Disparities in Mentoring Experiences and Academic/Career Outcomes
of STEM Undergraduates during the COVID-19 Pandemic

I. Problem and Objectives

In spring 2020, in response to the pandemic of coronavirus disease 2019 (COVID-19), hundreds of colleges and universities in the United States (and across the globe) suspended face-to-face classes, closed campuses, and only allowed essential activities and core facilities to continue. The COVID-19 outbreak has severely affected undergraduate STEM education at many levels. It disrupted the learning and development of STEM college students, many of whose daily/weekly routine includes in-person laboratory research and mentoring activities. During COVID-19 school closures, faculty were expected to continue mentoring and supporting their STEM students through electronic technology or, in certain circumstances, face-to-face meetings but with appropriately sized groups that allow social distancing. However, it remains unclear about the mentoring patterns, especially among underrepresented groups, and whether mentor-mentee interactions can mitigate negative impacts and promote positive outcomes for STEM undergraduates during the COVID-19 crisis. This study presents some of the first evidence on the disparities in mentoring experiences of STEM college students and how mentoring satisfaction with their primary mentor/advisor relate to their academic and career attitudinal outcomes during the COVID-19 pandemic.

II. Theoretical Perspectives and Relevant Literature

In the literature on mentoring, a well-established Mentoring Input-Process-Outcome (MIPO) model (Curtin et al., 2016; Eby et al., 2013) offers a useful theoretical framework for understanding and studying the interrelationships among mentoring processes and outcomes for STEM college students, while accounting for relevant backgrounds, during the COVID-19 outbreak. As posited by the MIPO model, antecedent or background characteristics of the mentee, mentor, or both (i.e., Inputs) are expected to influence the interaction and quality of mentoring (i.e., Processes), which are in turn expected to affect mentee outcomes (i.e., Outcomes; see Figure 1).

The first central component of MIPO model is perceived *instrumental support*, referring to mentor behaviors that facilitate mentee goal attainment (Kram, 1985; Spencer, 2007). The second key component is perceived *psychosocial support*, referring to mentor behaviors that promote mentee personal and emotional development (Kram, 1985; Johnson et al., 2007). For a mentee to reap the benefits of mentoring, *frequent interpersonal interaction* with their mentor is needed (Csiksizentmihalyi & Rathunde, 1998; Liang et al., 2008).

Prior studies have shown that individual *demographic characteristics*, including gender, race/ethnicity, and socioeconomic status, may influence interaction and perceptions of mentoring, especially when it matches mentor's demographics, which is termed as surface-level similarity (Harrison et al., 1998). However, *perceived deep-level similarity*—referring to similarity in attitudes, beliefs, values between mentee and mentor—tend to demonstrate stronger relationships with perceived instrumental and psychosocial support (Eby, 2012).

Numerous meta-analytic reviews based on studies on face-to-face mentoring found that perceptions of mentoring relate to mentoring satisfaction, which in turn predict a wide range of mentee outcomes (Allen et al., 2004; DuBois et al., 2002; Eby et al. 2013; Underhill, 2006). The limited, but growing, number of empirical studies on electronic mentoring also suggested that mentees can learn and benefit from mentoring support via virtual or electronic interactions, even without traditional in-person meetings (e.g., Chong et al., 2020; de Janasz & Godshalk, 2013).

