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Examining how social networks influence women and under-represented minority students' pursuit of engineering in university: when, who, and how?

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Abstract

Background Women and under-represented minority (URM) students continue to be under-represented in STEM and earn the lowest proportion of undergraduate engineering degrees. We employed a mixed methods research approach grounded in social capital theory to investigate *when* they first consider pursuing engineering as a college degree major, *who* influences this decision, and *how* the influence occurs. First, we surveyed 2186 first-year undergraduate students entering engineering programs at 11 universities in the U.S. during the fall of 2014. Next, we interviewed a subsample of 55 women and URM students.

Results Survey findings indicated that women were more likely than men to consider pursuing engineering while in high school, before admission into college, or while in college rather than considering it earlier in their education. Black and Latinx students were more likely than white students to consider pursuing engineering after high school. In addition, Black and Latinx students were more likely than white students to identify a school counselor (rather than a family member) as having the most influence on their engineering academic and career decisions. In interviews, women and URM students provided examples of influential people who connected their aptitude and enthusiasm for mathematics, science, and problem-solving to engineering, explained the benefits of being an engineer, and provided advice about engineering academic and career pathways.

Conclusions Encouraging earlier consideration of engineering majors, such as during middle school, could allow women and URM students time to take requisite courses and take advantage of college preparatory programming. Likewise, universities can engage in intentional efforts to identify women and URM students with engineering interests and provide guidance. Such efforts should also include connecting them with other women and URM students in engineering. In addition, universities should support K-12 and university personnel in offering advice that can influence students' decision to declare an engineering major, which could help recruit more women and URM students into engineering.

Keywords Ego-network analysis, Gender, Social capital, Women students, Under-represented minority students

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Introduction

Employment in STEM fields is projected to increase by 11% between 2014 and 2024, compared to a 7% increase expected for all occupations (National Science Board, 2018). However, women and racial/ethnic minority students and workers continue to be under-represented in STEM fields. Indeed, women and under-represented minority (URM) students are less likely to declare a STEM major[1], and URM students are less likely to persist in one (Fletcher et al., 2021; Mau, 2016). This underrepresentation is particularly pronounced in engineering (Roy, 2019). Meeting the growing demand for STEM jobs, improving social inequality, and addressing additional concerns to improve society (see Nardi, 2021) are the main reasons why broadening participation in STEM is important. Doing so requires innovative strategies to encourage women and URM students to enter undergraduate engineering degree programs and to retain them to graduation, given the climate they face (Campbell-Montalvo et al., 2022c; McGee, 2021). Understanding the lived experiences of such students is crucial to learning about the influences on their decisions to pursue engineering, an understudied area (Puccia et al., 2021; Sellers et al., 2022; Strutz & Ohland, 2012).

In this study, we examined the critical role of social networks, relationships with alters[2] (influential individuals), and the knowledge and resources accessible through those relationships (Bourdieu, 1986; Lin, 2001) in influencing students' decisions to pursue engineering as an undergraduate degree major. The literature demonstrates that social networks provide women and URM students with access to relationships and crucial resources that help them make academic and career decisions and succeed in STEM higher education (Cooper et al., 2021; Dika et al., 2020; Garrett et al., 2021; Joshi et al., 2019; Rincón & Rodriguez, 2021; Shekhar & Huang-Saad, 2021; Solanki et al., 2019). However, women and URM students may not have sufficient access to necessary and relevant social networks (Lin, 1999; Martin et al., 2011) due to their historical exclusion from STEM fields, which were created to serve white men in the middle-to-upper social class (Frehill, 2004; Slaton, 2010). To inform the pivotal initial step in the engineering career that includes declaring an engineering major,[3] we examine *when* students from various demographic groups first contemplate pursuing an engineering undergraduate major, the people *who* influenced their decision, and *how* or the mechanisms through which the influence occurred.

