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Which STEM relationships promote science identities, attitudes, and social belonging? A longitudinal investigation with high school students from underrepresented groups

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Abstract

A longitudinal science intervention with students from ethnic-racial underrepresented groups in an urban area examined the roles of intervention participation and STEM relationships in implicit and explicit science identity and attitudes and social belonging. Across a four-week geoscience program, Black, Latinx, and Native American/Alaskan Native (87.5%) students ($N=97$; $M_{age}=15.27$; female = 44%) from low socio-economic backgrounds engaged in hands-on activities, field trips, group projects, and listened to diverse speakers. During the intervention, students had the opportunity to form relationships with teachers and near-peer mentors (undergraduate STEM students). Participants exhibited increases in positive explicit and implicit science attitudes, identity, and social belonging. Also, psychosocial support from teachers and near-peer mentors developed over time, but near-peer mentorship uniquely explained changes in science identity and social belonging. Positive changes in implicit and explicit attitudes and explicit science identity were further qualified by past academic performance—only low, compared to high, achieving students benefited the most from the intervention. The present intervention provides evidence that immersing ethnic-racial minority high school students in an engaging science program with supportive STEM relationships promotes science-based cognitions that have implications for persistence in STEM.

Keywords STEM interventions · STEM diversity · Near-peer mentors · Implicit attitudes · STEM teachers

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1 Introduction

Across all educational pathways in science, technology, engineering, and math (STEM), Black, Latinx, and Native American students are underrepresented groups (URGs[1]) compared to White and Asian male students (non-URGs; National Science Foundation, 2019). Due to their numeric underrepresentation (National Science Foundation, 2019), URGs receive a lack of adequate recognition as STEM group members (Carlone & Johnson, 2007), and pervasive cultural stereotypes link STEM competence to White and Asian men (Eaton et al., 2020; Starr, 2018). Moreover, URG students in STEM often experience belonging uncertainty and concern about their acceptance (Walton & Cohen, 2007, 2011), feelings of isolation (Grossman & Porsche, 2014; Malone & Barbino, 2009; Seymour & Hewitt, 1997), subtle and overt forms of bias (Brown et al., 2016; Kuchynka et al., 2018; Rankin & Reason, 2005), and a divergence between their self-concept and STEM (Dasgupta, 2011; Stout et al., 2011).

One way to address the adverse experiences URGs confront in STEM is high-quality mentorship (Dennehy & Dasgupta, 2017; Kuchynka et al., 2020; National Academies of Sciences, Engineering, and Medicine, 2019). However, effective URG mentorship is variable, at best. Not all URG students receive mentorship, and when they do receive mentorship, it is not always effective (Pfund et al., 2016). Moreover, most STEM mentorship targets undergraduate students (Chang et al., 2014; NASEM, 2019), and less is known about the role of STEM mentorship among URG high school students (Tenenbaum et al., 2014). Targeting high school students in STEM learning environments is important because early STEM career expectations predict STEM degree attainment (Tai et al., 2006), and high school performance predicts future STEM persistence (Alkhasawneh & Hargraves, 2014; Chang, et al., 2014; Shaw & Barbuti, 2010; Wang, 2013). Although some studies demonstrate promising findings for mentoring URG high school students as one component of larger STEM interventions (Bystydzienski et al., 2015), no studies, to our knowledge, have isolated and compared the role of different mentoring relationships in STEM learning environments, the quality of these relationships, and how they relate to important STEM outcomes. The current research examines the roles of participating in a STEM intervention and STEM mentorship in URG high school students' STEM identity, attitudes, and social belonging, three social psychological constructs known to predict, and even causally influence, STEM persistence and performance (Chemers et al., 2011; Estrada et al., 2018; Estrada et al., 2011; Hernandez et al., 2013; Maltese & Tai, 2011). Another contribution of the present research is that we measure both explicit and implicit STEM attitudes and identities. Finally, we examine if students' past academic achievement moderates the role of the STEM intervention in STEM outcomes.

[1] White and Asian women are also underrepresented in certain STEM disciplines, but the present research focuses on men and women from Black, Latinx, and Native American groups.

1.1 STEM Relationships and Mentorship

Historically, mentorship in STEM has been tailored to meet the needs of White and Asian, upper middle class, men (NASEM, 2019), but supporting the overrepresentation of non-URGs in STEM maintains existing inequalities in STEM and reinforces cultural stereotypes about who fits in STEM and who has ability in STEM (Murphy et al., 2007). One way to reach critical mass of URGs in STEM is to identify effective forms of STEM mentoring relationships that address the unique belonging needs of URG students (e.g., creating welcoming communities and combatting stereotypes; Byars-Winston et al., 2011; Dennehy & Dasgupta, 2017; Hurtado et al., 2009; Kuchynka et al., 2020; NASEM, 2019). Two such relationships are with teachers and near-peers. *Teachers* are the professionals and experts who are primarily responsible for students' skill development and knowledge acquisition, and for being a source of mentorship and providing guidance on potential career paths (Rouse, 2008). *Near-peers* are students who are at least "one-step ahead" on their educational trajectory (e.g., a college student mentoring a high school student); as such, they can provide valued knowledge and realistic perspectives from recently lived experiences as someone of relatively close age and similar background who has achieved relative success in STEM (Tenenbaum et al., 2014). Near-peers serve as realistic role models, close confidants, and a source of friendship.

We propose that status proximity explains which STEM relationships will have the greatest impact on URGs' STEM outcomes such as identities, attitudes, and social belonging (also see Kuchynka et al., 2020). Status proximity refers to the academic and career trajectory distance between a mentee and mentor. In professional and academic settings, status is correlated with power and, accordingly, higher career status results in more influence over subordinates and institutional practices (Djurdjevic et al., 2017). Also, large status differentials in professional relationships negatively impact trust and self-disclosure (Gabarro, 1987), which results in poorer communication and reduced goal-oriented commitments (Bass, 1990). In mentee-mentor relationships, dissimilarity is inherent due to status (e.g., teachers wield more interpersonal and institutional power than students), thereby creating the potential for an uncomfortable and unrelatable relationship. However, a certain level of status distance between mentees and mentors is optimal for mentors to teach and role model norms and behaviors (Ensher et al., 2001).

