

Multiple Mentors' Competency and Undergraduate Researchers' Science Identity

Callie L. Avondet, Yolanda Chavez, Sara E. Grineski,
Timothy W. Collins, *University of Utah*
Danielle X. Morales, *University of Massachusetts Boston*

Abstract

Research experiences are important to undergraduate academic life, and many students conducted research during the COVID-19 pandemic, amid disruptions. Undergraduate researchers receive mentorship from faculty mentors and, sometimes, postgraduate mentors. Little is known about the role of multiple mentors' competency in the science personal-identity and science social-identity of undergraduate students. Using primary data collected in 2020 ($n = 841$), the authors examine both faculty and postgraduate mentor competency and the impact of COVID-19 on undergraduate researchers. Having both types of mentors is beneficial for students' science identities unless both the faculty and postgraduate mentor exhibit low competency. COVID-19 had no discernable impacts on either science identity. Findings suggest that faculty and program directors should consider mentor training to increase competency and to involve postgraduate mentors in undergraduate research experiences.

Keywords: *indirect (student perceptions, reflections), mentoring, one-on-one mentored (conventional); STEM*

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Undergraduate research experiences (UREs) are central to science education in the United States (Adedokun et al. 2013; Kuh 2008; Shanahan et al. 2015). During these experiences, faculty and sometimes postgraduates (graduate students or postdoctoral fellows) mentor undergraduate researchers. UREs happen for various durations throughout the year. These experiences help students become

part of the science community, and participation bolsters their science identity, which is comprised of both science personal-identity and science social-identity (Camacho et al. 2021; Morales, Grineski, and Collins 2021). Science personal-identity is an individual's adoption and perception of themselves as a scientist (Camacho et al. 2021; Estrada, Hernandez, and Schultz 2018). Science social-identity refers to a student's sense of belonging and prioritization of contributing to the scientific community (Camacho et al. 2021). Students with stronger science identities, whether personal or social, are more likely to enter a science occupation (Stets et al. 2017).

The COVID-19 pandemic in the United States disrupted many UREs. In 2020, illness and social distancing requirements forced students out of the lab, ending or changing many UREs (Speer, Lyon, and Johnson 2021). Research conducted before COVID-19 demonstrated that mentorship played important roles in undergraduate researchers' development (Byars-Winston et al. 2015; Camacho et al. 2021; Collins et al. 2017; Morales et al. 2021). Since then, research has shown the continued importance of faculty mentorship during the COVID-19 pandemic (Speer et al. 2021).

Faculty mentorship directly influences undergraduates' growth from their research experiences. Mentors provide essential guidance throughout the research process and sometimes help their protégés enter science careers by helping them define their research and career interests and navigate the next steps for graduate school or the job market. To measure effective mentorship, Fleming et al. (2013) created the Mentoring Competency Assessment (MCA). The MCA

consists of 26 questions that undergraduate researchers answer about their mentor(s). It includes six categories: “maintaining effective communication, aligning expectations, assessing understanding, addressing diversity, fostering independence, and promoting professional development” (p. 1003). Scholars have previously used the MCA to assess faculty mentorship in UREs. Before COVID-19, higher faculty mentor competency was positively associated with higher science personal-identity gains among undergraduate researchers (Morales et al. 2021). During the COVID-19 pandemic, studies using the MCA showed that mentor competency was significantly associated with undergraduate researchers' graduate school intentions and even mental health (Grineski, Morales, and Collins 2024).

Frequently, faculty engage postgraduates to mentor undergraduate students. An unpublished study reported that 44 percent of students engaging in summer UREs at US universities had a postgraduate mentor (Chavez et al. in review). The literature on these mentorship contributions is minimal. When examined, the literature more often has focused on postgraduates' presence than their competence, and reports are mixed on their influence. Some studies report that undergraduate mentees who predominantly communicate with a postgraduate mentor have less contact with their faculty mentor, reducing undergraduate students' gains compared to students who communicate regularly with both their postgraduate and faculty mentors (Aikens et al. 2016; Joshi, Aikens, and Dolan 2019). Morales, Grineski, and Collins (2018) found that students with a faculty and postgraduate mentor had the lowest gains (regardless of mentor-mentee gender concordance) compared to students with only a faculty mentor. However, another study found the opposite. When controlling for communication patterns within a triad, an undergraduate who is directly mentored by both a faculty mentor and postgraduate mentor, who all communicate together, experience the highest gains (Aikens et al. 2016). Two qualitative studies have explored the key competencies for postgraduate mentors (Ahn and Cox 2016) and the benefits and drawbacks of postgraduate mentorship (Mabrouk and Remijan 2023). These studies provide insight into how postgraduate mentorship affects UREs, but there is currently no study, to the authors' knowledge, that has systematically evaluated postgraduate mentor competency in UREs.