The influence of social networks on women and URM students' career decisions

Social networks are most beneficial when comprised of individuals with access to social capital (i.e., extensive knowledge and resources). Typically, parents are students' first alters and source of social capital. For example, parents may supplement their children's public education with informal learning via museum visits, literature, and travel (De Graaf et al., 2000; Goldrick-Rab, 2006; Haveman & Wolfe, 1995). In addition, children from higher socioeconomic statuses (SES) tend to attain higher test scores than those from lower SES (Alon, 2009), due to the advantages of their parents accessing postsecondary education conferred upon them and the documented class bias in the design of standardized tests. Moreover, children whose parents attended college and have higher incomes often face fewer structural obstacles and can return to their degrees after disruption at higher rates than those whose parents did not attend college (Goldrick-Rab, 2006). Parents have been found to promote their children's initial interest in STEM through actions such as providing affirmations, providing STEM-related games and toys, encouraging school involvement, advocating for placement in appropriate courses, and enrolling them in STEM programs (Berry, 2008; Burt & Johnson, 2018; Martin et al., 2014a, 2014b, 2020; Strayhorn, 2010; Wright et al., 2016). Our prior work (Puccia et al., 2021) highlighted parents' role in advising their children and how that influenced their children's decision to pursue an engineering major. We found that parents provided instrumental (concrete advice and resources) and expressive (emotional support and encouragement) advice their children leaned on to make their engineering major declaration. We also found that parents, family members, and other alters such as high school teachers provided advice tailored to women and URM students that warned them of the biases and discrimination they would likely experience in their engineering programs (Campbell-Montalvo et al., 2022c). By acting on that advice, women and URM students increased their ability to cope and persist in the first few years of their engineering major.

In addition to information obtained from parents and family members, students acquire knowledge and resources from their social networks comprised of high school teachers, counselors, and coaches, which enables them to pursue engineering as a career successfully (Coleman, 1988; Dufur et al., 2016; Martin et al., 2020).

[1] Majors are defined as specific subject areas that students specialize in during college or university matriculation.

[2] Alters are members of an individual's social network who are connected to the individual and may be influential in decision-making.

[3] Declaring a major means officially choosing a specialty during college or university that will define the coursework undertaken.

Due to social structure, middle-class K-12[4] students, primarily those who are white or have social networks comprised of parents, highly educated friends, teachers, and counselors/advisors, tend to have higher academic achievement, access to elite education, early knowledge about course-taking in preparation for college, insider information on how to navigate college successfully, and access to internship and job opportunities than marginalized students have (Hardie, 2015; Stanton-Salazar, 2011). Black students, who are also affected by social structure, may enter their undergraduate engineering programs with less social capital than other students (Skvoretz et al., 2020)—such social capital may be influential in the declaration of an engineering major. For instance, Hardie (2015) found that middle-class Black girls had lower-status individuals in their social networks and that poor and working-class Black girls had smaller social networks. In addition, Black students relied on high school teachers, guidance counselors, and leaders as sources of information about college and career readiness rather than family members; thus, their access to resources might be more limited and unsustainable.

In addition to family and teachers, connections with peers may also be a source of social capital for high school students. For instance, peer networks in which members took more advanced mathematics classes resulted in higher academic success for all students in the group (Crosnoe et al., 2008). Notably, Black students were found to access particular forms of social capital (i.e., race/ethnicity-focused professional engineering organizations, such as the National Society of Black Engineers [NSBE]) at higher rates than other groups, and such access was correlated with increased persistence in their engineering major (Campbell-Montalvo et al., 2022b; Smith et al., 2021).

The frequency of interactions with alters in a student's social networks may impact their level of influence on the student. For example, students tend to be influenced by those with whom they interact most often (Swail & Hosford, 2007), which may include teachers and counselors (Trusty & Watts, 1996) and parents (Hoyt, 1984; Otto & Call, 1985). Over half (54%) of the students, in a study of low-income students attending high school in Washington State, identified teachers (21%), parents (19%), and school counselors (14%) as the most helpful in how they learned about college (Peterson & Stroh, 2004).

Swail and Hosford (2007) categorized alters into primary (e.g., parents, siblings, and family members) versus secondary (e.g., teachers, counselors, friends, and peers) influencers and found that the status of the alters and the size of students' social networks change over time. For example, seventh-grade students viewed their family members as their most influential alters. In contrast, ninth-grade students viewed individuals other than their family members (e.g., counselors and boyfriends) as their most influential alters. In addition, 11th-grade students reported that a broader range of individuals (e.g., family, siblings, church members, coworkers, college coaches, recruiters, etc.) influenced them.