Although relationships with teachers and near-peers in STEM contexts contribute to STEM processes and outcomes (for a review, see Kuchynka et al., 2020), the present research proposes that STEM relationships with near-peers reap relatively stronger STEM psychological benefits. Because the status between mentees and near-peers is relatively proximal, mentees should experience stronger feelings of connection and closeness. As it relates to teachers, mentees may be less likely to identify with teachers whose higher status, based on their advanced age and academic and career accomplishments, may make them less relatable, more out of reach or even intimidating, and less psychologically close. Near-peers, however, can provide more realistic and non-threatening upward social comparisons such that mentees can imagine themselves achieving success in STEM and setting similar career goals. Indeed, near-peer mentoring positively impacts mentees' STEM-based skills

(Quitadamo et al., 2009), STEM interest (Wilson, & Grigorian, 2019), and STEM retention (Watson & Mazur, 2013). Teachers, undoubtedly, represent a stronger source of STEM expertise due to their established credentials and longer experience, which promotes skill development and knowledge acquisition that assist with student performance and persistence in STEM (Kim et al., 2018).

1.2 Psychosocial Support and Psychological Closeness

We propose that near-peer mentor relationships are more likely than teacher relationships to be a stronger source of promoting STEM identities, attitudes, and social belonging because near-peers in STEM learning environments are uniquely positioned to provide greater psychosocial support and promote psychological closeness. This hypothesis is based on traditional interpersonal relationship research that emphasizes the importance of similarity for relationship formation (e.g., Byrne, 1961; Byrne et al., 1971) and the cognitive and motivational processes of self-expansion (Aron & Aron, 1997; Aron et al., 1998).

Put plainly, individuals like others who are like them and the liking of similar others is fundamental to relationship formation and functioning (e.g., Byrne, 1961, 1971; Clore, & Baldridge, 1968). Individuals perceive similar others as socially and psychologically closer than dissimilar others (Campbell & Tesser, 1985), and they become motivated to form and maintain a relationship with similar others (Heider, 1958). In professional settings, perceived similarity between subordinates and their supervisors is associated with positive relationship and professional outcomes (Green et al., 1996; Liden et al., 1993; Ragins & Cotton, 1999; Ragins & McFarlin, 1990). Once a relationship is formed, incorporating a close other into the self (i.e., psychological closeness) covaries with positive and frequent interactions (Aron & Aron, 1997). This process of self-expansion allows individuals to share cognitive and psychological resources with one another, which is central to the pursuit of shared goals (Aron et al., 2004). Finally, overlapping identities and shared experiences are two common mechanisms that facilitate relationship comfort and trust in mentee-mentor relationships (Allen et al., 2005; Ragins, 1997).

A central component of professional relationships is psychosocial support (Ensher & Murphy, 1997; Gaskill, 1991), which is also true for STEM mentorship relationships with URG students (National Academies of Sciences, Engineering, and Medicine, 2019). Psychosocial support is a broad relationship construct that includes role modeling, personal connection, emotional support, cultural responsiveness, trust, self-disclosures, authentic engagement, and empathy (Haeger, & Fresquez, 2016; Morgenroth et al., 2015; NASEM, 2019). Psychosocial supportive mentorship predicts psychological benefits and URGs' STEM success (Ishiyama, 2007; Kendricks et al., 2013). For example, Black students are more likely than White students to report the importance of having a personal connection with their mentor and to experiencing stronger psychological benefits such as confidence from a mentoring relationship (Ishiyama, 2007).

1.3 STEM Identity, Attitudes, and Belonging

As noted above, the present research examines the role of STEM relationships in URG high school students' STEM identity, attitudes, and belonging. STEM identity is the cognitive association between the self and STEM disciplines (Dennehy & Dasgupta, 2017) and STEM group members such as peers, teachers, and professionals (McDonald et al., 2019). STEM identity is further qualified by perceptions of centrality (how important and valued STEM is; Ramsey et al., 2013) and typicality (how much one feels like a prototypical group member; Starr, 2018). Among URG students, strong STEM identities are related to higher STEM grades, higher retention and graduation rates, and greater persistence in and commitment to STEM even after college graduation (Estrada et al., 2011, 2018). STEM attitudes are operationalized as the degree to which students like or feel positive about STEM (Dennehy & Dasgupta, 2017). High school students' STEM attitudes are tied to choosing a STEM major in college (Maltese & Tai, 2011), but studies show that by high school and college many students express relative dislike and lack of interest in STEM (Chen & Soldener, 2013), thereby justifying the need to foster positive STEM attitudes relatively early on STEM pathways. Social belonging in an academic context is defined as feeling accepted, valued, and supported by communities and its members (e.g., peers; Strayhorn, 2018). Social belonging predicts STEM identity (Kuchynka et al., 2019), academic performance (Freeman et al., 2007), and is particularly important for STEM persistence among ethnic-racial minority students (Espinosa, 2011).

One contribution of the present research is that we explore the roles of participating in a high school STEM intervention and STEM relationships in both explicit and implicit STEM attitudes and identities. While explicit cognition is rooted in controlled and introspection processes, implicit cognition is rooted in automaticity and nonconsciousness (Greenwald & Banaji, 1995). As it relates to STEM, the impact of mentors and role models on URG students is often observed on measures of implicit cognition but not explicit cognition, because even when people explicitly reject URG-STEM stereotypes and their impact on the self, these learned stereotypes can still manifest implicitly (Dasgupta, 2011). To date, nothing is known about longitudinal changes in implicit STEM attitudes and identities among ethnic-racial URG high school students participating in STEM interventions, and how such changes are impacted by different types of STEM relationships. Because implicit social cognitions represent strong learned associations that may require time and repeated exposure to weaken (see Dasgupta & Rivera, 2008), we tested if a longitudinal STEM intervention yields changes in implicit identities and attitudes in addition to explicit identities and attitudes.

