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Who Are You Studying With? The Role of Diverse Friendships in STEM and Corresponding Inequality

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Abstract

While numerous studies have highlighted the consequences of exclusion in STEM, fewer studies have empirically tested the benefits of inclusion in peer relationships. We focus on the impact of having cross-racial or cross-gender study partners among one's close friends in a national sample of 408 STEM majors. Using structural equation modeling, we examined the direct and indirect relationships between having diverse study partners, key background and college experience variables, and college GPA. We identified a significant positive relationship, both direct and indirect, between studying with a close friend of a different race and GPA. We also found that having a cross-gender study partner is positively linked to organizing study groups and study-faculty interaction, which in turn improves GPA. However, Black students were less likely to have either cross-racial or cross-gender study partners among their close friends. We discuss implications for equity and the need to encourage positive intergroup relations in STEM.

Keywords Diversity · STEM · Friendship · Social capital · Race · Gender · Peer groups · Inclusion

Introduction

Peer support, friendship, and study groups play a critical role for students in the "sink or swim" climate of STEM (Park et al., 2019). Given that introductory STEM classes are large, with limited personal attention from faculty, peers are an important source of support for students (Dennis et al., 2005; Gasiewski et al., 2012; Harper, 2007). Students rely on each other to navigate coursework and find out about opportunities such as internships or research positions (Morganson et al., 2015). In particular, friendships provide important socio-emotional benefits (Bowman, 2012; Park, 2013), supporting persistence and retention in the competitive environment of STEM (Tate & Linn, 2005). Such friendships can

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be fostered through initiatives like living-learning, research, or mentoring programs, or informally through students socializing and studying together (Soldner et al., 2012).

Unfortunately, previous research highlights the exclusion of underrepresented students of color and women from peer networks and study groups in STEM, as well as more informal socializing (Burt et al., 2018; Justin-Johnson, 2004). Given that these students already experience marginalization (Cheryan et al., 2017; Diekman et al., 2015; Johnson et al., 2011; Kachchaf et al., 2015), such exclusion has deep negative ramifications for persistence and retention in STEM. If students of color and women have trouble forming positive relationships in STEM, they face barriers to accessing information, resources, and social capital pivotal to navigating STEM curriculum (Burt et al., 2018). Further, if they are persistently excluded from peer networks during college, such exclusionary norms leave majority-status students underprepared to work in a diverse workforce and limit the participation of women and people of color in the STEM workforce altogether, especially if exclusion leads to attrition from STEM. This dynamic is troubling because diversity in the STEM workforce is a highly critical need, and diverse working groups are linked with positive outcomes such as innovative problem solving and innovation (Ashcraft & Breitzman, 2012; Hong & Page, 2004).

Clearly there are dire consequences to exclusion, but what are the benefits of inclusion in STEM educational environments? More specifically, what is the value of promoting student friendship across race and gender for students in STEM and in particular, friendships that blend academic activities (e.g., studying) and the social support of friendship? Such friendships can be thought of as cross-group friendships, a term that refers to "an ongoing, meaningful relationship with a specific outgroup member or members that was closer than that of a mere acquaintance (in which the relationship is based solely on familiarity)" (Davies et al., 2011, p. 334). While more casual cross-racial interaction may be associated with a wider array of benefits (Bowman & Park, 2014), interracial friendships are linked with key benefits like empathy for different race/ethnicities, increased interracial interaction, positive race-related attitudes, and reductions in prejudice (Antonio, 2001; Levin et al., 2003; McClelland & Linnander, 2006; Pettigrew & Tropp, 2008s; Powers & Ellison, 1995).

Comparatively less is known about the impact of cross-gender friendships in educational settings, and very little research examines the impact of either types of relationship, cross-gender or interracial, in STEM environments. One study examined interracial friendship at the beginning of college for STEM majors (Ramirez Hall et al., 2017), but identifying the impact of such relationships over the course of college could bolster the case for fostering healthy intergroup relations in STEM higher education environments. To address this gap in the literature, we use structural equation modeling (SEM) to analyze a unique dataset, the National Longitudinal Study of Freshmen, which contains detailed information on students' relationships, including the race/ethnicity and gender of study partners among their close friends. The purpose of this study is to examine direct and indirect relationships between studying with a friend of a different race or gender, key background and college experience variables, and college GPA for 408 STEM majors in the fourth year of college. We ask: (1) What are the direct and indirect relationships between key background and college experience variables, having cross-gender/cross-race study partners, and college GPA among undergraduates in STEM? (2) Do other type of interactions with peers and faculty mediate the relationship between having cross-gender/cross-race study partners and college GPA for STEM majors? We chose GPA as the dependent variable given its importance for graduate admissions, as well it being a reflection of traditional forms of academic achievement (Mayhew et al., 2016).

Literature Review

In this section, we will review literature on the negative climate in STEM education and the impact on peer relationships. We then address the benefits students garner from diverse campus environments and cross-racial interaction, as well as the conditions necessary to facilitate intergroup relations, and discuss implications for STEM.

"Chilly Climate" in STEM and the Impact on Peer Relationships

Although the "leaky pipeline" metaphor is often used to describe the high attrition s of women and students of color from STEM (Packard, 2016; Preston, 2004), recent studies have emphasized the role of systemic factors such as racism and sexism in pushing students out of STEM (Dortch & Patel, 2017; Xu, 2017). Women and students of color often experience "chilly climates" in STEM contexts, encountering marginalization from peers and faculty (Dortch & Patel, 2017; McGee, 2013; Strayhorn et al., 2013). This trend not only affects academic outcomes, but negatively impacts students' sense of belonging and ability to form positive peer relationships (Amelink & Creamer, 2010; Carlone & Johnson, 2007; Dortch & Patel, 2017; Johnson, 2012; Ong et al., 2011). For instance, Ong et al. (2018) concluded that students of color—especially women of color—experience isolation and microaggressions as one of few in STEM, reinforcing feelings of not belonging and discomfort. This isolation can occur in the form of being excluded from joining study groups or more informal socializing opportunities that promote the formation of positive relationships (Amelink & Creamer, 2010; Ong et al., 2011; Treisman, 1985). Gender can also affect the ability of students to develop positive social ties in STEM, given the pervasiveness of exclusionary norms and underrepresentation of women in certain disciplines (author omitted). Women in STEM may encounter male peers who do not take them seriously, and/or make them feel uncomfortable through unfriendly comments and attitudes (Seymour & Hewitt, 1997). This difficult climate can make it difficult to form positive social ties (Margolis et al., 2000).