Although extant research offers a framework to scaffold understandings of how the configuration of social networks among various demographic groups affects the declaration of an engineering major, more research is needed to identify *when* students first contemplate pursuing an engineering major, *who* their alters are, and *how* they influence their decisions. In this study, we address this gap by answering the following research questions:

1. When do women and URM students first decide to pursue engineering as a college major?
2. Who are the alters in the students' social networks that influence this decision?
3. How does this influence occur?

Methods

To support the robust presentation of this study and permit it to be interpreted both on its own and within the broader body of literature, we used the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guidelines (Elm et al., 2007). STROBE entails being forthcoming about the study's initial design and how it ended up being carried out as well as what was found and what those findings mean.

Study context and design

This study was part of a larger, longitudinal 5-year project that examined the engineering degree program persistence and attainment of women and URM students (see Campbell-Montalvo et al., 2022b, 2022c; Puccia et al., 2021; Skvoretz et al., 2020; Smith et al., 2021). We employed a *partially mixed sequential dominant status design,* whereby the quantitative component preceded the qualitative component, both components were weighted equally in addressing the research questions, and mixing occurred after the data analysis stage (Leech & Onwuegbuzie, 2009). The *quantitative component* consisted of a yearly online survey administered in English and Spanish. The sample comprised only survey respondents with verified enrollment as first-year engineering undergraduates in fall 2014. The *qualitative component* involved two rounds of interviews with a subsample of 55

[4] In the United States, compulsory education for children and youth includes kindergarten through 12th grade, also called K-12.

women and URM respondents to the first survey (36 of whom completed a second interview).

Instrumentation: online survey

Guided by results from previous research (Wao et al., 2010), we adapted the *resource generator* instrument (Snijders, 1999; Van de Gaag & Snijders, 2005) and the *name and resource generator* instrument (Martin et al., 2011; see also Skvoretz et al., 2020) to identify survey items measuring social capital. We also added survey items based on the information identified by 31 stakeholders (engineering faculty, advisors, and students) as beneficial for success in engineering programs as part of our *free listing* exercise (Smith et al., 2015). Free listing allows researchers to gather rich preliminary data to improve the validity of survey instruments and interview protocols. Here, a sample comprised of members of the targeted population lists as many items or beliefs they can recall about one or more dimensions of a cultural model identified from previous studies and the literature. Free listing assumes that individuals with extensive knowledge (1) provide more responses than those with less knowledge, (2) list most familiar and meaningful responses first, and (3) provide responses that reflect their local cultural knowledge (Weller & Romney, 1988). Ultimately, free listing measures the strongest beliefs shared by participants about the dimension.

Survey 1 (S1) respondents were asked to *think back to their high school experiences* when responding to survey items. The survey inquired about students' demographic characteristics (e.g., age, gender, race/ethnicity); alters who influenced their decision to pursue engineering, the alters' demographic characteristics, and how the identified alters influenced their decisions to pursue engineering; and the high school programs or activities in which they participated (e.g., advanced placement courses or science camp).

To determine the validity of the items, S1 was pilot-tested with a diverse sample of 30 engineering undergraduates who were not part of the study. To refine and increase the validity of the survey items, we conducted a *think-aloud exercise* (i.e., a verbal cognitive validation protocol) with a diverse sample of nine additional engineering undergraduates who also were not part of the study. Researchers observed the students' body language as they read the questions aloud while taking the online survey (Trenor et al., 2011). These students evaluated the survey, gave feedback on item clarity, and suggested ways to clarify questions. We used the feedback from this exercise, which identified some cognitive and structural issues, to revise the survey. Next, the refined survey was reliability-tested for internal consistency with 100 engineering undergraduates. Once we were confident in the validity and reliability of the items, we finalized and administered the survey.

Instrumentation: semi-structured interview protocol

We designed the interview protocol to collect in-depth descriptive data to elucidate responses to survey items. Social capital questions focused on students' relationships with their alters and how they accessed and activated social capital through these relationships in high school and their first year as engineering majors. For example, students were asked to elaborate on their relationship with alter(s) they identified in S1 as influencing their decision to pursue an engineering major. In addition, students were asked about the types of advice received from alters, how they acted on it, and how it influenced their decision to pursue engineering. The interview protocols used "tell-me-more" probes and requested specific examples, encouraging students to give detailed responses (Bernard, 2011). The baseline interview protocol was pilot-tested with two engineering undergraduates who provided feedback about the questions before the items were refined and finalized.