1.4 The Role of Student Academic Achievement

The impact of STEM interventions on students' outcomes may depend on the level of their academic achievement prior to starting intervention. Targeting low-achieving students is critical for promoting positive STEM outcomes because high school performance as measured by GPA, class rank, and college entrance exam scores, predicts long-term STEM success (Alkhasawneh & Hargraves, 2014; Chang et al., 2014; Shaw & Barbuti, 2010; Wang, 2013). Fortunately, STEM interventions often demonstrate disproportionately strong effects among low, compared to high, achieving students (Lin-Siegler et al., 2016). Since belongingness needs are directly related to academic performance (Niemiec & Ryan, 2009), and ethnic-racial minority students often express weak belonging in STEM (Carlone & Johnson, 2007; Espinosa, 2011), low-performing ethnic-racial minorities may especially benefit from STEM interventions. For example, students' sense of belongingness in STEM domains predicts their perceptions of their own ability above and beyond actual performance (Veilleux et al., 2013). Therefore, we posit that the impact of STEM relationships with teachers and near-peers, and being immersed in a community of like-minded high school peers may be especially pronounced for low-achieving students.

1.5 Overview of the Present Research

The present longitudinal study tested if a four-week STEM intervention, particularly in the area of geoscience, yields positive changes in implicit and explicit science identity and attitudes and social belonging among a sample of URG high school students from Newark, New Jersey; if any observed changes are explained by increases in psychosocial support from teachers versus near-peer mentors; and if the STEM intervention especially benefits low achieving students. To our knowledge, our research is the first STEM intervention with high school students from ethnic-racial minority group that includes measures of both explicit and implicit science identity and attitudes and that directly compares the relative role of two types of STEM relationships in URG students' STEM-related cognition. Our hypotheses are:

Hypotheses 1a-1e Participants will exhibit greater positive implicit (1a) and explicit (1b) attitudes in science, and stronger implicit (1c) and explicit (1d) identities with science and (1e) social belonging (1e) over the four-week intervention.

Hypotheses 2a-2e Stronger psychosocial support from teachers and near-peers over the four-week intervention will explain student participants' positive changes in implicit (2a) and explicit (2b) science attitudes and implicit (2c) and explicit (2d) identities with science, and social belonging (2e).

Hypotheses 3a-3e Positive changes in implicit (3a) and explicit (3b) science attitudes and implicit (3c) and explicit (3d) identities with science, and social belonging (3e) will be moderated by past academic achievement such that low achieving students will exhibit the strongest STEM psychological outcomes.

Table 1 Sample Demographics (N = 97)

Variable	
Age (mean years)	15.27 (1.01)
Gender	
Male	56.8
Female	43.2
Ethnic-Racial Group	
Black or African-American	63.6
Latinx or Hispanic	21.6
Middle Eastern or North African	0.0
White or European American	0.0
Asian or Asian American	4.5
American Indian or Alaska Native	2.3
Other Identity	5.6
High School or College Status	
First year or Freshman	22.7
Second Year or Sophomore	37.5
Third Year or Junior	27.3
Fourth Year or Senior	10.2
Parents Level of Education	
GED	4.5
High School	25.0
Some College	13.6
College Graduate	27.3
I do not know	26.1

Note. Values represent percentages, unless otherwise noted in parentheses after variable. For means, standard deviations are in parentheses

2 Method

2.1 Participants and Design

We invited all high school students enrolled in a four-week geoscience program at a northeastern urban university during the summers of 2018 ($n = 53$) and 2019 ($n = 45$) to participate in the study. Due to attrition, the total sample size of students who completed all measurements varied across the three time points (Times 1–3 Ns = 97; 95; 88). A sample size of 88–97 participants yields strong statistical power for a single cell, repeated measures design to detect a small to medium effect size (Brysbaert, 2019). Table 1 lists all participants' demographics and Table 2 lists the near-peer mentors' and teachers' demographics. Participation in the study was voluntary, but students received a stipend for completing the program. We obtained both parental consent and child assent. The study adopted a

Table 2 Near-Peer and Mentor Demographics

Variable	Near-Peer Mentors ($N=17$)	Teachers ($N=5$)
Gender		
Male	29.4	80.0
Female	70.6	20.0
Ethnic-Racial Group		
Black or African-American	52.9	60.0
Latinx or Hispanic	29.4	0.0
White or European American	11.7	40.0
Asian or Asian American	5.8	0.0

Note. Values represent percentages.

one factor, three-level (Time: 1/beginning of program, 2/middle of program, 3/end of program) within-participants design.

2.2 Intervention Program and Procedure

The summer geoscience program was a four-week intervention that educated high school students from a major urban city about earth resources, energy, and the environment (Gates, 2019). Student participants received mentorship from teachers and undergraduate college students (i.e., near-peer mentors, referred to in the program as "undergraduate student mentors") and were immersed in a community of mostly Latinx and Black high school peers.[2] Student participants were not paired with a specific teacher or near-peer mentor; all participants received instruction and support from all near-peer mentors and teachers. In addition, student participants were exposed to a variety of geoscience materials through active learning activities such as field trips and group projects. Finally, student participants attended presentations from diverse geoscience professionals who were deliberately chosen to reflect the composition and background of the URG students participating in the program.

