore	0.01	-1.26	1.28	0.99	0.57*	0.05	1.09	0.03	0.16	-0.41	0.72	0.59
	Junior/senior	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
First-time undergraduate researcher:													
	Yes	0.06	-0.87	0.99	0.90	0.59*	0.06	1.11	0.03	0.08	-0.37	0.53	0.73
	No	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>

* p<0.05

** p<0.01

*** p<0.001

Table 3. Pooled results of GEEs predicting students' experiences of inadequate emotional support (n=514)

Model 4					Model 5			
	b	Lower CI	Upper CI	p	b	Lower CI	Upper CI	p
<i>Intercept</i>	4.12	0.30	7.95	0.03	4.04	0.10	7.99	0.04
Protective Factors:								
Man mentor & woman/TGNC mentee	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	0.08	-0.71	0.87	0.85
Woman/TGNC mentor & man mentee	-0.08	-0.87	0.71	0.85	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
Woman/TGNC mentor & woman/TGNC mentee	-0.68*	-1.31	-0.04	0.04	-0.60	-1.45	0.25	0.16
Man mentor & man mentee	-0.62*	-1.19	-0.06	0.03	-0.54	-1.28	0.19	0.14
Racial concordance variable	-0.06	-0.58	0.46	0.82	-0.06	-0.58	0.46	0.82
Faculty mentor competency assessment (MCA)	-0.89***	-1.15	-0.63	<0.0001	-0.89	-1.15***	-0.63	<0.0001
Culturally responsive mentoring (CRM)	-0.37***	-0.57	-0.16	<0.0001	-0.37	-0.57***	-0.16	<0.0001
Mentor-mentee communication frequency	-0.20	-0.48	0.07	0.15	-0.20	-0.48	0.07	0.15
Having a postgraduate mentor	0.58*	0.13	1.03	0.01	0.58	0.13*	1.03	0.01
Having multiple faculty mentors	-0.61*	-1.15	-0.07	0.03	-0.61	-1.15*	-0.07	0.03
Control Variables:								
LBGQ+ status:								
Yes	0.06	-0.35	0.48	0.76	0.06	-0.35	0.48	0.76
No	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
Race/ethnicity:								
White	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
Black	-0.44	-1.61	0.74	0.47	-0.44	-1.61	0.74	0.47
Hispanic	0.11	-0.59	0.81	0.76	0.11	-0.59	0.81	0.76
Asian	-0.26	-0.98	0.45	0.47	-0.26	-0.98	0.45	0.47
Other racial groups	-0.21	-0.99	0.57	0.59	-0.21	-0.99	0.57	0.59
First-generation college student status:								
Yes	-0.32	-0.87	0.23	0.25	-0.32	-0.87	0.23	0.25
No	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>

GPA		1.06*	0.16	1.96	0.02	1.06*	0.16	1.96	0.02
Academic Classification:									
	Freshman	-0.15	-0.94	0.64	0.71	-0.15	-0.94	0.64	0.71
	Sophomore	0.17	-0.40	0.73	0.56	0.17	-0.40	0.73	0.56
	Junior/senior	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>
First-time undergraduate researcher:									
	Yes	0.07	-0.38	0.52	0.76	0.07	-0.38	0.52	0.76
	No	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>	<i>ref</i>

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

In Model 4, man mentor & woman/TGNC mentee was used as the reference group, and in Model 5, woman/TGNC mentor & man mentee was used as the reference group.

Table 4. Empirical Findings of Inadequate Mentoring: Protective Factors in Mentoring Relationships

Form	Prevalence	Protective Factors			
Inadequate research support	Low	Enhanced mentoring skills	Frequent mentor-mentee interactions		
Inadequate educational/career guidance	Medium	Enhanced mentoring skills	Culturally responsive mentoring		
Inadequate emotional support	High	Enhanced mentoring skills	Culturally responsive mentoring	Gender concordance	Multiple faculty mentors

Figure 1. Conceptual Model of Inadequate Mentoring: Protective Factors in Mentoring Relationships