COVID-19 changed mentorship practices in URE, as most traditional in-person lab interactions ceased in late spring 2020 and then slowly restarted near the close of 2020 and into 2021. Studies have not fully clarified the implications of the global pandemic on undergraduate researchers. Research has shown that many students reported stronger relationships with their research advisers due to the pandemic and the move to virtual mentorship, partially because of the informality associated with video calling (Speer et al. 2021). However, COVID-19 also magnified

challenges with negative mentorship. Students with less competent mentors (faculty or postgraduate) were less motivated to pursue a graduate degree in science because of COVID-19 (Morales, Grineski, and Collins 2022). Grineski et al. (2022) found that over two-thirds of students still doing research late in the spring 2020 semester experienced task uncertainty and motivation issues. Furthermore, Grineski et al. (2021) found that each negative COVID-19 research impact that students experienced was associated with increased depression and anxiety symptoms. It is not known how mentorship quality and structure during COVID-19 was associated with undergraduate student science personal-identity and social-identity.

In studying student science identities, it is recognized that identities are fundamental sources of motivation and that they are both personally and socially constructed (Byars-Winston et al. 2016; Camacho et al. 2021; Carlone and Johnson 2007; Kim, Sinatra, and Seyranian 2018). Science identity is considered a personal and social construct because previous identity research shows that both social and personal identification make up an individual's identities (Camacho et al. 2021; Kim et al. 2018; Tajfel and Turner 1986). To give an example, Carlone and Johnson (2007) explain that the science identity of women of color in STEM fields is based on both self-recognition (often because of personal interests and goals) and others' recognition (or lack thereof). This underscores the importance of considering both the personal and the social science identities. Although it may be more common to consider science identity as a personal or individual process, Kim and colleagues (2018) argue that considering social identities “expand[s] our thinking to include the role played by other people in the environment in the creation and maintenance of ingroups and outgroups and the view of STEM identity development as a community-oriented and socially situated process” (612). Read together, this understanding of the social and personal aspects of identity formation point to their mutually reinforcing yet distinct roles in overall science identity formation. As Camacho et al. (2021) noted, “personal and social identities can shape a student's educational experience and decision to pursue a career in science” (2). In line with their work, both science personal-identity and science social-identity will be examined. Studying mentor competency in relation to science personal-identity helps clarify that mentorship can help students understand how science fits with their interests and goals. Similarly, evaluating a relationship between mentor competency and science social-identity provides greater insights into how mentors can advance students' sense of belonging within STEM.

Accordingly, the following questions were addressed: How does faculty and postgraduate mentoring competency affect undergraduate researchers' science personal-identity and science social-identity? How did COVID-19 affect

undergraduate researchers' science personal-identity and science social-identity?

Answering these questions addresses gaps in the literature. The first contribution looks at mentor competency of both faculty and postgraduate mentors within mentoring triads. Although it is well known that many students work with postgraduate mentors, more knowledge is needed about how they shape student growth and development. Second, the effects of COVID-19 research challenges on undergraduate student science identities is evaluated. Science identity is an important predictor for student persistence in STEM fields (Estrada et al. 2018; Merolla and Serpe 2013), however it is not yet known how COVID-19 influenced this. It is important to document the consequences of the COVID-19 pandemic on students. Results can inform future decision-making about UREs during global or local crises. They also will help undergraduate research program directors and faculty mentors better support student development in adverse conditions (Burns, Dagnall, and Holt 2020; Grineski, Morales, and Collins 2023).

Methods

Survey data collected from students at 18 US universities about their research experiences and opportunities during spring and summer 2020 were analyzed. The research team connected with undergraduate research program directors through the National Institutes of Health's BUILDing SCHOLARS URE program and by soliciting participants on the Council on Undergraduate Research's LISTSERV. Some of the program directors who responded ran several programs at their institution, and others helped connect the research team to other research programs at their institution (Grineski et al. 2023, 2021, 2022; Morales et al., 2022, 2024).

The 18 program directors cooperating with the study sent the survey link to 2,237 qualified students. The response rate was 54.5 percent. The survey included 160 questions (excluding contact information). It took approximately 30 minutes. This analysis included only students who participated in research in spring 2020 (some also participated during summer 2020) and had at least one faculty mentor ($n = 841$). The project was approved by the University of Utah Institutional Review Board (#00133477).