Limitations

Retrospective capturing of pre-admission social capital has the potential for recall bias in students' responses as we ask them to "think back" about with whom they interacted and the nature of such interactions. However, name generators are designed to elicit strong ties—that is, the names of people with whom the respondent has a close relationship. Therefore, we expect these to be salient and meaningful relationships with people whom should be easily recalled. In addition, we expect respondents' memories to be accurate given the short (approximately 1 year) time lapse between graduation from high school and when the study started. Had we administered the survey when students were in high school, they may have overlooked certain interactions, particularly if they had weaker ties to those alters, or perhaps they may not have realized the impact the advice they were receiving had on their declaration of an engineering major. Finally, we can account for recall differences due to the number of years spent in college by restricting our population to a cohort of students at the same academic career stage (first year in university). In addition, this approach permits the comparison of results with students who switch to a different major or leave university without completing a degree. Thus, the limitation of retrospective recall is outweighed by the benefits of the information provided.

Data collection

Our population consisted of first-year undergraduate students in an engineering program in fall 2014 at 11

Table 1 Students' race/ethnicity by gender

Race/ethnicity	Men		Women		Total	
	n	(%)	*n*	(%)	*N*	(%)
White	736	(69)	335	(31)	1071	(49)
Latinx	371	(70)	158	(30)	529	(24)
Asian	236	(67)	114	(33)	350	(16)
Black/African American	76	(58)	55	(42)	131	(6)
Middle Eastern/North African/Arab	32	(74)	11	(26)	43	(2)
Other ethnicity, race or origin	22	(51)	21	(49)	43	(2)
American Indian/Alaska Native	6	(75)	2	(25)	8	(0)
Native Hawaiian/Pacific Islander	2	(67)	1	(33)	3	(0)
Total	1481	(68)	698	(32)	2178[a]	(100)

[a] 8 respondents did not indicate race/ethnicity, thus the total sample size was 2186

universities, representing a range of learning contexts across three states in the U.S. and one U.S. territory. The universities included seven Predominately White Institutions (PWIs), three Hispanic-Serving Institutions (HSIs), and one Historically Black College/University (HBCU). Respondents to the first survey constituted the sample for this study. We followed our sample for 5 years as they matriculated through their degree programs, including those who stayed in engineering, switched to another program, or exited the university.

Our sample comprised 2186 students (36% response rate) from 11 institutions who responded to S1, administered in spring 2015. This survey had limited missing data as all of the questions (except the one on race/ethnicity, of which only eight students did not complete in S1) were forced-response items, requiring students to respond to each question before moving on to the next.

Table 1 shows that two-thirds of the S1 participants were men, and one-third were women. About half the sample was white and a quarter Latinx, with the remainder being Asian (15%), Black (5%), and from other groups. Given the overrepresentation of men and white students in the discipline, this sample is not unexpected. In addition, the overrepresentation of Latinx students is explained by the participation of three HSIs in the study.

We interviewed 55 women and URM students who responded to S1 from five of the 11 participating universities (one HBCU, one HSI, three PWIs). S1 respondents were selected to participate in interviews based on their probability of activation of social capital, a dichotomous ego-network variable calculated based on responses to S1 that indicated whether or not a student made use of resources accessible through identified alters in their network (see Skvoretz et al., 2020). We contacted all the survey respondents who were women or URM students from the five universities with low or high probabilities of activation. To identify interview candidates, we emailed each of the targeted survey respondents up to three times. We called or sent texts to targeted respondents from universities, where only a small number of participants responded via email, up to two times each. Each 30–60-min interview was audio-recorded and transcribed.

Table 2 shows the demographic characteristics of the interview participants. Except for the white interviewees, the sample included more men than women, reflecting their overall representation in the study sample.