Time 1 data collection was the very first activity on day 1 of the program, Time 2 occurred around day 9, which was around the mid-point, and Time 3 was measured on day 19, the final day of the program. Participants completed the measures in the order listed below, with three exceptions. First, the measures of implicit science attitudes and implicit science identity were counterbalanced between-participants. Second, the measures of explicit science attitudes and explicit science identity were similarly counterbalanced to parallel the order of the implicit measures. Finally, the

[2] The third author was one of the teachers, but he did not participate in the design and administration of, and was blind to students' performance on, the measured variables.

measured variables were completed across all three time points, unless otherwise noted in parentheses.

2.3 Measured Variables

2.3.1 Implicit Science Attitudes

A single-category Implicit Association Test (SC-IAT; Karpinski & Steinem, 2006) measured participants' reaction time to assess how quickly they paired science stimuli with good vs. bad stimuli. SC-IATs are administered when a mental representation, such as science, has no clear comparison category. Participants saw three categories of stimuli appear on the center of the computer screen in rapid succession. Semantic stimuli representing science (*science, engineering, geology, geoscience, energy*), good (*paradise, smile, joy, gift, laughter*), and bad (*war, filth, poison, disaster, vomit*) concepts were presented randomly on the screen and remained until the participant responded. Simultaneously, category labels were appropriately and randomly positioned on the top left and top right sides of the screen. For one block of trials, participants were instructed to use the "A" key to classify "science" and "bad" words and the "K" key to classify "good" words (i.e., "science + bad" trials). In the other block of trials, the key assignment was reversed — participants used the "A" key to classify "bad" words and the "K" key to classify "science" and "good" words ("science + good" trials). The order of the two tasks was counterbalanced between-participants. For each block, participants first read a set of instructions and then completed 17 practice trials followed by 50 critical trials. Following each response, participants were given feedback regarding the accuracy of their response. For each trial, the target words remained on the screen until participants pressed a key. If the participant pressed the correct key, a new target word appeared. If the participant pressed the wrong key, the word "ERROR" appeared in red in place of the centered target word until the participant appropriately categorized the target word.

Consistent with Karpinski and Steinman's (2006) scoring algorithm, only critical SC-IAT blocks were scored. A SC-IAT score is the difference in standardized reaction times between science + good trials and science + bad trials. A relatively high SC-IAT score indicates faster reaction times when science and good semantic stimuli were paired than when science and bad semantic stimuli were paired. In other words, higher SC-IAT scores reflect stronger positive implicit attitudes toward science (Times 1–3 $\alpha s = 0.74$; 0.83; 0.73).

2.3.2 Implicit Science Identity

A second SC-IAT measured how quickly participants paired science stimuli with self vs. other stimuli. This task followed the same measurement and scoring procedures detailed in the above SC-IAT, except that semantic stimuli representing science (identical to the above SC-IAT), first-person pronouns (*I, me, my, mine, self*), and third-person pronouns (*they, them, their, theirs, others*) were presented on the computer screen. A relatively high SC-IAT score indicates faster reaction times when science and self semantic stimuli were paired than when science and other semantic stimuli were paired. In other words, higher SC-IAT scores reflect stronger implicit science identities (Times 1–3 $\alpha s = 0.72; 0.78; 0.79$).

2.3.3 Explicit Science Attitudes

Adapted from Dennehy and Dasgupta (2017), participants reported the extent to which they rated the science stimuli in the SC-IATs above on four 7-point semantic differentials ranging from -3 to + 3 anchored by dislike–like, hate–love, boring–fun, and bad–good. Higher scores mean stronger explicit positive attitudes toward science (Times 1–3 $\alpha s = 0.81; 0.92; 0.89$).

2.3.4 Explicit Science Identity

Following Dennehy and Dasgupta (2017), participants responded to three items-“How important is science to you?”, “How useful is science to you?”, and “How much do you care about doing well in science?”-on 7-point scales ranging from 0 (*not at all*) to 6 (*very much*). Higher scores mean stronger explicit science identities (Times 1–3 $\alpha s = 0.83; 0.81; 0.84$).

2.3.5 Social Belonging (Times 2 and 3 only)

Following Good et al. (2012), participants responded to four items—“I feel connected to my peers in the science program,” “I feel accepted by my peers in the science program,” “I feel like an outsider among my peers in the science program” (reverse coded), and “I feel invisible among my peers in the science program” (reverse coded)—on a 7-point scale ranging from 0 (*not at all true*) to 6 (*very true*). Higher scores indicate stronger belonging (Times 2 and 3 $\alpha s = 0.64; 0.74$).

2.3.6 Psychosocial Support from and Psychological Closeness with Teachers and Near-Peer Mentors (Times 2 and 3 only)

Following Dennehy and Dasgupta (2017), and consistent with the conceptualization that psychosocial support includes multiple relationship functions (see Introduction), our global assessment included perceived similarity, personal chemistry, connection, support, role modeling, and assistance. Participants responded to eight questions separately targeting teachers and mentors – for example, “How much support have you been getting from your teacher (or mentor)?”; “How much has your teacher (or mentor) been available to you?”; “Can you imagine yourself achieving a similar level of success in science as your teacher (or mentor) in the future?”—on a 7-point scale ranging from 0 (*not at all*) to 6 (*very much*). The support measures targeting teachers (Times 2 and 3 $\alpha s = 0.87; 0.91$) and near-peer mentors (Times 2 and 3 $\alpha s = 0.91; 0.93$) exhibited strong internal reliability. Also, we adapted the single-item Inclusion of the Other in the Self Scale (Aron et al., 2004) to measure students’ psychological closeness with (a) teachers and (b) near-peer mentors.