The"sink or swim" nature of STEM classes, wherein students are encouraged to compete rather than support each other, is another deterrent to forming collaborative and relationships in STEM (Cheryan et al., 2017; Diekman, et al., 2015). Further, the demographic underrepresentation of students of color and women in certain STEM sub-fields continues to limit the ability of minoritized students to find a strong community of supportive peers (Johnson, 2007a, 2007b; Shapiro & Sax, 2011). Students of color and women can even encounter outright hostility from peers, who question their competency and intellectual merit (Beasley & Fischer, 2012; Cole & Espinoza, 2008; Johnson, 2012); this troubling dynamic can have a deeply detrimental effect on students (McGee, 2016).

Climate issues are even more challenging for women of color in STEM, who experience a "double bind" due to the combination of racial and gender discrimination (Ong et al., 2011). Ong (2002) found that women of color in physics had to take on extensive amounts of "invisible work" (p. 43) in order to establish themselves as legitimate members within the STEM discipline. The "invisible work" included alternately emphasizing as well as masking their gender, race/ethnicity, and/or class minority status. Additionally, these women of color had to learn the "unspoken rules of membership" (Ong, 2002, p. 43) in their departments by unpacking the invisibility of Whiteness and maleness that make up the culture of physics. When women of color are forced to carry the burden of fitting into these norms, the structural and cultural structures that position them as outsiders remain unchallenged (Ong, 2002).

Altogether, these negative conditions are a considerable threat to equity in STEM, given that supportive environments with encouraging faculty, staff, and peers are positively linked with persistence (Bonous-Hammarth, 2000). When students are able to engage in intellectual communities and develop strong relationships with classmates, they are more likely to view their educational experiences positively (Astin, 1993; Weidman, 1989). Morganson et al. (2015) found that peers play a fundamental role in shaping how STEM students feel about their major. In their study, connecting with STEM peers of similar backgrounds provided students a sense of solidarity and camaraderie.

For students of color in STEM, forming peer support groups is critical to academic and social development, as well as overall college success (Palmer et al., 2011). For example, Palmer et al. (2011) found that students of color pursuing STEM majors felt more confident and less pressured when studying for exams with peers from similar classes who shared their academic goals. Strong peer support networks can also help women in STEM exchange valuable information, as well as find study partners and peer role models (Hyde & Gess-Newsome, 2000; Kahveci et al., 2008). To counteract isolation, a number of STEM diversity initiatives specifically seek to equip students with social capital through building peer networks and relationships to combat marginalization, where students build friendships that also provide academic support (Dickey, 1996; Ong, 2002).

Reflecting these initiatives, in one study, conditions that facilitated persistence for women of color in physics included providing counter-spaces where supportive learning environments were promoted through positive peer interactions and mentorship (Ong et al., 2018). In another study, Tate and Linn (2005) found that women of color majoring in engineering cultivated friendship groups outside of their STEM peers in order to find social support. While this tactic may have helped students survive, it likely limited participant's access to certain resources and information networks in STEM.

Benefits of Diversity and Conditions Needed for Diverse Relationships

Though the experiences of women and URMs in STEM are often tenuous at times, researchers have established that there are numerous benefits for students exposed to racially diverse environments. Racially diverse social connections can provide valuable social capital given that "ties to dissimilar others provide access to non-redundant information, resources, and opportunities" (Wong, 2009, p. 1). Engaging in cross-racial interaction and interracial friendship during college positively facilitates academic, intellectual, and social development (Antonio et al., 2004; Bowman, 2013a, 2013b; Chang, 2011; Denson & Chang, 2015). Such engagement is positively linked with retention and persistence rates (Astin, 1993; Umbach & Kuh, 2006), stronger interest in intellectual engagement (Maruyama & Moreno, 2000; Gurin et al., 2002), increased comfort with people of different backgrounds (Sidanius et al., 2008), and improved overall satisfaction with college (Bowman, 2013a, 2013b; Bowman 2012; Luo & Jamieson-Drake, 2009). Additional positive outcomes include cultural awareness, cross-cultural empathy, social perspective taking and psychological well-being (Bonner et al., 2012; Bowman, 2013a, 2013b; Chang, 2002; Pike et al., 2007).

Overall, immersion in a diverse campus and classroom environment is linked with enhanced problem solving and critical thinking skills (Antonio et al., 2004; Pascarella et al., 2001; Terenzini et al., 2001). Furthermore, students benefit from these experiences after college (Bowman et al., 2016; Denson et al., 2017). All of these outcomes are critical both to undergraduate education and STEM education in particular, given the need to prepare STEM majors to work collaboratively in a diverse workforce (Pitt & Packard, 2012).

A primary pre-condition for interracial friendship among students is the availability of racially diverse peers within an institution, reflecting "structural" or "compositional" racial diversity (Chang et al., 2004; Kim et al., 2015; Park & Kim, 2013; Pike & Kuh, 2006). Structural racial diversity is a particularly strong predictor of engagement with racial diversity for white students, given that students of color have no choice but to interact across race at most traditionally white institutions (Bowman & Park, 2014; Park et al., 2013). Homophily, the phenomena of "likes attract likes," is a dominant force shaping social interactions (McPherson et al., 2001). For White students, the high availability of same-race peers means that there is little opportunity to counteract the currents of homophily, especially in the absence of higher levels of structural diversity (Park, 2013).