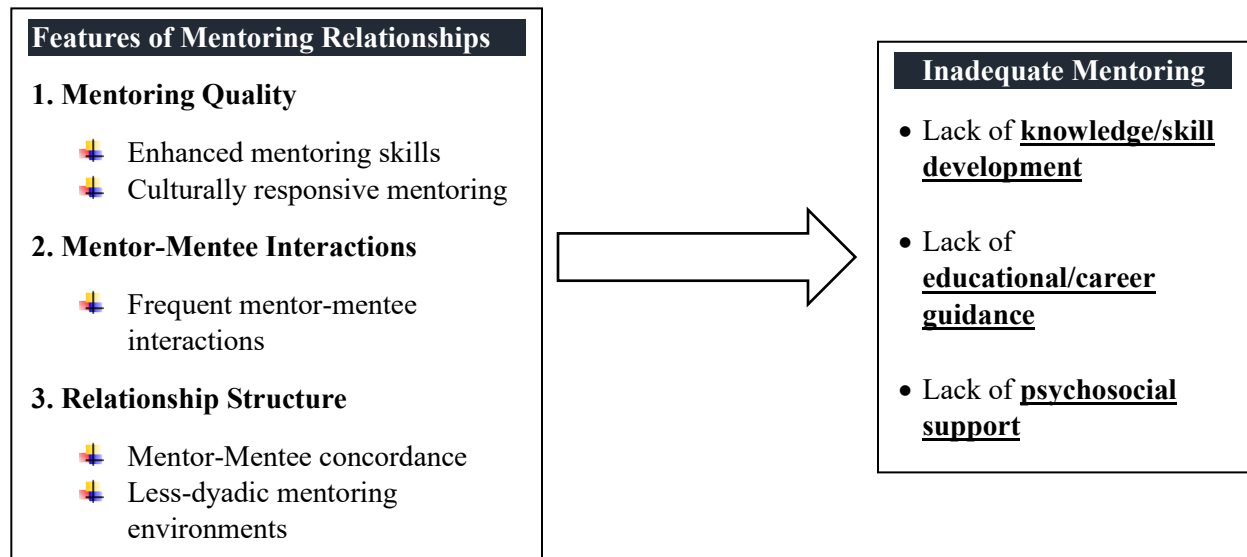
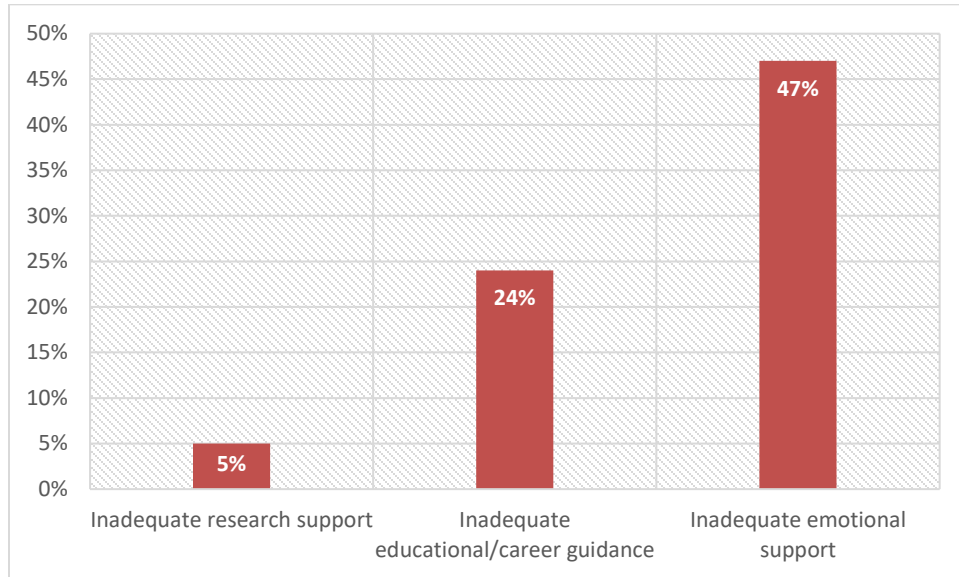


Figure 2. Three forms of inadequate mentoring



Supplemental Materials:

Table 5. Correlations between Inadequate Mentoring and Mentoring Competency Assessment (MCA) subscales

	Inadequate research support	Inadequate educational/career guidance	Inadequate emotional support
MCA: communication	-0.26	-0.37	-0.46
MCA: managing expectations	-0.29	-0.40	-0.46
MCA: gauging students' understanding	-0.26	-0.41	-0.41
MCA: fostering students' independence	-0.26	-0.43	-0.48
MCA: providing professional development opportunities	-0.26	-0.44	-0.45