Participants were also asked, “Which of the pictures best describes your teacher (or mentor)-student relationship?,” then presented with seven pairs of circles (like Venn diagrams) ranging from non-overlapping to near-complete overlapping (or inclusion of teachers and mentors within students’ self-concept). Given the strong correlations between psychosocial support from and psychological closeness with teachers (Times 2 and 3 *r*s = .64; .55, *ps* < .001) and mentors (Times 2 and 3 *r*s = .72; .78, *ps* < .001), all nine-items were averaged to create two psychosocial support composites, one for teachers and one for near-peer mentors. Higher scores indicate students’ perceptions of stronger support.

2.3.7 Demographics

Participants completed a demographics and background questionnaire which included gender, age, parents’ education status, ethnic-racial identity, year in high school, and high school grade point average (GPA), which we used to test Hypotheses 3a-3e on the moderating role of academic achievement. See Table 1 for a list of all demographics.

3 Results

Table3 lists the zero-order correlations among all variables included in the analyses. We sought to understand the role of the intervention in science attitudes and identity and social belonging above and beyond any explained variance of student participants’ year in high school and parents’ education status. Older students may start the program with stronger science identities, positive science attitudes, and sense of belonging due to their academic success or advanced experiences with science courses. Similarly, students of parents with higher levels of education may also start the program with stronger identities, positive science attitudes, and sense of belonging because of their access to more academic and extracurricular resources. Finally, we used listwise deletion for missing data.

3.1 Hypotheses 1a-1e: Changes in Science Attitudes, Identity, and Social Belonging

To test our hypotheses that implicit and explicit science attitudes and identity would increase over time, we first ran a repeated measures MANCOVA in which Time was the three-level within-participants factor (Times 1–3), and year in high school and parents’ education status were covariates, $F(8, 64) = 1.31$, $p = .25$, $\eta_p^2 = 0.14$. Next, we examined the pairwise comparisons to decompose the four measures as a function of Time to test Hypotheses 1a-e (see Table4 for means and standard errors). Positive implicit science attitudes marginally increased from Time 2 to Time 3 $|M_{diff}| = 0.14$, $SE = .07$, $p = .07$, 95% CI [−0.28, 0.01], and, similarly, implicit science identity marginally increased from Time 2 to Time 3 $|M_{diff}| = 0.09$, $SE = 0.05$, $p = .09$, 95% CI [-0.21, 0.01]. No other changes across time emerged. Hypotheses 1a

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Table 3 Zero-Order Correlations Among All Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. GPA	_																			
2. HS Year	.16	_																		
3. SES	-.12	-.007	_																	
4. Explicit Attitudes T1	.02	-.16	.09	_																
5. Explicit Attitudes T2	.04	-.13	-.04	.74**	_															
6. Explicit Attitudes T3	-.07	.01	.002	.57**	.72**	_														
7. Explicit Identity T1	.01	.07	.04	.63**	.49**	.45**	_													
8. Explicit Identity T2	.23*	.07	-.05	.62**	.65**	.56**	.73**	_												
9. Explicit Identity T3	.13	-.05	-.09	.58**	.61**	.63**	.74**	.79**	_											
10. Implicit Attitudes T1	-.19	-.13	.08	-.03	.03	.05	-.16	-.04	-.09	_										
11. Implicit Attitudes T2	-.03	-.14	.10	.03	.09	-.02	-.004	0.18	-.03	.34**	_									
12. Implicit Attitudes T3	-.22	-.07	.27*	.007	-.002	.01	.02	-.04	-.11	.17	.09	_								
13. Implicit Identity T1	-.16	-.12	.03	.13	.20	.11	.06	.11	.08	-.22	.17	-.26*	_							
14. Implicit Identity T2	-.02	-.07	.03	-.01	.04	-.09	-.12	.04	-.09	.22	.07	-.08	.17	_						
15. Implicit Identity T3	.16	.003	.09	.02	.06	-.07	-.18	-.05	-.22	.25*	.30**	.07	.27*	.21	_					
16. Belonging T2	.00	-.29*	.05	.07	.06	.08	.05	.16	.17	-.03	.07	-.01	.05	.00	-.07	_				

Table 3 (continued)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
17. Belonging T3	-.15	-.19	.03	.03	.03	.17	-.11	-.05	.08	.05	.04	-.25	-.13	-.06	-.07	.58**	_			
18. Teacher Support T2	-.14	-.03	.05	.23*	.39**	.48**	.25*	.40**	36**	.05	.11	.02	.15	.05	.06	.39**	.24*	_		
19. Teacher Support T3	-.07	.13	.08	.17	.30**	.51**	.19	.34**	.40**	.17	-.04	-.06	-.02	-.11	.08	.09	.33**	.61**	_	
20. Mentor Support T2	-.11	.07	.09	.24*	.35**	.41**	.24*	.40**	.29**	.05	.11	.04	.05	-.07	.13	.39**	.25*	.81**	.61**	
21. Mentor Support T3	-.02	.11	.03	.24*	.36**	.44**	.21	.32**	.45**	.03	-.10	-.08	.003	-.06	.05	.12	.31**	.58**	.79**	.65**

Note. T1 = Time 1, T2 = Time 2, T3 = Time 3; Teacher Support = Teacher Psychosocial Support; Mentor Support = Mentor Psychosocial Support; Belonging = Social Belonging*$p < .05$, **$p < .01$

Table 4 Descriptive Statistics as a Function of Time

Variable	Time 1	Time 2	Time 3
Implicit Attitudes	0.20 (0.04)	0.12 (0.06)	0.26 (0.04)
Implicit Identity	−0.17 (0.04)	−0.23 (0.04)	−0.14 (0.04)
Explicit Attitudes	1.41 (0.13)	1.24 (0.13)	1.50 (0.13)
Explicit Identity	4.68 (0.13)	4.61 (0.12)	4.77 (0.13)
Social Belonging		3.86 (0.13)	4.25 (0.14)
Teacher Psychosocial Support		3.82 (0.14)	4.06 (0.14)
Near-Peer Psychosocial Support		3.68 (0.16)	4.27 (0.15)

Note. Estimated means and standard errors in parentheses.

and 1b were partially supported. Also, positive explicit science attitudes increased from Time 2 to Time 3 $|M_{diff}| = 0.26$, $SE = 0.10$, $p = .01$, 95% CI [0.06, 0.46] and, similarly, explicit science identity increased from Time 2 to Time 3 $|M_{diff}| = 0.16$, $SE = 0.08$, $p = .04$, 95% CI [0.001, 0.32]. No other changes across time emerged. Hypotheses 1c and 1d were partially supported.