While the overall demography of the institution matters, racial and gender diversity can vary considerably within the same university, with some STEM departments notoriously having lower levels of both types of diversity. Subcultures of the university can serve as filtering agents through which students experience diversity (Park, 2013); immersion in less diverse subcultures (e.g., certain STEM majors) often result in more homogeneous peer groups and concurrently, fewer interracial or cross-gender friendships, given the dominant force of homophily and lack of counteracting forces (e.g., structural diversity).

Also critical for promoting healthy interracial relationships is fostering an inclusive campus racial climate, which consequently enhances the quantity and quality of cross-racial interaction (Chang, 2007; Denson & Chang, 2015; Gurin et al, 2002). Structured opportunities for cross-racial interaction include initiatives like intergroup dialogue, racial/cultural awareness workshops, leadership training programs, and diversifying the curriculum (Bowman & Park, 2015; Gurin, et al., 2002; Park & Bowman, 2014). Informal interactions include casual discussions, daily interactions in residence halls, and co-curricular activities such as multicultural student organizations (Bowman, 2013a, 2013b; Gurin, et al., 2002; Park & Bowman, 2014). While an overall positive campus racial climate can mitigate the negative racial climate within STEM (Ong, 2005; Tate & Linn, 2005), such efforts may be limited given the extensive amount of time that STEM majors spend in STEM-related coursework and laboratory settings, which may not reflect the diversity present in the broader student body.

Different environments can deter cross-gender social ties and interactions. In a male-dominated organizational culture, females may feel less comfortable forming close relationships with males, given concerns of sexual harassment and innuendo (Felmlee et al., 2012). Allen and Eby's study (2004) examined cross-gender mentoring relationships in professional context and demonstrated that female mentors are less likely to form cross-gender friendships for fear of scrutiny by others in the organization. Similarly, male protégés may be reluctant to accept mentoring from female mentors for fear of appearing weak or subordinate to a woman (Allen & Eby, 2004). In male-dominated STEM fields, similar gender-related stereotypes and concerns may also apply, and female students can experience gender bias via differentiated treatment from male peers in STEM (Colbeck et al., 2001; Robnett, 2016). To reduce feeling of threat from gender stereotypes, Dasgupta et al. (2015) discovered that women in engineering thrive in microenvironments, including in-class teams and study groups with a majority of female students or equal number of females and males.

Some research points to positive outcomes linked with friendship diversity for prospective STEM majors at the start of college. Having a more racially diverse friendship group was linked with academic self-efficacy and intention to major in STEM (Ramirez Hall et al., 2017). Friendship diversity also served as a buffer against the negative impact of discrimination in their study: A negative relationship existed between experiencing discrimination and intent to major in STEM for students with low friendship group diversity, but no relationship existed for those with more diverse friendship groups. However, Ramirez Hall et al. (2017) surveyed students at the beginning of college, and no study to date has investigated the impact of diverse friendships for STEM majors over the course of college.

Conceptual Framework

Our study is influenced by the theoretical concept of social capital, which refers to how valuable information and resources are embedded within relationships and social networks (Bourdieu, 1986; Coleman, 1988). Previous work highlights how students in highly competitive STEM majors tend to not just lean on each other for academic support, but also social and emotional support (Treisman, 1985, 1992). In this way, socio-emotional flourishing and connectedness are critical components of supporting academic achievement in STEM, and peer relationships are an important source of social capital. While students gain benefits from studying with more casual peers and acquaintances, we propose that they will derive unique benefits when they have at least some study partners who are also close friends, given the need that STEM students have to rely on one another for emotional support and encouragement in the "sink or swim" climate (Treisman, 1985). Further, cultivating friendships that blend social-emotional support with academically oriented activities (e.g., studying) can be an important source of support for URM students, even if those friends are not fellow STEM majors (McCabe, 2016; Tate & Linn, 2005).

While previous studies have controlled for measures like studying with others as a proxy for social capital in STEM (Chang et al., 2014; author omitted), they have been limited by the lack of detailed data on student peer groups and friendship patterns—*who* students are studying with. Correspondingly, we hypothesize that having a study partner of a different race among one's friends will be advantageous for STEM majors, given previous work identifying benefits linked with interracial friendship (Bowman & Park, 2014; Davies et al., 2011; Park & Kim, 2013). Having a study partner of another race among one's friends may signify that a student is less racially isolated and marginalized within a STEM environment, or that majority-status students are reaping benefits from engaging with racially diverse peers. Students of all races gain from the varying perspectives and viewpoints of peers of different backgrounds, and diverse working groups are associated with innovation in problem solving (Hong & Page, 2004). Such relationships may also embody intercultural capital (Nuñez, 2009), a term that refers to the gains associated with intergroup relationships and engagement with racial diversity.

While less work has examined benefits associated with cross-gender friendships in higher education, given the underrepresented status of women in most STEM fields, we also hypothesize that studying with a friend of a different gender will also be advantageous for students due to a higher likelihood of exposure to non-redundant information, potential differences in studying styles that spur deeper engagement, and the exchange of resources that can occur in such settings (Wong, 2009). Similar to patterns related to interracial engagement, friendship across gender lines that combines studying may also reflect that a student is less isolated within their major, and/or that a student is reaping benefits from engagement with a heterogeneous peer group.