Variables

Table 1 lists coding of all variables, including the survey questions used to create the variables, and Table 2 contains descriptive statistics for variables in the analyses. More detail on the survey questions can be found in the supplemental material. The dependent variables are science personal-identity and science social-identity. The independent variables are faculty mentor competency, postgraduate mentor competency, and COVID-19 research disruptions. There was a continuous variable for faculty

mentor competency and a dichotomous variable for postgraduate mentor competency based on above and below median competency. Above median was referred to as "high" competency and below median as "low" competency. Postgraduate mentor competency was dichotomized because not all students had a postgraduate mentor. The postgraduate mentor mean MCA score was 4.10 (standard deviation: 0.8; range: 1.27–5; descriptive statistics not shown in Table 2). Then, to examine the intersection of faculty and postgraduate mentor competency, a dichotomous variable was created for faculty mentor competency (also based on the median) and cross-classified with postgraduate mentor competency. This yielded six categories (see Figure 1). These categories referenced whether the mentors were high competency (HC) or low competency (LC) and if the student was in a mentoring dyad or triad. Dyads referred to mentoring relationships between one faculty member and one student. Triads referred to relationships including one faculty mentor, one postgraduate mentor, and one undergraduate student. Control variables were known to be associated with outcomes, including GPA, communication frequency with faculty mentor, grade, major, race/ethnicity, previous research experience, gender, sexual minority status, first-generation student status, and research conducted during summer 2020.

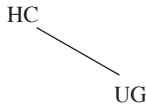
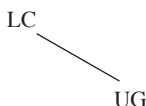
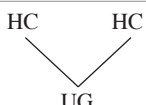
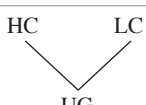
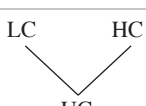
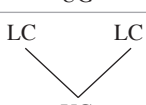
Statistical Methods

After running descriptive statistics (Table 2), multiple imputation was performed because failure to account for missing values could introduce additional bias into the research and result in less statistical power (Sterne et al. 2009). Utilizing STATA 16, 20 data sets with 200 iterations between each estimated data set were imputed.

Then generalized estimating equations (GEEs) were performed, which extended the generalized linear model to clustered data. Because students from the same universities likely had similar experiences, not accounting for clustering would violate the independence assumption of generalized linear models (Hardin and Hilbe 2013). Students at the same university were placed into a cluster. GEEs assumed each cluster (rather than each case) was independent of each other (Collins et al. 2017; Hardin and Hilbe 2013). Similar models have been used in other studies of undergraduate research (Collins et al. 2017; Grineski et al. 2018, 2022; Morales et al. 2022). There were a total of 256 clusters in the analysis. When testing for GEE model fit, the inverse Gaussian distribution with a log link fit both science personal- and social-identity models best compared to normal or gamma with a log or identity link and inverse Gaussian distribution with an identity link.

Using the multiply imputed data, three GEEs were run for each dependent variable. Model 1 examines faculty and postgraduate mentor competency as separate variables. Models 2 and 3 consider faculty and postgraduate

FIGURE 1. Mentor Competency Combinations

Faculty mentor competency	Postgraduate mentor competency		Name
High competency (HC)	No postgraduate		HC dyad
Low competency (LC)	No postgraduate		LC dyad
High competency	High competency		HC-HC triad
High competency	Low competency		HC-LC triad
Low competency	High competency		LC-HC triad
Low competency	Low competency		LC-LC triad

Note: High competency for faculty MCA is ≥ 4.00 (median), and high competency for PG is MCA ≥ 4.08 (median).

MCA, Mentoring Competency Assessment; PG, postgraduate; UG, undergraduate.

mentor competency combined. These models were run twice, rotating the reference from LC-LC triad (Model 2) to HC-HC triad (Model 3). Using both the most competent and least competent categories as the reference showed the differences between two mentorship extremes.

Results

Science Personal-Identity

Table 3 presents Model 1 results for science personal-identity. Faculty mentor competency was significantly associated with higher scores. Students who rated their faculty mentors to be 1 point more competent had 2.7 percent higher personal science identity scores ($p = 0.003$). Above-median competency postgraduate mentors were associated with higher science personal-identity scores relative to students working with postgraduate mentors who had below-median competency scores ($p = 0.018$). There were no significant differences in science personal-identity for those with no postgraduate mentor versus one with low competency. Additionally, having many COVID-19 research impacts or a canceled research experience had no significant impact on science personal-identity compared to students who had few COVID-19 disruptions.

Table 4 presents results for Model 2, which used 6 mentorship competency combinations with an LC-LC triad as the reference category. Students in an HC-LC triad were found to have 11.0 percent higher science personal-identity scores than those in an LC-LC triad ($p = 0.006$). The same held true for students in an LC-HC triad; they had science personal-identity scores that were 12.2 percent higher ($p = 0.002$). This meant that students in triads with at least one adviser rated above the median were associated with higher personal-identity scores than when both mentors were below-median competency. Students in an HC-HC triad also had scores that were 11.0 percent higher ($p = 0.003$).