Next, to test our hypotheses that social belongingness would strengthen over time, we conducted a paired t-test in which Time was the two-level within-participants factor (Times 2 and 3). As expected, social belongingness significantly increased from Time 2 ($M = 3.86$, $SD = 1.25$) to Time 3 ($M = 4.12$, $SD = 1.29$), $t(83) = 1.95$, $p < .001$, 95% CI [0.004, 0.52]. Hypothesis 1e was fully supported.

3.2 Hypotheses 2a-2e: Changes in Science Attitudes, Identity, and Social Belonging via Relationships with Teachers versus Near-Peer Mentors

Before testing Hypotheses 2a-2e, we ran two preliminary tests. First, we examined the multivariate effect of Time on teacher and near-peer mentor psychosocial support. A repeated measures MANCOVA in which Time was a two-level within-subject factor (Times 2–3), STEM relationship type was a two-level within-subject factor (teacher vs. near-peer mentor), and year in high school and parents' education status were covariates, yielded a significant interaction, $F(1, 80) = 3.98$, $p = .049$, $\eta_p^2 = 0.047$, and a strong multivariate effect of Time $F(1, 80) = 3.98$, $p < .001$, $\eta_p^2 = 0.16$ (see Table 3lists all means and standard errors). Pairwise comparisons showed that over time students reported greater psychosocial support from their teachers $|M_{diff}| = 0.24$, $SE = 0.12$, $p = .04$, 95% CI [0.008, 0.48] and their near-peer mentors $|M_{diff}| = 0.59$, $SE = 0.12$, $p < .001$, 95% CI [0.36, 0.83]. Second, we compared the teacher-targeted versus mentor-target relationship variables to test the status proximity assumption of our hypothesis that students should experience greater relationship quality with their near-peer mentors compared to teachers. At Time 2, psychosocial support was not significantly different between near-peers and teachers ($p = .12$), but a significant difference emerged at Time 3 such that students reported more psychosocial support from near-peer mentors $|M_{diff}| = 0.21$, $SE = 0.09$, $p = .018$, 95% CI [0.037, 0.38].

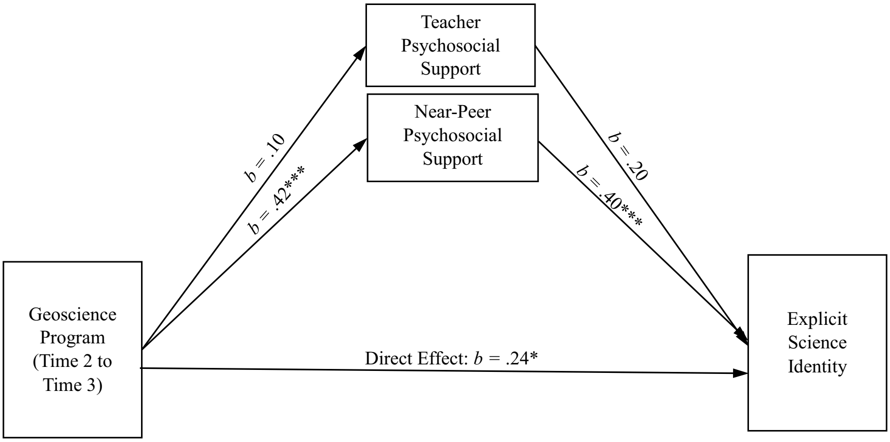

Fig. 1 Role of Geoscience Program in Explicit Science Identity Mediated by Teacher and Near-Peer Mentor Psychosocial Support. Note. *p < .05, **p < .01, ***p < .001.

Finally, to test Hypotheses 2a-2e, we examined if the increases in attitudes, identity, and belonging observed from Times 2 to 3 were mediated by changes in psychosocial support from teachers versus near-peers. Using Montoya and Hayes' (2017) MEMORE (macro Model 1), the predictor represents exposure to the intervention from Time 2 to Time 3, and we submitted psychosocial support as the repeated measures mediators, and the five measures of attitudes, identities, and belonging as outcome variables in five separate models. These analyses allow for pairwise comparisons between the indirect effects, thereby testing which type of relationship support (mediators) accounts for the largest portion of variance between participating in the intervention over time (predictor) and attitudes, identity, and belonging (outcomes).

As displayed in Fig. 1, results showed that increases in psychosocial support from near-peer mentors over time indirectly predicted explicit science identity $b = 0.15$, $SE = 0.07$, 95% CI [0.02, 0.29]. However, teacher-related psychosocial support did not mediate the relation between the participation in the intervention and explicit science identity. That is, psychosocial support from near-peer mentors indirectly predicted positive changes in explicit science identity from Time 2 to Time 3 above and beyond teacher-related psychosocial support. Hypothesis 2d was supported. Similarly, and displayed in Fig.2, psychosocial support from near-peers, but not from teachers, over time indirectly predicted social belonging $b = 0.27$, $SE = 0.12$, 95% CI [0.06, 0.53]; see Fig. 2. Thus, psychosocial support from near-peers indirectly predicted positive increases in social belonging from Time 2 to Time 3 above and beyond teacher-related psychosocial support. Hypothesis 2e was supported. Finally, no other mediation models were supported (Hypothesis 2a-2c).