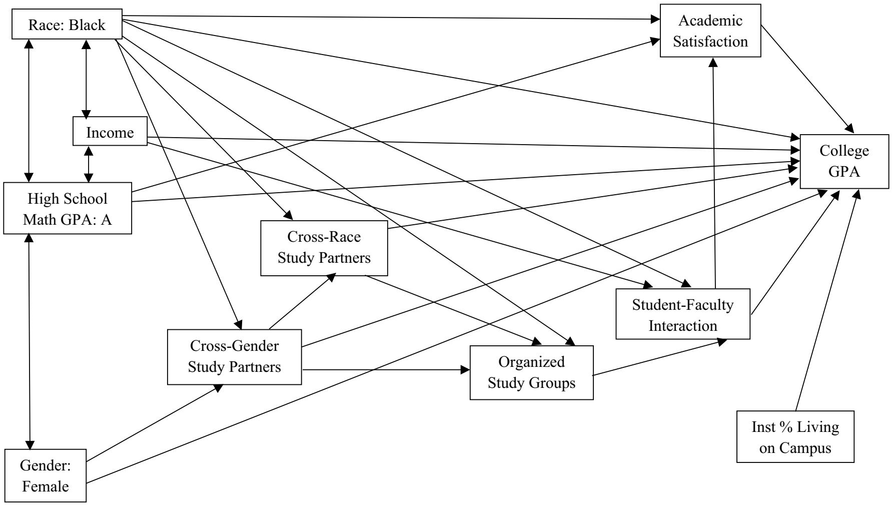

Fig. 1 Conceptual model for the relationship between cross-gender/cross-race study partners and college GPA

We control for two additional variables that reflect other facets of social capital, student-faculty interaction and frequency of organizing study groups, which likely reflect connectedness to STEM and the ability to access information, resources, and support (Cole & Espinoza, 2008). Other key variables (e.g., high school math achievement, income, gender, and academic satisfaction) reflect findings from literature on predictors of college GPA for students in STEM (Cole & Espinoza, 2008; Cintina & Kana'iaupini, 2019; Radunzel et al., 2016). Figure 1 displays the hypothesized path model for the relationship between predictor variables and college GPA among college students in STEM majors.

It is important to delineate that in highlighting the benefits of interracial and/or cross-gender friendships, we do not view students of color or women as harboring deficits vis-à-vis majority-status and male peers, or being in need of some sort of enlightenment from their non-minority status peers. Instead, we hypothesize that students of all races and genders benefit from having friendships that blend academic and socio-emotional support across demographic lines, positing that such friendships represent an important source of social capital, and thus seek to test the impact of studying with diverse friends on GPA for STEM majors.

Method

Data and Sample

This study used data from the National Longitudinal Study of Freshmen (NLSF). Housed at Princeton University, the NLSF is a multi-wave longitudinal survey of 3,864 students from 28 selective institutions. The survey was administered to students in waves at five different time points from 2000 to 2004 and gathered extensive information on students' backgrounds, college experiences, and college outcomes. For this study, we used data collected at the beginning of the first year of college (wave 1), and end of the first (wave

2), second (wave 3), and fourth year of college (wave 5). Wave 4 data was not included because many items from wave 4 were also asked through wave 3 data collection. Also, wave 3 items focused more on the nature of interactions with peers and faculty, versus wave 4, which tended to focus on the quantity of general interactions; the former was of greater interest to us and had stronger alignment with our research questions. Thus, the sample of the study is limited to those students who (a) completed the surveys in aforementioned four waves (i.e., waves 1, 2, 3, and 5) and (b) declared a STEM major[1] at the entry of college and were still in a STEM major at the end of the fourth year. Students from Historically Black Colleges and Universities were not included because their context for racial demography differed substantially from the rest of the sample. We cleaned the data to meet the statistical assumptions of SEM and replaced missing data with values estimated from EM (expectation maximization) algorithm. Consequently, the final sample used for the data analysis was composed of 408 STEM undergraduates across 27 institutions. Gender and ethnic compositions of the analytical sample are as follows: 221 (54.2%) male and 187 (45.8%) female students; 105 (25.7%) White, 86 (21.1%) Black, 84 (20.6%) Latinx, and 133 (32.6%) Asian American students. When we grouped students based on five major academic disciplines within STEM, 123 (30.1%) students came from Biological Sciences, 51 (12.5%) from Computer Science, 173 (42.4%) from Engineering, 9 (2.2%) from Mathematics or Statistics, and 52 (12.7%) from Physical Sciences.

Variables

Endogenous Variables

This study utilized one ultimate endogenous (dependent) variable and five mediating endogenous variables. The ultimate endogenous variable in our path model was students' college GPA, measured by a survey item of students' self-reported GPA at the end of their fourth year of college. Students were asked to report their GPA using a number with two decimal points; hence, students' GPA used for the data analysis in this study is a continuous variable.

In addition to the ultimate endogenous variable, we included five mediating endogenous variables in the hypothesized path model: number of cross-gender study partners among close friends, number of cross-race study partners among close friends, experience with organizing study groups, student-faculty interaction, and academic satisfaction. Students were asked to list their four closest friends, and then asked to report the friend's gender and race, as well as the activities they shared with the friend (e.g., studying). The number of cross-gender study partners gauged a student's total number of study partners of a different gender out of their four closest friends. In the same way, the number of cross-race partners assessed a student's total number of study partners of a different race/ethnicity among their four closest friends. Students did not report their friend's major, and thus we

[1] We employed the definition of STEM used by Department of Commerce (DOC) to identify STEM majors for the current study. Informed by Sax et al. (2015), we then grouped these STEM majors into five disciplines for the purpose of data analysis. The five disciplines and specific majors included in each discipline are as follows: Biological Sciences (Bio-chemistry, Biological Basis of Behavior, Biology); Computer Science (Computer Science); Engineering (Bio-engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Other Engineering); Mathematics/Statistics (Math, Actuarial Science); Physical Sciences (Chemistry, Material Science, Physics, Other Physical Science).

are limited in understanding whether or not their study partners were fellow STEM majors. While it is reasonable to assume that most STEM students would study at least periodically, if not more often, with fellow majors, for URM students, research points to some socio-emotional benefits linked with studying with friends even if they are not in the same major (McCabe, 2016; Tate & Linn, 2005). Even if the measure may capture some possible level of studying with non-STEM friends, it is important to capture the friendship patterns of URM students in STEM, who may be more likely to study with friends outside of the major due to marginalization experienced within the major (Tate & Linn, 2005).