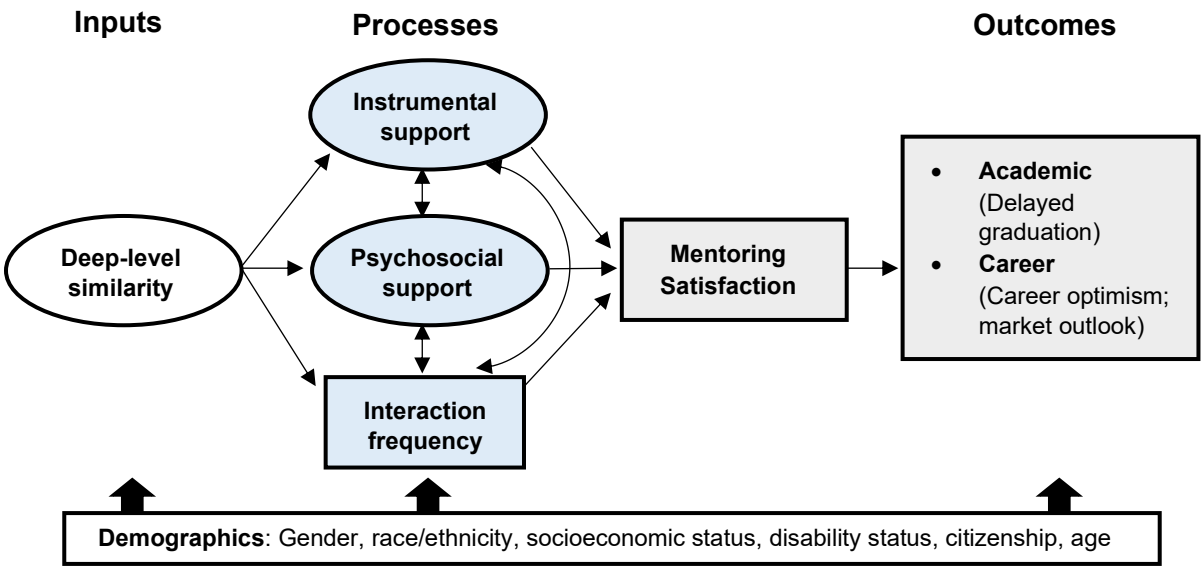

Figure 1. A hypothesized model linking the inputs, processes, and outcomes of mentoring for STEM undergraduates during the COVID-19 pandemic

III. Data/Methods

Data/Sample. This study designed and administered a 15-minute long survey through an online survey platform—Qualtrics—on June 3-22, 2020. Survey invitations were emailed to the STEM undergraduates through deans and associate deans from colleges of engineering and science across the country. Informed consent from participants was obtained electronically prior to their participation in the survey. The final analytic sample comprised 2,356 STEM undergraduate students (from 43 higher education institutions in 25 states) who reported having at least one mentor/advisor on campus in the spring of 2020. With respect to the primary mentor with whom they learn/work most closely, 57.3% were faculty members, 19.4% were senior students, 12.7% were staff members, 3.4% were graduate students, and 7.2% were others.

Measures. As shown in Table 1, perceived deep-level mentor-mentee similarity—one key measure on mentoring input—was constructed by four indicators with a 4-point Likert scale ranging from 1 ("not at all agree") to 4 ("strongly agree"; Ortiz-Walters & Gilson, 2005). The Cronbach's alpha is 0.87. Regarding mentoring processes, students were asked to compare the changes in interaction frequency with their primary mentor from prior to during the COVID-19 outbreak via face-to face, video conferencing, email, phone, and social media. The options include much less hours (-2), less hours (-1), about the same hours (0), more hours (1), and much more hours (2). The total changes in frequency of those five types of interaction were defined as changes in mentoring interaction frequency during the COVID-19 pandemic. Perceived instrumental support and perceived psychosocial support—two key mentoring process measures—were respectively measured by two sets of four indicators, as shown in Table 1 (Marie Taylor & Neimeyer, 2009; Ortiz-Walters & Gilson, 2005; Tenenbaum et al., 2001). Based on the experience before and during the pandemic, students rated the support from their mentor on a 5-point Likert scale that ranged from 1 ("much less support") to 5 ("much more support"). The Cronbach's alphas for the two perceived support factors are both .91. Mentoring satisfaction was assessed with a single-item question: "How satisfied were you with the support you received from your PRIMARY MENTOR during this past spring 2020 semester?". The response options ranged from 1 ("extremely dissatisfied") to 9 ("extremely satisfied").

Table 1. Summary Statistics for STEM Undergraduate Students (*n* = 2,356)