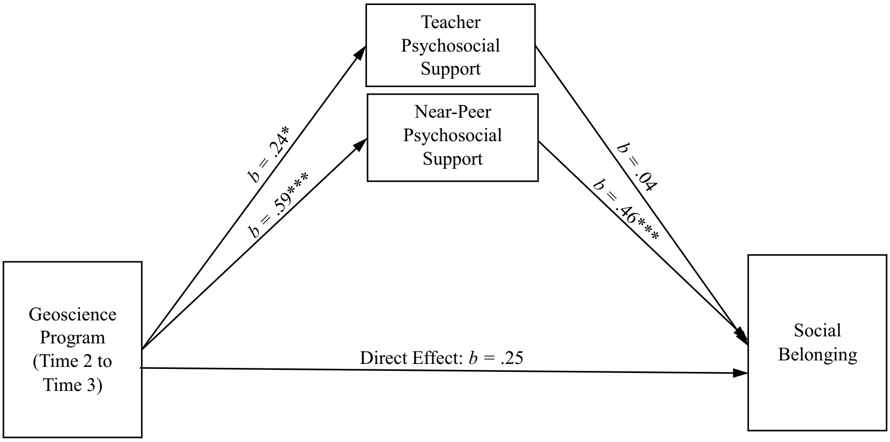

Fig. 2 Role of Geoscience Program in Social Belonging Mediated by Teacher and Near-Peer Mentor Psychosocial Support. Note. *p < .05, **p < .01, ***p < .001.

3.3 Hypotheses 3a-3e: Moderating Role of Past Academic Achievement in Science Attitudes, Identity, and Social Belonging Changes

To test Hypotheses 3a-3e, we examined whether the intervention differentially impacted low versus high achieving students as a function of time. We first probed changes from Time 1 to Time 3 by submitting implicit and explicit attitudes and identity as repeated measures outcome variables and GPA as the moderator in four separate models using Montoya and Hayes' (2017) MEMORE (macro Model 2). Students with high GPAs exhibited increases in positive explicit science identities $b = 0.22$, $SE = 0.14$, $p = .03$, 95% CI [0.02, 0.49] and (marginal) implicit science identities $b = 0.13$, $SE = 0.07$, $p = .05$, 95% CI [−0.003, 0.27]. No significant changes from Time 1 to Time 3 emerged for low performing students ($ps > 0.22$), and GPA did not moderate the effect of Time on implicit or explicit science attitudes ($ps > .51$). Thus, Hypotheses 3a-3e were not supported.

Next, we adopted a similar statistical approach to probe changes from Time 2 to Time 3, because this time period is when students appear to be experiencing the most psychological gains. Students with low GPAs exhibited increases in positive implicit science attitudes $b = 0.20$, $SE = 0.09$, $p < .05$, 95% CI [0.01, 0.39], positive explicit science attitudes $b = 0.35$, $SE = 0.13$, $p = .01$, 95% CI [0.08, 0.62], explicit science identities $b = 0.27$, $SE = 0.11$, $p = .01$, 95% CI [0.06, 0.48], and social belonging $b = 0.53$, $SE = 0.18$, $p < .01$, 95% CI [0.17, 0.88]. No changes emerged among students with high GPAs ($ps > .25$), and GPA did not moderate the effect of Time on implicit science identity ($p = .12$). Thus, these findings provide partial support for Hypotheses 3a-3e.

4 General Discussion

A four-week geoscience summer program introduced URG high school students to a diverse community of primarily Black and Latinx high school student peers, undergraduate student (near-peer) mentors, and teachers. Student participants learned about earth science topics through field trips, guest speakers, and group projects. The longitudinal investigation demonstrated positive changes in science-related cognition and relationship-related psychological factors. Specifically, students exhibited increases in explicit and implicit science attitudes and identity and social belonging as well as stronger relationships with their teachers and near-peers from the middle to the end of the program. Direct comparisons of two types of STEM relationships suggested that relationships with near-peer mentors, compared to those with teachers, explained changes in URG high school students' explicit science identity and social belonging. Altogether, our data suggest that high school STEM interventions and near-peer mentors are an important and distinct source of psychosocial support for URG students in science.

We posited that relationships with near-peer mentors, compared to teachers, promote unique changes in science identity because of status proximity. To construct a professional identity, individuals must identify an individual they perceive as similar to themselves but more advanced in their desired career to begin adopting domain behaviors and to align goals (Gibson, 2003). The distance in status proximity between mentees and their near-peer mentors yields psychological closeness and a strong relationship foundation that presumably facilitates trust, self-disclosures, comfort, and ease of social bonding. The present longitudinal study provides evidence for this assumption—high school students reported stronger psychosocial support and psychological closeness with near-peer undergraduate student mentors compared to teachers by the end of the four-week program in geoscience.

Though teachers reflect an established STEM expert relative to undergraduate students, high school students may perceive them as too advanced in their career trajectory and, thus, difficult to identify with and intimidating, which inhibits relationship comfort and communication (Bass, 1990; Gabarro, 1987). Undergraduate student mentors, on the other hand, represent more relatable mentors, because of their relative proximal status. High school students should perceive undergraduate students as near-peers who started a successful STEM career trajectory with lived experiences, have knowledge to share, and are relatively easy to identify with. These findings are consistent with the literature on close relationships showing that feelings of psychological closeness help form interpersonal relationships and repeated positive interactions with close others lead to the incorporation of the other into one's self-concept (Aron & Aron, 1997). Psychosocial support from near-peers—but not teachers—indirectly predicted increases in social belonging such that near-peer mentors appear to help build a STEM community for high school students to connect with one another. By directly comparing two STEM relationships, the present study demonstrated that near-peers play a unique role in science identity formation and social belonging among high school students via psychosocial support.