Model 3 (Table 4) shows the association between mentor competency and science personal-identity compared to students in an HC-HC triad. Students in an HC dyad had 6.2 percent lower science personal-identity scores than those in an HC-HC triad ($p = 0.006$). Students in an LC dyad had 9.2 percent lower scores than students in an HC-HC triad ($p < 0.001$). Consistent with the findings in Model 2, students in an LC-LC triad had significantly reduced science personal-identity relative to the HC-HC triad group ($p = 0.003$).

TABLE 1. Variable Coding

Variable name	Survey question(s)	Coding
Science personal-identity (DV)	Indicate to what extent the following statements are true of you: I have a strong sense of belonging to a community of scientists; I derive great personal satisfaction from working on a team that is doing important research; I have come to think of myself as a “scientist”; I feel like I belong in the field of science (Camacho et al. 2021).	Averaged the 4 Likert scale scores ranging from (1) strongly disagree to (5) strongly agree.
Science social-identity (DV)	Indicate the importance to you of each of the following: Obtaining recognition from colleagues for contributions to my special field. Making a theoretical contribution to science. Becoming an authority in my field. (Questions from the Cooperative Institutional Research Program; Camacho et al. 2021.)	Averaged the 3 Likert scale scores ranging from (1) strongly disagree to (5) strongly agree.
Faculty mentor competency (IV)	MCA, including 26 Likert questions about student’s mentor’s competency	Averaged the 26 Likert scale scores to create a continuous variable for Model 1. Used the averaged score to make the series of above and below mean mentor combination variables.
Postgraduate mentor competency (IV)	MCA, including 26 Likert questions about student’s mentor’s competency	After averaging the 26 Likert responses, a dichotomous variable was created for mentors below median competency (reference), at or above the median, or no postgraduate mentor.
COVID-19 research disruptions (IV)	Multiple selection question, with 16 potential challenges caused by COVID-19 in spring 2020 that may have influenced student’s research capabilities (Grineski et al. 2021).	3 categories: research experience canceled (reference), few COVID-19 impacts (< 5 [median]), many COVID-19 impacts (≥ 5).
Mentorship combinations (IV)	MCA, including 26 Likert questions about student’s mentor’s competency. Do you have any postgraduate mentors (graduate students or postdoctoral fellows) you closely work with?	See Figure 1.
GPA	Based on a 4-point scale, what was your GPA in spring 2020 overall?	Continuous.
Communication frequency with faculty	How often did you usually communicate with your primary faculty mentor during COVID-19?	1 (daily) to 6 (less than once a month).
Grade level	Based on the credit hours you had taken, what was your class level in spring 2020?	3 dichotomous categories: first- or second-year, third-year, fourth-year.
Major	Please select your major from below; 90 majors listed.	Primary undergraduate major coded to 6 mutually exclusive categories: life sciences, engineering, health, social and behavioral sciences, other, and computer science, math, and physical science.
Race/ethnicity	What is your race/ethnicity?	Coded to 5 dichotomous racial categories: Black, Asian, Hispanic, White, other race (including Native American, Native Hawaiian or other Pacific Islander, Multiracial, other, and/or unknown).
Previous research experience	How many times (in semesters) have you participated in academic year research prior to spring 2020 ? How many times have you participated in summer research prior to summer 2020?	0 = less than 2 semesters or summers (novice) and 1 = 2 or more semesters or summers (experienced).

(table continues)

TABLE 1. (cont.)

Variable name	Survey question(s)	Coding
Gender	What is your gender/gender identity?	Coded to 3 categories: man, woman, transgender or gender nonconforming (TGNC).
Sexual minority status	What is your sexual orientation?	0 = heterosexual/straight, 1 = LGBQ (including asexual, bisexual, gay, lesbian, pansexual, not listed).
First-generation student status	Highest degree or level of school your parent "1" completed. Asked again for parent "2," with the option of only having 1 parent/guardian.	0 = 1 or more parent has a bachelor's degree or higher, 1 = no parent has a bachelor's degree or higher.
Continued research during spring 2020	Were you doing research in between mid-March and the end of April 2020?	0 = stopped research during COVID-19, 1 = continued research during COVID-19.
Continued research during summer 2020	When COVID-19 hit in March 2020, were you planning to do research in summer 2020? Which statement best characterizes the current status of your summer research opportunity?	0 = did not conduct research in summer 2020, 1 = conducted research during summer 2020.

Note: DV, dependent variable; IV, independent variable; MCA, Mentoring Competency Assessment (Fleming et al. 2013).