Variables	Mean	S.D.	Min.	Max.	Miss. (%)
Perceived deep-level mentor-mentee similarity					
Share similar interests	2.92	0.82	1.00	4.00	0.00
Look at things in much the same way	2.89	0.79	1.00	4.00	0.00
Hold similar values	3.06	0.80	1.00	4.00	0.00
Analyze problems in a similar way	2.85	0.81	1.00	4.00	0.00
Mentoring Processes					
Mentoring frequency					
Face-to-face	-1.31	0.94	-2.00	2.00	0.00
Video conferencing	-0.15	1.28	-2.00	2.00	0.00
Email	-0.14	1.09	-2.00	2.00	0.00
Phone	-0.30	0.95	-2.00	2.00	0.00
Social media	-0.30	0.85	-2.00	2.00	0.00
Instrumental support					
Finish my assignments/projects	-0.12	0.85	-2.00	2.00	0.00
Improve my writing skills	-0.26	0.76	-2.00	2.00	0.00
Prepare for my presentations	-0.25	0.79	-2.00	2.00	0.00
Explore my career options	-0.15	0.88	-2.00	2.00	0.00
Psychosocial support					
Discuss my concerns about academic projects	0.01	0.87	-2.00	2.00	0.00
Pursue my learning interests	-0.03	0.82	-2.00	2.00	0.00
Work toward my career goals	-0.01	0.86	-2.00	2.00	0.00
Talk about my anxiety in career outlook	-0.03	0.90	-2.00	2.00	0.00
Mentoring satisfaction	6.93	2.14	1.00	9.00	13.84
Academic and Career Outcomes					
Delayed graduation (month)	0.41	1.76	0.00	14.00	0.04
Career optimism					
More excited when I think about my career	2.91	1.01	1.00	5.00	2.25
More eager to pursue my career dreams	3.19	1.03	1.00	5.00	2.38
Market outlook					
Finding a job for which I am qualified	-0.50	0.85	-2.00	2.00	2.42
Finding a job in a company/institution that I prefer	-0.58	0.86	-2.00	2.00	2.38
Finding a job for which I am prepared	-0.47	0.83	-2.00	2.00	2.33
Demographics (Covariates)					
Male*	0.42	0.49	0.00	1.00	0.00
Female	0.47	0.50	0.00	1.00	0.00
Other gender/did not report – gender	0.11	0.32	0.00	1.00	0.00
White*	0.52	0.50	0.00	1.00	0.00
Black/Hispanic/Native American	0.17	0.37	0.00	1.00	0.00
Asian	0.15	0.36	0.00	1.00	0.00
Other race/did not report - race	0.16	0.37	0.00	1.00	0.00
Socioeconomic status (SES)	6.34	1.71	1.00	10.00	9.89
Non-disabled*	0.75	0.43	0.00	1.00	0.00
Disabled	0.15	0.36	0.00	1.00	0.00
Did not report – disability status	0.10	0.30	0.00	1.00	0.00
US citizen/permanent resident*	0.87	0.34	0.00	1.00	0.00
International student	0.03	0.17	0.00	1.00	0.00
Did not report – citizenship status	0.10	0.31	0.00	1.00	0.00
Age	21.36	3.05	18.00	58.00	10.10

Note. n = sample size; S.D. = standard deviation; Min. = minimum; Max. = maximum; Miss. = missing data. * = reference group.

This study focuses one three academic and career attitudinal outcomes, including delayed graduation, career optimism, and job search self-efficacy. Students were asked to estimate their expected graduation date delayed due to the pandemic. Their answers were calculated into the number of months. Career optimism, referring to the tendency for students to expect the best career outcome or to emphasize positive aspects of their career since the COVID-19 outbreak, was measured by two items (shown in Table 1) on a scale from 1 ("strongly disagree") to 5 ("strongly agree"; Rottinghaus et al., 2005). The Cronbach's alpha is 0.86. Job search self-efficacy during the COVID-19 outbreak was measured by three items (listed in Table 1) with a 5-point Likert scale from 1 ("much less confidence") to 5 ("much more confidence"; Manuti, 2012). The Cronbach's alpha is 0.88.

Several demographic characteristics were measured and included as covariates in the model, including gender, race/ethnicity, socioeconomic status (SES), disability status, citizenship status, and age. To measure student's SES, we used the MacArthur Scale of Subjective Social Status (Adler et al., 2000). Students were given an image of a ladder with ten rungs to choose from 1-10 that best describes their SES. Ten stands for people who have the most money, most education, and best jobs, while one represents people who have the least money, least education, and worst jobs or no job. Table 1 reports the demographic distribution of sample and descriptive statistics for all variables examined in this study.

Analytic Strategy. To examine the theoretical model proposed by this study, structural equation modeling (SEM) was employed. SEM allows for identifying the interrelationships among observed and latent variables simultaneously, while accounting for the measurement errors of observed items. The analysis was conducted in Mplus 8.4 using the maximum likelihood estimator. In the estimations for perceived deep-level mentor-mentee similarity, interaction frequency, instrumental support, psychosocial support, delayed graduation, career optimism, and job search self-efficacy, we controlled for the covariates listed in Table 1. Missing data ranged from zero to a high of 13.8%. We utilized the full information maximum likelihood (FIML) approach to handle the missing data and improve the estimation (Mazza et al., 2015).

IV. Results

The theoretical model in SEM showed a good fit with the data, RMSEA = .038, CFI= .961, and SRMR = .037. Figure 2 presents the model with statistically significant paths (solid lines), and the standardized coefficients are also denoted along with the paths. Overall, the hypothesized PIMO model was largely supported by our empirical data.

Interrelationships among Mentoring Inputs, Processes, and Outcomes. As expected, the perceived deep-level mentor-mentee similarity was positively related to the perceptions of instrumental support and psychosocial support as well as the mentoring interaction frequency during the COVID-19 outbreak (see Figure 2). Student's perceptions of instrumental and psychosocial support were positively associated with mentoring satisfaction during the pandemic. Although the mentoring interaction frequency was not significantly related to mentoring satisfaction, it was moderately correlated with perceived instrumental support and psychosocial support. Importantly, mentoring satisfaction is positively associated with career optimism and job search self-efficacy during the COVID-19 outbreak, and negatively related to delayed graduation, suggesting that the higher mentoring satisfaction, the fewer expected months of delayed graduation.