Experience with organizing study groups was measured by a survey item on the self-rated frequency with which a student organized study groups with friends or classmates. Student-faculty interaction was a four-item factor scale that assesses the extent to which students experienced the following forms of faculty interaction ($\alpha = .78$): asked professors questions in class, raised hand during a lecture when you did not understand something, approached professors after class to ask a question, and met with professors in their offices to ask about material you did not understand. While our primary interest is the role of cross-gender or interracial friendship, we included the latter two variables in order to account for another form of social capital in STEM environments and also to see whether either variable mediates the relationship between cross-group friendship and GPA (Chang et al., 2014; Cole & Espinoza, 2008). Academic satisfaction was a three-item factor scale that assesses the extent to which students were satisfied with courses taken, quality of instruction, and mastery of subjects ($\alpha = .80$).

Exogenous Variables

Our model included five exogenous (independent) variables: race (Black), household income, gender (female), high school math GPA, and institutional percentage of students living on campus. Race and gender are dichotomous variables with Black and female students coded as 1 and their corresponding counterparts coded as 0, respectively. We specifically chose to control for Black self-identification in the model given the research base that suggests Black students in particular may experience isolation and marginalization in STEM (Burt et al., 2018; Treisman, 1985). Income and high school math GPA were gauged by students' self-report on their annual household income and high school math GPA while institutional percentage of students living on campus was assessed by actual institutional data. Correlations among all the variables used in the hypothesized path model of the study are presented in Table 1.

Analysis

This study utilized structural equation modeling (SEM) to examine direct and indirect effects among students' background characteristics, cross-gender/cross-race study partners, study groups, other college experiences, and college GPA. As an extended form of the general linear model, SEM tests two or more regression equations simultaneously and allows researchers to examine both direct and indirect relationships among variables (Byrne, 2016). We first specified a hypothesized path model based on empirical findings from previous research (see Fig. 1) and estimated the model using AMOS 25.0. Since our path model includes six endogenous variables (one ultimate and five mediating endogenous variables), our SEM analysis generated and tested six different regression equations (one

Table 1 Correlations among the variables used in the hypothesized path model for the relationship between cross-gender/cross-race study partners and college GPA among STEM undergraduate students (n = 408)

Variable	1	2	3	4	5	6	7	8	9	10	11
1. College GPA	–										
2. Academic satisfaction	.21**	–									
3. Student-faculty interaction	− .04	.08*	–								
4. Organized study groups	− .06	.00	.28**	–							
5. Cross-race study partners	.19**	.12**	.01	.11*	–						
6. Cross-gender study partners	.02	.01	.01	.10**	.07	–					
7. Inst % living on campus	.22**	.07	.03	.01	.16	− .01	–				
8. High School Math GPA: A	.19**	.13**	.00	.01	− .01	.01	.07	–			
9. Income	.16**	.10*	− .07	− .05	− .01	.11*	− .01	.05	–		
10. Black	− .27**	− .05	.21**	.10*	− .17**	− .07	.01	− .03	− .18**	–	
11. Female	− .13**	.03	.06	.14**	− .05	− .06	.05	.07	− .02	.19**	–

*p < .05, **p < .01

equation per endogenous variable). Then based on AMOS recommendations, the hypothesized path model was re-specified until the model reached a good fit to the data.

Limitations

While our study provides valuable insight into the potential gains associated with studying with close friends of other races and/or genders, it is important to note several limitations. First, the sample is restricted to students at an array of selective institutions and thus generalizability to all institutions of higher education is somewhat limited. The age of the NLSF data, collected in 2004, should also be noted. While we recognize the drawbacks of using an older dataset, no other existing national dataset includes such finely grained data on the racial and gender composition of students' peers/friendships, as well as what behaviors they participate in with peers. Thus, we view our study as a starting point to inspire future data collection and analysis around the impact of diverse relationships for STEM majors. Also, we did not control for the specific STEM major, as we were more interested in understanding the phenomena of cross-group friendships in STEM more generally. Future studies can consider controlling for major or sub-field of STEM.

An additional caveat is that in the NLSF survey, our mediating endogenous variables of interest capture the activity of studying with a friend of a different race or gender. However, we are limited in our knowledge of whether the actual studying is with a fellow STEM major, or whether the studying pertains to STEM coursework. Given that our sample is limited to STEM majors, we make the assumption that the majority of studying encompasses STEM coursework; however, it is possible that the variable could capture cases of students studying with friends for non-STEM coursework, or with friends outside of the major. While an ideally constructed study would be able to identify the friend's major and/or subject matter of the coursework that friends were studying, such variables were unavailable in the NLSF dataset. Further, we recognize value in the possibility that the variable could contain students studying with non-STEM close friends, given research highlighting the value in URM students in STEM being able to study with friends regardless of major (McCabe, 2016; Tate & Linn, 2005). Also, previous investigations of STEM majors at the start of college found benefits linked with having diverse friendships, regardless of the academic major of the friend or whether friends were specifically socializing or studying within a STEM-related environment (Ramirez Hall et al., 2017). Thus, we see merit in our current analysis, although we recognize its limitations. Future studies can and should account for more finely grained information among STEM students' study patterns and relationships.

It should be also acknowledged that the measure of studying with a friend of a different race or gender is limited to a STEM major's four closest friends; hence, our study is measuring a closer form of interracial or cross-gender friendship among study partners, versus weaker social ties. Given research documenting the significance of weaker or more casual social relationships as regards to racial diversity (Bowman & Park, 2014; Clarke & Antonio, 2012), ideally future research should be able to capture a wider swatch of students' peers (e.g., the composition of their broader social networks beyond close friends). While we could not address the effect of weaker or more casual social relationships in this study because these variables were not available in the NLSF data, we believe that our findings will make a preliminary contribution to our understanding of college outcomes associated with studying with diverse peers.