Science Social-Identity

In Model 1 (Table 3), both faculty mentor competency and postgraduate competency were significant ($p < 0.05$) for science social-identity. When faculty mentors were rated 1 point higher on the MCA, students reported science social-identity scores 6.3 percent higher. Students whose postgraduate mentor was at or above the median competency had an approximately 7.1 percent higher science social-identity score than their peers with a below-median competency postgraduate mentor. There were no significant differences in science social-identity for those with no postgraduate mentor versus one with below median competency. Students with many COVID-19 research disruptions or with canceled research experiences had no significant difference in science social-identity compared to students with few disruptions.

In Model 2 for science social-identity (Table 3), every mentorship combination except an LC dyad was significantly positively associated with higher science social-identity scores compared to an LC-LC triad. Students in an HC dyad had 13.8 percent higher social-identity scores than students in an LC-LC triad ($p < 0.001$). Students in an HC-LC triad had 16.2 percent higher social-identity scores than those in an LC-LC triad ($p = 0.002$). In an HC-HC triad, students reported 14.4 percent higher social-identity scores than those in an LC-LC triad ($p < 0.001$). When students were in an LC-HC triad, they had about 18.6 percent higher social-identity scores than their peers in an LC-LC triad ($p < 0.001$).

In contrast (Model 3, Table 4), if students had one mentor at or above median competency (i.e., HC-LC triad

or LC-HC triad) there were no significant differences in science social-identity compared to an HC-HC triad. Students in an LC dyad had about 90 percent lower science social-identity scores than peers in an HC-HC triad ($p = 0.001$). Students in an LC-LC triad reported about 12.6 percent lower social-identity scores than their peers in an HC-HC triad ($p < 0.001$). This was the reverse of the finding already noted in Model 2.

Control Variables

Model 1 shows several significant control variables for each dependent variable. Students with engineering ($\exp(B) = 0.965, p = 0.041$), health ($\exp(B) = 0.932, p = 0.012$), social and behavioral science ($\exp(B) = 0.891, p < 0.001$), math, computer science, and physical science ($\exp(B) = 0.956, p = 0.043$), and other ($\exp(B) = 0.743, p \leq 0.001$) majors were more likely to report lower science personal-identity scores than their life science major peers. Experienced (two-plus semesters of research) undergraduate researchers reported about 3.4 percent higher personal-identity scores than their peers with less experience ($p = 0.025$). For science social-identity, transgender or gender-nonconforming (TGNC) students were more likely to report lower science social-identity scores than men ($\exp(B) = 0.826, p = 0.013$). Students with an "other" major reported 28.9 percent lower science social-identity scores than their life science major peers ($p \leq 0.001$). Students who conducted research in summer 2020 had scores that were 5.0 percent higher than those who did not ($p = 0.004$).

Discussion

This study evaluated the ways the quality of multiple mentors affected undergraduate researchers' science

TABLE 2. Descriptive Statistics (*n* = 841)

Variable	No	Yes	Min	Max	Mean
Science personal-identity	832		1	5	3.88
I have a strong sense of belonging to the community of scientists.	836		1	5	3.55
I derive great personal satisfaction from working on a team that is doing important research.	835		1	5	4.31
I have come to think of myself as a “scientist.”	835		1	5	3.64
I fell like I belong in the field of science.	833		1	5	4.04
Science social-identity	832		1	4	2.71
Obtaining recognition from colleagues for contributions to my special field.	836		1	4	2.63
Making a theoretical contribution to science.	833		1	4	2.95
Becoming an authority in my field.	832		1	4	2.56
MCA faculty mentor	782		1.27	5	3.98
Postgraduate (PG) mentor	818				
MCA above median PG mentor		115			
MCA below median PG mentor		113			
No PG mentor		590			
MCA combinations (see Figure 1)					
HC dyad	796	312			
LC dyad	796	235			
HC-HC triad	792	87			
HC-LC triad	792	27			
LC-LC triad	792	83			
HC-LC triad	792	41			
Communication frequency with faculty	805		1	6	3.73
COVID-19 research disruptions	841		0	13	3.70
Spring 2020 research experienced canceled		362			
Few COVID-19 impacts (below median)		171			
Many COVID-19 impacts (above median)		308			
Grade Level	840				
First- or second-year		149			
Third-year		298			
Fourth-year		393			
Major	841				
Biological and life sciences		339			

(table continues)

TABLE 2. (cont.)