Data analysis

Quantitative: ego-network analysis

We used binary logistic regression to determine when students first considered pursuing engineering as a college major (RQ1) and who influenced this career decision (RQ2). Thus, whether or not a student considers pursuing engineering as a college major is the outcome of interest. Binary logistic regression allows for modeling the *consideration* (a binary response) as a function of individual independent variables separately (e.g., gender, race/ethnicity, race/ethnicity-gender intersection). With this technique, these variables are not required to

Table 2 Gender of interviewees by race/ethnicity

Race/ethnicity	Men	Women
	n	*n*
White	0	14
Latinx	15	3
Black/African American	11	6
Middle Eastern/North African/Arab	3	0
Other ethnicity, race, or origin	2	1
Total	31	24

be "normally distributed, linearly related, and have equal variance within each group" (Tabachnick & Fidell, 1966, p. 575). Primary constructs in the model included *network size* (number of alters identified as being influential in a student's career-related decisions) (Borgatti et al., 1998; Lin, 1999, 2001) and whether the alter was primary (i.e., familial) or secondary (i.e., school-based), which may speak to *strength of ties* (frequency of ego-alter communication) (Borgatti et al., 1998; Granovetter, 1973) or the type of advice provided through the ties. We conducted all statistical analyses using SAS (SAS Institute, 2011).

Qualitative: coding and thematic analysis

We conducted a reflexive thematic analysis of interview data to determine the mechanism through which alters influenced students' decision to declare an engineering major (RQ3). Five members of the qualitative research team created and refined the codebook based on the literature, the interview guide, and an initial review of the interview data (Ryan & Bernard, 2003; see Puccia et al., 2021). We developed primary codes and sub-codes consistent with social capital constructs, including its content (e.g., instrumental, expressive), types of alter (e.g., parent, teacher), and so on. The team coded two interviews to test the usability of the codebook and made additional refinements (DeCuir-Gunby et al., 2011). Codes were clarified, and illustrative examples were added to the codebook to support the interpretation of each construct. To test the codebook's efficacy, each researcher coded three interviews independently to determine ease of use and make further refinements. The team compared results, evaluated codes based on their coding experiences, and finalized the hierarchical coding structure (Thomas, 2006). After we finalized the codebook, two researchers coded one final interview and obtained 83% intercoder reliability based on a line-by-line comparison of their codes (Bernard, 2011). These two researchers each coded half the interview transcripts on paper, and another researcher entered the codes into QSR NVivo 11.0.

We analyzed sub-codes to determine how alters influenced students' decisions to pursue engineering as a major and examined the examples of this influence provided by students. We analyzed trends in these data based on the frequency or patterned nature of the responses as well as 'keyness' or whether the data captured something essentially related to the social networks and their influence (Braun & Clarke, 2006). We then grouped these trends into emergent themes, and identified illustrative excerpts to exemplify our findings.

Results

When students first considered pursuing engineering as a college major

Respondents were provided a survey prompt of "*I first thought about engineering as a college major*" along with the response choices of "in elementary school[5] or earlier," "in middle school,"[6] "in high school,"[7] "after high school before enrolling in college," or "after enrolling in college." Most respondents (59%) noted that they first considered an engineering major in high school (Table 3). Women were less likely than men to consider engineering in elementary or middle school, but were more likely to do so in high school, before college, or in college. Black and Latinx students were more likely than white students to consider engineering after high school. Students from other ethnic groups were less likely than white students to consider engineering in middle school. Asian students were more likely than white students to consider engineering after high school (OR = 2.07, CI 1.33, 3.24).

We examined variations in students' decisions to pursue engineering based on gender and race/ethnicity intersection using white men as the reference category (Table 3). Black men, Latinx men, and Latinx women were more likely than white men to consider engineering as a college major after high school. Black women were more likely to consider engineering as a college major while in college, and Latinx women were less likely to consider engineering as a college major in middle school.

Alters who influenced decisions to pursue an engineering major while in high school

To identify the alters who influenced students' decisions to pursue engineering while they were in high school, students were prompted on the survey, "*Think back to when you were considering engineering as a college major while in high school or middle school. Indicate the person(s) who influenced your decision-making process at that time in some way*." Respondents could select parent/guardian, sibling/other family members, peer/classmate/friend, high school teacher, high school counselor, club/organization contact, or other (to be specified).

Students more frequently identified familial alters than school-based alters, 86% and 63%, respectively (Table 4). Parent/guardian was the most frequently identified familial alter (identified by 80%), and teachers were the most frequently identified school-based alter (identified by 47%). Although there were no respondent gender differences in the type of alters identified, there

[5] In the U.S., elementary school includes kindergarten through 5th grade.