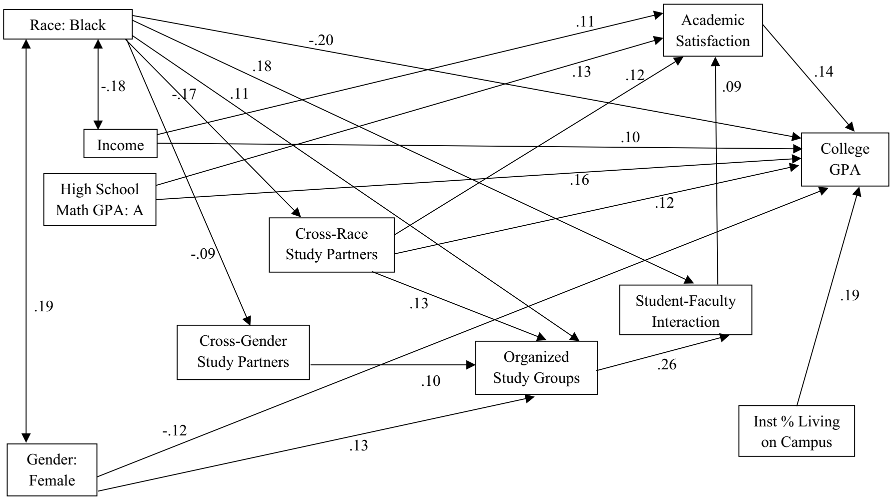

Fig. 2 Final path model for the relationship between cross-gender/cross-race study partners and college GPA among STEM undergraduate students. Path model (n = 408); $\chi^2 = 32.62$, $p > .40$; CFI = .99; RMSEA = .01. All structural paths and correlations were statistically significant at the .05 level. Disturbances for endogenous variables were omitted from the figure

Results

Final Path Model

Figure 2 displays the final path model developed by the study, presenting standardized direct effects. Both the chi-square statistic and other fit indices indicate that the model has a good fit to the data ($\chi^2 = 32.62$, $p > .40$; CFI = .99; RMSEA = .01). Most parameter estimates were significant and consistent with our hypothesized model. The final path model indicates that the number of cross-race study partners had a both direct and indirect (mediated by study groups, student-faculty interaction, and academic satisfaction) positive effect on STEM students' college GPA. As we hypothesized, the number of cross-gender study partners positively affected students' experience with organizing study groups; experience with organizing study groups had an indirect positive effect on college GPA, mediated by frequent student-faculty interaction and greater levels of academic satisfaction. Black students were significantly less likely to have cross-gender/cross-race study partners and tended to report lower college GPA than their peers of other racial groups.

On the other hand, the final path model also demonstrated that some of the paths in our hypothesized model were statistically non-significant and inconsistent with our assumptions. While the number of cross-gender study partners had an indirect positive effect on college GPA among STEM students, this form of peer interaction did not directly affect college GPA. Similarly, we assumed in our initial model that student-faculty interaction had both direct and indirect effect on college GPA; however, our final path model showed that there was only an indirect relationship between the variables. Also, some direct effects hypothesized for some variables were statistically insignificant: the effect of race on academic satisfaction, income on student-faculty interaction, gender on the number of cross-gender study partners, and the number of cross-gender study partners on the number of cross-race study partners.

Table 2 Summary of direct and indirect effects of the final path model for the relationship between cross-gender/cross-race study partners and college GPA among STEM undergraduate students (n = 408)

Variables	Direct effects (β)	Indirect effects (β)	R^2
Cross-race study partners			.03
Black	− .17***	–	
Cross-gender study partners			.02
Black	− .09*	–	
Organized study groups			.05
Black	.11*	− .03*	
Female	.13**	–	
Cross-race study partners	.13**	–	
Cross-gender study partners	.10*	–	
Student-faculty interaction			.11
Black	.18***	.02*	
Female	–	.03**	
Organized study groups	.26***	–	
Cross-race study partners	–	.03*	
Cross-gender study partners	–	.03*	
Academic Satisfaction			.05
Black	–	− .01	
Female	–	.01	
High school Math GPA: A	.13**	–	
Income	.11*	–	
Student-faculty interaction	.09*	.01	
Cross-race study partners	.12**	.02*	
Cross-gender study partners	–	.00	
Organized study groups	–	.01	
College GPA			.21
Black	− .20***	− .02**	
Female	− .12**	.00	
Income	.10*	.02**	
High school Math GPA: A	.16***	.02**	
Cross-race study partners	.12**	.02**	
Cross-gender study partners	–	.00	
Academic satisfaction	.14**	–	
Organized study groups	–	.01*	
Student-faculty interaction	–	.01*	
Institutional % living on campus	.19***	–	

* $p < .05$, ** $p < .01$, *** $p < .001$

Direct and Indirect Effects

Results from the final path model showed several direct and indirect effects among variables in the path model (refer to Table 2 for a summary). Results indicated that having cross-race study partners (β=.12, $p<.01$) had a positive direct effect on college GPA among

STEM students, even after controlling for students' demographic characteristics and other college experiences. The results suggests that STEM students who had more study partners of a different race among close friends tended to report higher college GPA at the end of their fourth year of college. Academic satisfaction also had a direct positive effect on college GPA (β=.14, p<.01). When it comes to the direct effects of student demographics and high school experiences, higher-income students (β=.10, p<.05) and students who had a higher Math GPA from high school (β = .16, p < .001) reported higher college GPA, whereas Black (β = −.20, p < .001) and female students (β = −.12, p < .01) tended to report lower college GPA.

Students' demographic and high school experience variables were also significantly related to some mediating endogenous variables in the final model. Results showed that Black STEM students were *less* likely to have cross-gender (β = −.09, p < .05) or cross-race study partners (β = −.17, p < .001) whereas they seemed to interact *more* frequently with faculty (β = .18, p < .001) and organize study groups *more* frequently (β = .11, p < .05). Students who had a higher Math GPA in high school (β = .13, p < .01) and students who had higher household incomes (β = .11, p < .05) appeared to be more satisfied with their academic experience in college; female students seemed to organize study groups more frequently (β = .13, p < .01).