Variable	No	Yes	Min	Max	Mean
Engineering		191			
Math, computer science, and physical science		94			
Social and behavioral science		94			
Health		51			
Other		72			
Race/ethnicity	761				
White, non-Hispanic		270			
Asian, non-Hispanic		152			
Black, non-Hispanic		36			
Hispanic, non-Hispanic		255			
Other race, non-Hispanic		48			
Previous research experience	840				
Novice		229			
Experienced		611			
Gender	763				
Man		289			
Woman		461			
TGNC (transgender, gender nonconforming)		13			
LGBQ (lesbian, gay, bisexual, queer)	754	146			
First-generation	754	257			
Conducted research in summer 2020	841	405			

Note: Dyad, student with faculty mentor; HC, high-competency mentor (MCA score at or above median); LC, low-competency mentor (MCA score below median); MCA, Mentoring Competency Assessment; SD, standard deviation; triad, student with faculty and postgraduate mentors.

personal-identity and social-identity during the COVID-19 pandemic. The research centered both faculty and postgraduate mentor competency; the literature has previously ignored postgraduate mentors or focused mainly on whether or not they mentor. Furthermore, the investigation provides insight into how COVID-19 affected undergraduate researcher outcomes.

For science personal-identity and social-identity, when accounting for faculty mentor competency separately, it was found that undergraduates exhibited higher scores when their postgraduate mentor had an above median mentoring competency (vs. below median). Having no postgraduate mentor versus having one with low competency was not associated with any difference in science personal- or social-identity. This suggests that, although a competent postgraduate mentor is an asset, a weaker postgraduate mentor is not worse than only having a faculty

mentor. Others have emphasized that postgraduate mentors contribute to undergraduate students' science identity formation through their teaching skills, personality, presence, and helping students become more independent (Mabrouk and Remijan 2023). Paired with the findings of this study, this suggests that the benefits of postgraduate mentorship may be generalizable to other contexts.

When cross-classifying faculty and postgraduate mentor competency, it was found that having both mentors, provided at least one mentor was high competency, was associated with higher science personal-identity scores. Every mentorship triad combination was associated with significantly higher science personal-identity scores than the LC-LC triad. Furthermore, the only combinations associated with significantly lower science personal-identity scores than an HC-HC triad were an LC-LC triad and, importantly, both types of dyads, regardless of faculty competency. When

TABLE 3. Model 1: Pooled Results of GEEs Predicting Science Personal-Identity and Science Social-Identity ($n = 841$)

	Science Personal-Identity				Science Social-Identity			
	B	Exp(B)	<i>p</i>	Lower CI	Upper CI	B	Exp(B)	<i>p</i>
Intercept	1.212	3.359	<0.001**	1.038	1.385	0.484	1.623	<0.001**
Faculty mentor competency	0.027	1.027	0.003**	0.009	0.045	0.061	1.063	<0.001**
<i>Ref: low postgraduate competency</i>								
High postgraduate mentor competency	0.058	1.060	0.018*	0.010	0.107	0.069	1.071	0.031*
No postgraduate mentor	-0.027	0.973	0.156	-0.065	0.010	0.019	1.020	0.442
GPA	0.023	1.023	0.206	-0.013	0.059	0.039	1.040	0.105
Faculty communication frequency	-0.004	0.996	0.415	-0.015	0.006	0.008	1.008	0.266
<i>Ref: few COVID-19 impacts</i>								
Many COVID-19 impacts	-0.011	0.989	0.517	-0.046	0.023	0.012	1.012	0.617
Research experience canceled	-0.006	0.994	0.750	-0.042	0.030	0.016	1.016	0.510
<i>Ref: first- and second-year</i>								
Third-year	0.017	1.017	0.359	-0.020	0.054	0.045	1.046	0.071
Fourth-year	0.029	1.030	0.110	-0.007	0.066	0.016	1.017	0.498
<i>Ref: biological and life science majors</i>								
Engineering	-0.036	0.965	0.041*	-0.070	-0.001	0.005	1.005	0.842
Health	-0.070	0.932	0.012*	-0.125	-0.016	-0.012	0.988	0.739
Social and behavioral science	-0.116	0.891	<0.001*	-0.158	-0.073	0.039	1.040	0.193
Math, computer science, and physical science	-0.045	0.956	0.043*	-0.088	-0.001	0.008	1.008	0.782
Other	-0.297	0.743	<0.001**	-0.344	-0.250	-0.117	0.890	0.001**
<i>Ref: White</i>								
Black	0.039	1.040	0.222	-0.024	0.102	0.080	1.084	0.075
Asian	-0.018	0.982	0.338	-0.056	0.019	-0.023	0.978	0.384

(table continues)

TABLE 3. (cont.)