4.1 High Achieving Versus Low Achieving High School Students

When we investigate the role of academic achievement over time in the intervention, we observed different positive patterns emerge for high versus low performing students. High achieving students were more likely to experience increases in explicit science identity and implicit science identity from start to the end of the program, whereas low-performing students only exhibited gains on implicit and explicit science, explicit science identities, and social belonging from midpoint to end of the program. These findings contribute to research demonstrating the promising impact of STEM interventions for lower-achieving students (Lin-Siegler et al., 2016). High school in-class STEM environments are typically characterized by high-stakes standardized testing and competitive atmospheres (Appel et al., 2011; Chen & Soldner, 2013; McNeil, 2000), and learning STEM material is stressful for most students (Beilock & Willingham, 2014). In contrast, the present geoscience summer program represented a low-stakes learning environment where students were encouraged to form meaningful relationships with peers, near-peers, and teachers. Students were also given the opportunity to learn STEM through hands-on activities instead of passively learning STEM through "teaching-by-telling." Therefore, the geoscience summer program offered a fun environment tailored toward improving the high school students belonginess needs, which is particularly important for lower-achieving students.

The different positive patterns for high versus low achieving students are also consistent with STEM intervention research that reports *fluctuations* in STEM-related social psychological constructs (Dasgupta & Dennehy, 2017; Estrada et al., 2019; Kuchynka et al., 2019; Liu, 2018). For example, students typically start STEM programs with relatively high STEM self-efficacy that then decreases after they are exposed to the rigors of STEM coursework and expectations (Findley-Van Nostrand & Pollenz, 2017; Kuchynka et al., 2019; Liu, 2018). URG students in particular may be at an increased risk of fluctuating STEM-related social psychological constructs (e.g., STEM identity) because they are more likely to experience academic isolation (Grossman & Porsche, 2014; Malone & Barbino, 2009), bias (Rankin & Reason, 2005; Swim et al., 2003), and a lack of support and recognition (Carlone, & Johnson, 2007) in STEM. Finally, the present intervention included a variety of active learning components, which can be anxiety-inducing for students (Iran-Nejad, 1990; Ishiyama, 2013), even though they provide strong and consistent learning benefits (for a review, see Ishiyama, 2013; for a meta-analyses, see Freeman et al., 2014; Schroeder et al., 2007). In sum, the present data are consistent with past work showing that changes in STEM-based social psychological constructs do not always follow a linear trajectory (especially for low-performing students), but often fluctuate due to exposure to novel STEM environments and challenging material.

4.2 Implicit Attitudes and Identities

Investigating implicit social cognitive processes underlying STEM attitudes and identities is an important avenue for STEM intervention research (Dasgupta, 2011; Nosek & Smyth, 2011). First, research that exclusively includes self-report measures of science-related cognition relies on thoughts available to an individual's consciousness, but this is limiting because this is only a fraction of what occurs in the mind (Bargh & Chartrand, 1999; Nisbett & Wilson, 1977). Second, although implicit science cognition occurs automatically and sometimes outside of conscious awareness, it can surreptitiously influence belonging, persistence, and performance (Dasgupta, 2011). The present research, to our knowledge, represents the first STEM intervention with ethnic-racial URG high school student participants that measured implicit (as well as explicit) science cognitions. Our data show high school students' implicit attitudes and identity can positively change in a four-week science intervention, suggesting that STEM interventions can undermine the impact cultural stereotypes (i.e., associations that link STEM competence to White and Asian men) on URG students' STEM cognitions that operate automatically (Dasgupta, 2011).

4.3 Limitations and Future Directions

The high school intervention did not include a comparison group, so we cannot account for possible self-selection and longitudinal time or maturation effects (i.e., the sheer passage of time can influence participants' psychological constructs; Blanchard et al., 1977). For example, the high school students who participated in the geoscience program may be uniquely motivated to pursue science. However, the question we mainly sought to answer centered on factors (i.e., different types of STEM relationships) that facilitate cognitive and psychological change during the program. Specifically, we investigated the underlying STEM relationship mechanisms that explain increases in science identity, attitudes, and belonging within the context of the interventions. Given this goal, comparisons to students' science identity, attitudes, and belonging outside the program are less pertinent to our main research goal. However, to address potential longitudinal aging or maturation effects, we tested and showed that past academic achievement moderated increases in science identity, attitudes, and, to a lesser extent, belonging. So, the observed effects of intervention participation were not solely a function of time or maturation, otherwise all students should have yielded similar levels of STEM psychological increases regardless of their past academic performance. Nonetheless, future research should experimentally test the role of near-peer mentors on psychological outcomes to determine causal effects.

Future research should also test whether teachers compared to near-peers exert stronger impacts on other important STEM-related variables including knowledge acquisition or skill development. We argue that near-peers are uniquely influential for belongingness-based needs central to the pursuit of STEM among ethnic-racial minority students. However, teachers may be better than near-peers at other mentorship functions such as professional development, which should be empirically tested.

4.4 Implications and Conclusion

Since strong STEM identities, positive attitudes, and belonging predict STEM persistence among URG students (Carlone & Johnson, 2007; Chemers et al., 2011; Estrada et al., 2018), these findings have promising implications for long-term STEM engagement. Cultivating a liking toward and an identification with STEM prior to college is important for combatting a general dislike of STEM witnessed by high school students in the United States (Chen & Soldener, 2013). Near-peer STEM relationships provide access to valued resources such as knowledge, norms, and guidance on career paths, and of particular importance for URG students, offer a source of connection and recognition. The lessons learned from the present intervention can be applied to URG students who are not part of a targeted STEM intervention; implementing mentorship programs that include near-peers could be one way to scale some of the most effective elements from STEM interventions to a much broader student population.

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Availability of data and material All data and materials can be located at Open Science Foundation, #32,267.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Consent to participate All participants signed an informed assent prior to participation in the study, and we also obtained parental consent.

Consent for publication Not applicable.

Ethical approval This study was approved by the institutional review board (#Pro2018001101).

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