Results also indicated some interesting indirect effects among the variables. The number of cross-race study partners had a positive indirect effect on college GPA, mediated by organizing study groups, student-faculty interaction, and academic satisfaction. That is, students who had more study partners from a different race tended to organize study groups more frequently, interact more often with faculty, and be more satisfied with their academic experience during college, which in turn was linked with higher college GPA. The number of cross-gender study partners had a similar indirect relationship with college GPA, but the indirect effect was not statistically significant. Results also showed positive indirect effects of income and high school Math GPA on college GPA, mediated by academic satisfaction. This finding suggests that students who came from higher household incomes and had higher Math GPA in high school tended to be more satisfied with their academic experience in college, which was linked with higher college GPA. In contrast, being a Black student had a negative indirect effect on college GPA, mediated by the number of cross-race and cross-gender study partners, organizing study groups, student-faculty interaction, and academic satisfaction. That is, Black students were less likely to have cross-race or cross-gender study partners than their peers in other racial groups. This lower likelihood of having cross-race or cross-gender study partners in turn adversely affected their college GPA, likely by hindering access to organizing study groups, student-faculty interaction, and academic satisfaction that are linked with having cross-race or cross-gender study partners and associated with higher college GPA.

Discussion

Findings highlight key insights into the benefits of studying with diverse friends, as well as insight into populations less likely to study across race or gender. First, studying with close friends of different races had both direct and indirect positive effects on GPA for STEM majors overall, making our study the first of its kind to document a benefit associated with studying with someone of a different race in STEM. While studying with a close friend of a different gender had neither a direct nor indirect effect on GPA, it had a direct positive effect on organizing study groups and an indirect positive effect on student-faculty interaction, both of which were positive predictors of GPA. Overall, we provide empirical evidence supporting the idea that cross-racial and to some extent, cross-gender relationships represent a valuable form of social capital for students in STEM. We also extend research that identified benefits of friendship diversity for incoming STEM students (Ramirez Hall et al., 2017), showcasing how benefits persist over the course of college for STEM majors.

However, not all students reaped the benefits associated with having diverse study partners among close friends: Black students were less likely to have cross-gender and cross-racial study partners among close friends, and thus were less likely to receive the positive direct and/or indirect effects of such experiences on organizing study groups, student-faculty interaction, academic satisfaction, and GPA. Interestingly, our findings indicate that Black students were more likely to organize study groups and interact with faculty; however, they were less likely to experience the additional benefits linked with diverse study partners. The phenomena is not due to Black students having a lack of close interracial friendships: Overall, 74.3% of Black students in the NLSF reported having at least one close friend of a different race (Park & Kim, 2013). In contrast, only 48.5% of White students reported having a close friend of another race in the NLSF dataset.

Likely, Black students are less likely to have these interracial friendships within the STEM environment. Previous research has found that Black students in particular often have difficulty finding study partners and forming positive relationships in STEM classes (Burt et al., 2018; Justin-Johnson, 2004). Campus and/or departmental climates hostile to Black students, or campuses that may have very few Black students in STEM, may create an atmosphere of distrust, limiting the opportunity for Black students to form friendships across race and gender within STEM. For Black students at predominantly White institutions, same-race organized study and friendship groups may be a more attractive option, as well as a reaction to the underrepresentation and marginalization that Black students face in STEM (Ong et al., 2018; Tate & Linn, 2005). While studying with same-race friends provides emotional support for Black students in STEM, it could limit their ability to gain academic support from majority-status peers within their actual major. Future studies could consider including experiences of discrimination as a mediating variable between being a Black student and having less cross-race study partners among close friends to examine whether discrimination decreases Black students' willingness to study with peers from other races.

Beyond the "push" factor of discrimination and the chilly climate in STEM, there may also be other "pull" factors that encourage same-race study and friendship group formation for Black students. Programs catering to URM students, STEM-focused and otherwise, likely serve as an informal hub for students to form relationships, and previous work documents that these groups are pivotal to retention in STEM, combining academic and socio-emotional peer support (Treisman, 1992). The existence of these initiatives does not negate the negative impact of discrimination, which has been extensively documented as a barrier to social tie formation for students of color in STEM (Amelink & Creamer, 2010; Cole & Espinoza, 2008; Dortch & Patel, 2017; Johnson, 2012). Thus, "pull" factors encouraging participation in same-race support systems likely co-exist with "push" factors, wherein such initiatives become more attractive to Black students in light of difficult campus or departmental climates.

Why Black students are less likely to have close friends of a different gender with whom they study is somewhat of a mystery; however, existing literature offers some suggestions. Existing studies highlight the "double bind" that exists for women of color in STEM and in particular, Black women (Ong et al., 2011). It may be that Black women in particular are having trouble accessing not just cross-racial study partners and groups, but friends of a different gender who are also study partners. One contributing factor could be the overall underrepresentation of Black men in higher education (Harper & Harris, 2012; Naylor et al., 2015), leading to a dearth of potential same-race, but cross-gender friendships and study partners. Reflecting this pattern, in our final model, being a Black student was highly correlated with being a female, suggesting an underrepresentation of Black men among STEM majors in our sample. (In our sample of STEM majors, 36.0% of Black students were men; in contrast, 62.4% of Asian American students, 57.1% of Latinx students, and 56.2% of White students were men.) Another reason for an overall lack of cross-gender study partners could be the combination of racism and sexism that Black women experience; previous research highlights how experiencing multiple overlapping forms of difference can make it more difficult to cross demographic lines (McGee, 2013; Park et al., 2013). Concurrently, it could be that due to the intersecting oppression that stems from simultaneous racism and sexism, Black women, and even Black men find it more necessary to band together as a means of survival. In this context, cultivating same race and/or same gender peers may be more appealing. As noted, previous work highlighted how women of color cultivated counter-spaces amongst themselves in order to survive in STEM (Ong et al., 2018). Ideally, future research would address the intersection of race/ethnicity—particularly, being Black—and gender among STEM students to better understand the negative connection between being Black and having cross-gender study partners among their friends observed in the current study.