	Science Personal-Identity				Upper CI	Lower CI	Science Social-Identity			
	B	Exp(B)	p				B	Exp(B)	p	
Hispanic	−0.008	0.992	0.629		0.024	−0.039	0.010	1.010	0.668	
Other race	0.033	1.034	0.249		0.090	−0.023	0.042	1.043	0.288	
Experienced researcher	0.034	1.034	0.025*		0.063	0.004	0.006	1.006	0.751	
<i>Ref. man</i>										
Woman	−0.011	0.989	0.440		0.017	−0.038	0.005	1.005	0.798	
TGNC	−0.038	0.963	0.445		0.060	−0.136	−0.191	0.826	0.013*	
LGBQ	−0.014	0.986	0.436		0.021	−0.049	0.027	1.027	0.254	
First- generation	−0.004	0.996	0.763		0.024	−0.033	−0.001	0.999	0.971	
Conducted research in summer 2020	0.007	1.007	0.567		0.033	−0.018	0.049	1.050	0.004**	

Note: GEE models use an inverse Gaussian family with identity link and account for clustering based on the student's home university.

CI, confidence interval; GEE, generalized estimating equation; LGBQ, lesbian, gay, bisexual, queer; ref, reference; TGNC, transgender, gender nonconforming.

*** $p < 0.01$, ** $p < 0.05$.

TABLE 4. Models 2 and 3: Results for GEEs Predicting Science Personal-Identity and Science Social-Identity ($n = 841$)

	Science Personal-Identity			Upper CI	Lower CI	Science Social-Identity		
	B	Exp(B)	<i>p</i>			B	Exp(B)	<i>p</i>
Intercept	1.293	3.645	<0.001**	1.140	1.446	0.713	2.040	<0.001**
Model 2								
<i>Ref: LC-LC triad</i>								
LC dyad	-0.011	0.989	0.633	-0.055	0.033	0.031	1.032	0.283
HC dyad	0.021	1.022	0.344	-0.023	0.066	0.129	1.138	<0.001**
HC-LC triad	0.104	1.110	0.006**	0.030	0.179	0.150	1.162	0.002**
HC-HC triad	0.086	1.090	0.003**	0.030	0.142	0.135	1.144	<0.001**
LC-HC triad	0.115	1.122	0.002**	0.043	0.187	0.171	1.186	<0.001**
Model 3								
<i>Ref: HC-HC triad</i>								
LC dyad	-0.096	0.908	<0.001**	-0.144	-0.049	-0.104	0.901	0.001**
HC dyad	-0.064	0.938	0.006**	-0.111	-0.018	-0.006	0.994	0.854
HC-LC triad	0.019	1.019	0.632	-0.058	0.095	0.015	1.015	0.763
LC-LC triad	-0.086	0.918	0.003**	-0.142	-0.030	-0.135	0.874	<0.001**
LC-HC triad	0.030	1.030	0.434	-0.045	0.104	0.036	1.037	0.449

Note: Models control for GPA, frequency of communication with faculty, COVID-19 research disruptions, grade level, major, race, previous research experience, gender, sexuality, first-generation student status, and doing summer 2020 research. GEE models use an inverse Gaussian family with identity link and account for clustering based on the student's home university.
 CI, confidence interval; dyad, student with faculty mentor; GEE, generalized estimating equation; HC, high-competency mentor (MCA score at or above median); LC, low-competency mentor (MCA score below median); MCA, Mentoring Competency Assessment; ref, reference; triad, student with faculty and postgraduate mentors.
 ** $p < 0.01$, * $p < 0.05$.

predicting science social-identity, the direction and significance of the mentor competency combinations were identical to the findings for science personal-identity with two exceptions. First, an HC dyad was associated with greater science social-identity relative to an LC-LC triad. Second, an HC dyad was statistically equivalent to an HC-HC triad for science social-identity (for personal-identity, the dyad was significant and negative).

These findings, when taken together, emphasize the value of mentoring triads and are consistent with research documenting the benefits of having multiple mentors, especially when students have direct contact with both faculty and postgraduate mentors (Aikens et al. 2016; Joshi et al. 2019). The different types of mentorship offered by faculty and postgraduate students may provide the most value and gains for students' science personal-identity (Mabrouk and Remijan 2023). Having a postgraduate mentor provides undergraduates with more science connections, possibly boosting students' science social-identity. Camacho et al. (2021) found that students with a mentor feel more connected to the science community. Having an additional mentor, and therefore more connections, seems unlikely to hurt undergraduate researchers' sense of community connection. Experience with multiple mentors provides students with positive experiences (Frederick et al. 2021). There is little evidence of a postgraduate "penalty" (Morales et al. 2018). The only time a postgraduate mentor has a significantly negative effect on science identity (personal or social) is when comparing a low-competency triad to a high-competency triad.