Disparities in Mentoring and Academic/Career Outcomes. Our SEM model also reveals significant disparities in mentoring experience and academic/career outcomes during the COVID-19 pandemic. Asian and lower SES students reported lower levels of perceived deep-

level mentor-mentee similarity. It is concerning that lower SES students also reported lower interaction frequencies with their mentor, and lower levels of perceived instrumental and psychosocial support. In terms of academic and career outcomes, our data indicate that students who were Blacks/Hispanics/Native Americans, lower SES, with disabilities, and older age were more likely to delay their graduation due to the COVID-19 crisis. Students who were females, other gender identities, lower SES, and younger age reported lower levels of career optimism. Further, students who were females, Asians, lower SES, and with disabilities reported lower levels of job search self-efficacy.

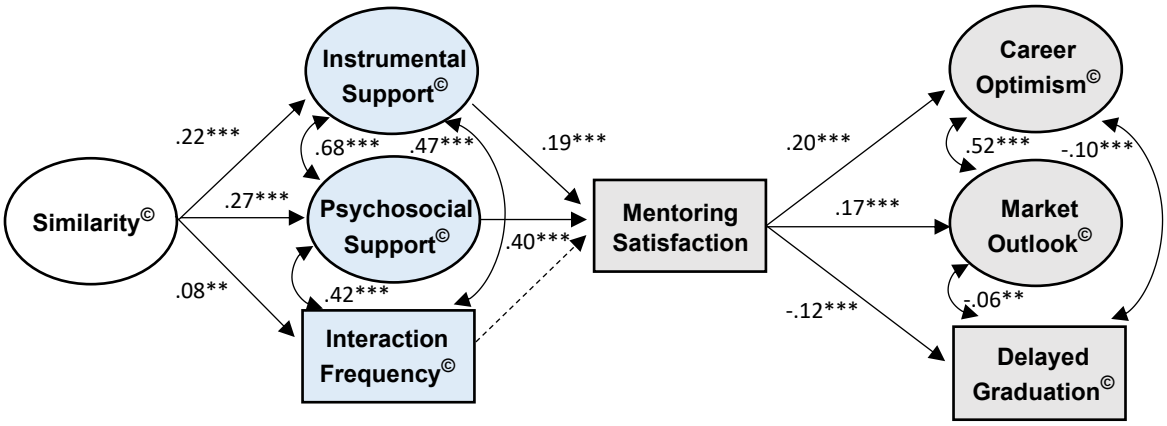

Figure 2. SEM results of interrelationships among inputs, processes, and outcomes of mentoring for STEM undergraduates during the COVID-19 pandemic

Note. SEM = structural equation modeling. Latent variable = oval; observed variable = rectangle. © = controlled for the covariates listed in Table 1. Values are standardized path coefficients. Dashed paths are not statistically significant. For reasons of clarity, all the covariates, factor loadings, and uniquenesses are not shown. All the factor loadings are over .700. R^2 for similarity = .02**; R^2 for instrumental support = .07***; R^2 for psychosocial support = .08***; R^2 for mentoring frequency = .02**; R^2 for mentoring satisfaction = .31***; R^2 for career optimism = .07***; R^2 for job search self-efficacy = .08***; R^2 for delayed graduation = .07***. *p<.05, **p<.01, ***p<.001.

V. Contribution to the STEM education and General Interest to NARST Membership

This study will be of interest to NARST members as it makes several theoretical, methodological, and practical contributions to the literature on undergraduate STEM education, STEM mentoring (2021 NARST Strand #2: teacher-student interactions), and crisis responses. Our study is one of the first to extend and empirically tests the applicability of a well-established Mentoring Input-Process-Output (MIPO) model with a nationwide, diverse sample of STEM college students, which allows greater generalizability. Second, it documents that the academic progress and career attitudes of STEM underrepresented groups—females/other gender identities, Blacks/Hispanics/Native Americans, lower SES students, and persons with disabilities—disproportionately negatively affected by the COVID-19 pandemic. The findings of our study should concern greatly STEM educators and stakeholders in higher education. Third, and importantly, our data show that perceived instrumental and psychosocial support of mentoring are positively associated with mentoring satisfaction, which in turn positively linked to academic and career outcomes of STEM college students. In short, our study suggests that increased mentoring during the time of crisis such as the COVID-19 pandemic could alleviate the negative crisis effects and improve positive outcomes for mentees, in our case, STEM undergraduates.

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