While Black STEM majors receive some benefits from having higher levels of organized study groups and student-faculty interaction, it is important to note that Black students overall had significantly lower GPAs even when controlling for the indirect effects of these variables. In other words, participating in organized study groups and student-faculty interaction was not enough to mitigate the other institutional barriers that Black students face in STEM settings, such as racial isolation, marginalization, and lack of access to resources. Furthermore, previous studies indicate that Black students in STEM are particularly vulnerable to negative forms of student-faculty interaction, including racial discrimination, that diminish the benefits typically linked with student-faculty interaction more generally (author omitted). Studies indicate that Black STEM students tend to experience student-faculty interaction more frequently than do their peers of other racial/ethnic groups (Park et al., 2019), but do not experience the same gains as other students. It may be that Black students actually had negative experiences when engaging in the activities included in our measure of student-faculty interaction (e.g., asking questions in class, meeting with faculty to discuss confusing material). Another possibility is that the higher rate of engaging in such activities reflects that some students are struggling with the material, in part due to systemic inequities that Black students face in pre-college preparation, in combination with racial discrimination and/or microaggressions in the classroom (Ortiz et al., 2019). This finding adds to the concern that Black STEM students do not reap the same benefits from their encounters with faculty members as do their peers, at least when it comes to traditional metrics of academic achievement, despite of their greater exposure to student-faculty interaction.

An additional area for future research is the need to potentially disaggregate between the experiences of U.S.-born Blacks versus international background Black students (or potentially Black students who are the children of immigrants), given research that has shown variation in their experiences in STEM (Fries-Britt et al., 2014). Previous research documents how these populations experience and perceive racial identity development and racialization differently (Fries-Britt et al., 2014; Phelps et al., 2001), which may impact their likelihood of forming cross-racial friendships and study partners. While we focused specifically on Black students for this study given research documenting their exclusion from peer networks in STEM (Burt et al., 2018; Treisman, 1985), future research should continue to examine this diversity both between and within racial groups, including studies that compare effects for students of different racial/ethnic groups (i.e., subgroup analysis). For example, previous research indicates that White students tend to gain the most from diverse interactions (Gurin et al., 2002) and such analyses could allow researchers to see whether such patterns pertain to STEM contexts.

Finally, while we included many key predictors of GPA for STEM majors included in other studies (e.g., Cole & Espinoza, 2008), the NLSF dataset did not include measures around STEM identity or a student's sense of attachment to the major, which some prior studies have identified as predictors of GPA (Kuchynka et al., 2018). Future studies could possibly improve model fit by including these measures.

Conclusion

Our findings indicate that studying with friends of different races had both direct and indirect positive effect on GPA, and studying with friends of a different gender had a direct or indirect positive effect on positive predictors of GPA (i.e., organizing study groups and student-faculty interaction). However, not only were Black students less likely to have study partners of a different race among their close friends, but this phenomena apparently has an indirect negative effect on GPA, shedding additional light on forces contributing to inequities in STEM-related social capital. Black students had more frequent interactions with faculty and involvement in organized study groups, but this interaction was not enough to prevent inequities in GPA, likely due to institutional barriers such as racial isolation and marginalization that hinder academic performance.

These troubling results confirm findings from multiple sources, which highlight the isolation experienced by students of color and women in STEM (Amelink & Creamer, 2010; Ong et al., 2011; Treisman, 1985). Knowing that students of color and women in STEM continue to experience marginalization, we urge faculty, administrators and institutions to implement support structures that facilitate positive cross-racial and cross-gender interactions and friendships among students, particularly for Black students. Maintaining an overall racially diverse student body is a foundational pre-condition for interracial friendship to occur at all (Park & Kim, 2013). Since one of the issues impacting cross-racial and cross-gender engagement in STEM relates to the racial and gender composition of STEM majors, we encourage higher education institutions, and in particular STEM departments, to pursue racial and gender diversity through recruitment, admissions, and retention practices.

More importantly, fostering a healthy racial and gender-related climate is the next critical step towards a community of supportive peers. In order to promote inclusion for students of color and women of all races who have been historically marginalized in STEM, departments and institutions should examine how departmental and institutional practices perpetuate unhealthy climates and prevent students of color and women from forming positive interracial and cross-gender connections in STEM (author omitted). To ameliorate discrimination, departments and institutions should raise awareness on bias that reinforces chilly climate for students of color and women and create programs that promote an inclusive climate across the entire campus. Furthermore, institutions can develop strength-based programs that counteract marginalization and foster a sense of belonging among students of color and women on campus.

A healthy campus racial climate includes opportunities for intergroup and intragroup relations (author omitted), and for women of color, STEM departments may need to purposefully create counter-spaces within STEM that connect women of color with each other, build coalitions, and combat marginalization collectively (Ong et al., 2018). Such counter-spaces may also include purposeful teambuilding and opportunities for positive social tie formation with students of other races and genders, such as shared events and programming with other student sub-communities within STEM. In these cases, additional guidance and support from faculty, postdoctoral fellows, and/or student affairs educators could help facilitate opportunities for healthy intergroup and intra-group relations. As women of color simultaneously encounter racism and sexism (Ong et al., 2011), they tend to cultivate peer groups outside of STEM (Tate & Linn, 2005), which may provide emotional support but may also limit participants' access to important STEM-related intercultural and social capital. To help compensate, departments can establish mentoring programs that connect women of color with alumni and working professionals who can share experiences and resources, promoting both same race/gender and cross-race/gender mentoring relationships. Additionally, STEM departments can consider organizing formal programs and informal events, such as workshops, talks and socials, that help students of color and women of all races build peer networks that provide both academic and emotional support. Apart of organizing programs within STEM departments, faculty and staff can also share resources regarding campus-wide student organizations, affinity groups, and community groups that strengthen support to women of color.

In identifying the benefits associated with studying with friends across race and gender in STEM, our work further affirms the importance of supporting diversity and inclusion in STEM. Not only are there deep negative consequences to exclusion (Burt et al., 2018), there are benefits to supporting inclusion via interracial and cross-gender relationships that combine academic and social support. STEM departments will continue to struggle in retaining students of color and women if these populations continue to be excluded from opportunities to advance academically and professionally, leading to a more homogeneous workforce and negative repercussions for society at large. Altogether, promoting a healthy climate conducive to positive intergroup relations is critical within STEM departments, fostering collaboration and friendship across demographic lines.

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