The findings also indicate that students' science personal-identity and social-identity were not associated with COVID-19 research disruptions. Although not focused on science identities, other studies have found mixed effects in how the pandemic influenced STEM students. For example, the American Association of American Medical Colleges reported a 20 percent increase in medical school applications in 2020 (Marcus 2020). Undergraduate researchers early in the pandemic who experienced more severe COVID-19 life impacts also had posttraumatic growth (i.e., when crises result in positive life changes; Morales et al. 2024). When looking at the outcome of how COVID-19 shaped graduate school intentions, however, having more COVID-19-related challenges in students' personal lives was associated with decreased motivation (Morales et al. 2022). Taken together, these findings shed light on the complexity of the pandemic's influence on students' science trajectories.

The consistency of science identities associated with COVID-19 research challenges is a hopeful finding, given that it is associated with entry into a science career (Stets et al. 2017). Because identity is a "core sense of self" (Jones and McEwen 2000), science personal-identity may

be somewhat resistant to change, based on five months of unforeseen circumstances due to COVID-19. There is little research on how science identities change through time to allow triangulation of these findings, but one study analyzing the course of one semester found very little change in science identity for students enrolled in a gateway chemistry course at a major public institution: only 5.6 percent of students experienced a statistically significant change in science identity (Robinson et al. 2019).

This study did include several limitations. "Low-competency" mentors still received high scores on the MCA (faculty < 4 and postgraduate < 4.08 out of 5). This may conflate the negative impacts of true low-competency mentors with mediocre mentors. Another limitation was the questions on the survey. Because there was no control for other factors that might increase science identity (such as public recognition of the importance of research during the pandemic), another effect might have been captured. Findings pertaining to the positive impact of the postgraduate mentor on science personal-identity and science social-identity might be spurious, and instead related to conducting research at a more research-intensive institution that had more graduate students and postdoctoral students. This limitation could not be fully addressed because the survey did not have usable data on where each student completed the URE. Students were clustered by their home institution in the models, accounting for any effects of home institution as a nuisance parameter. However, this remained a limitation because not all students did their URE at their home institution. Also, because data were collected in July 2020, students engaged in summer research were likely still completing their experiences, and those engaged only in spring 2020 research were several months removed from their projects. Students with more significant COVID-19 research impacts may not have been able to take the survey, also skewing the sample.

Additionally, the cross-sectional nature of the survey prevented evaluation of students' science personal-identity and social-identity prepandemic and throughout their career. It was not able to be determined whether students with higher science identities chose more competent mentors or whether working with more competent mentors resulted in higher science identities. A presurvey-postsurvey design would have been ideal for evaluating the role of COVID-19 and science identities, but this was not possible given the sudden onset of the pandemic in March 2020. Finally, although the sample included students from across the United States, it might not have captured nationwide regional and local impacts of COVID-19 on undergraduate researchers.

Conclusion

These findings have practical implications for UREs. Most significantly, the study finds that the Morales et al. (2018)

postgraduate “penalty” had minimal effect on this group of students for these outcomes at this historical moment. Instead, having a postgraduate mentor was associated with better outcomes. Faculty and program directors should consider involving postgraduate mentors in UREs. Programs can incentivize postgraduate mentorship by providing additional funding for those who take on mentoring roles, explaining to faculty mentors the benefits of postgraduate mentorship for undergraduates, and providing additional resources and supports for postgraduates filling mentorship roles.

Furthermore, the study indicates that mentorship quality is important to student science identities. Providing mentors with training that encourages reflecting on their research mentoring skills, such as Entering Mentoring (Handelsman et al. 2005), will boost mentor competency (Young and Stormes 2020) and potentially student outcomes. Specific to postgraduate mentors, graduate programs may include mentor training in already required pedagogy courses for teaching assistants. Training postgraduates in formal settings expands the number of mentors trained to effectively work with undergraduate students.

Data Availability

The data underlying this study are not publicly available due to student privacy issues. They are available from the corresponding author upon reasonable request and IRB approval.

Institutional Review Board

This project was approved by the IRB at the University of Utah (#00133477).

Conflict of Interest

No conflicts of interest to declare.

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Sara E. Grineski

University of Utah, sara.grineski@soc.utah.edu

Sara E. Grineski is a professor of sociology at the University of Utah. Her research interests include mentorship, diversity, and undergraduate research.

Callie L. Avondet graduated with undergraduate degrees in sociology and history from the University of Utah in May 2024. She is currently a doctoral student at the University of Illinois Urbana-Champaign. As

an undergraduate student, Avondet investigated undergraduate research.

Yolanda Chavez is a PhD student in sociology at the University of Utah. Her research interests include socially marginalized students, mentorship in higher education, and undergraduate research.

Danielle X. Morales is an assistant professor of urban studies at University of Massachusetts Boston. Her research interests include STEM education, undergraduate research, diversity, and mentorship.

Timothy W. Collins is a professor of geography at the University of Utah. His research interests include undergraduate research, mentorship, and diversity.