[6] In the U.S., middle school includes grades 6–8.

[7] In the U.S., high school includes grades 9–12.

Table 3 When students first consider engineering as a college major: bivariate analysis by gender, race/ethnicity, and gender-race/ethnicity intersection

Level: when	n	%	OR (95% CI) Women	OR (95% CI) Black	OR (95% CI) Latinx	OR (95% CI) Other
Elementary	220	10.1	0.45 (0.32, 0.64)*	0.78 (0.40, 1.53)	1.27 (0.92, 1.77)	1.83 (0.80, 4.22)
Middle	474	21.7	0.63 (0.50, 0.80)*	0.84 (0.53, 1.32)	0.83 (0.64, 1.07)	0.35 (0.12, 0.98)*
High	1286	58.8	1.56 (1.30, 1.88)*	0.91 (0.63, 1.31)	0.79 (0.64, 0.98)*	1.32 (0.69, 2.53)
After high	165	7.5	1.27 (1.27, 1.27)*	2.31 (1.24, 4.27)*	2.37 (1.62, 3.49)*	0.94 (0.22, 3.99)
College[a]	41	1.9	1.85 (1.85, 1.85)*	1.92 (0.64, 5.76)	1.29 (0.61, 2.76)	1.45 (0.19, 11.1)
			Black Women	**Black Men**	**Latinx Women**	**Latinx Men**
Elementary	220	10.1	0.31 (0.07, 1.28)	0.96 (0.44, 2.06)	0.55 (0.28, 1.09)	1.36 (0.94, 1.96)
Middle	474	21.7	0.50 (0.23, 1.08)	0.91 (0.52, 1.59)	0.58 (0.37, 0.91)*	0.78 (0.58, 1.05)
High	1286	58.8	1.49 (0.83, 2.67)	0.81 (0.50, 1.29)	1.25 (0.88, 1.78)	0.79 (0.61, 1.01)
After high	165	7.5	2.23 (0.83, 5.95)	2.99 (1.37, 6.52)*	2.69 (1.46, 4.95)*	2.77 (1.72, 4.46)*
College[a]	41	1.9	3.97 (1.07, 14.7)*	0.92 (0.12, 7.21)	2.25 (0.77, 6.57)	1.13 (0.42, 3.08)
			Asian Women	**Asian Men**	**White Women**	
Elementary	220	10.1	0.15 (0.04, 0.60)*	1.10 (0.70, 1.73)	0.58 (0.36, 0.93)*	
Middle	474	21.7	0.66 (0.40, 1.09)	1.02 (0.73, 1.43)	0.60 (0.44, 0.83)*	
High	1286	58.8	1.34 (0.89, 2.02)	0.80 (0.60, 1.08)	1.54 (1.18, 2.02)*	
After high	165	7.5	3.37 (1.77, 6.43)*	1.95 (1.09, 3.50)*	1.51 (0.87, 2.63)	
College[a]	41	1.9	1.23 (0.27, 5.62)	1.19 (0.37, 3.76)	1.42 (0.54, 3.69)	

OR odds ratio, *CI* confidence interval

*Statistically significant at 0.05 level

[a] While enrolled in college

Table 4 Alter type and network size of students in high school by gender and race/ethnicity

Alter	N	%	Women OR (95% CI)	Black OR (95% CI)	Latinx OR (95% CI)	Other OR (95% CI)
Familial	1873	86	0.99 (0.76, 1.27)	1.06 (0.63, 1.80)	1.08 (0.80, 1.45)	0.74 (0.34, 1.63)
Parent/guardian	1744	80	0.98 (0.78, 1.23)	0.77 (0.50, 1.18)	0.94 (0.73, 1.21)	1.09 (0.50, 2.38)
Sibling	939	43	1.10 (0.92, 1.32)	1.39 (0.96, 1.99)	1.58 (1.29, 1.95)*	0.65 (0.33, 1.26)
School-based	1377	63	1.12 (0.93, 1.35)	1.21 (0.82, 1.78)	1.01 (0.81, 1.25)	1.14 (0.60, 2.18)
Teacher[b]	1031	47	1.16 (0.97, 1.39)	1.10 (0.77, 1.58)	0.85 (0.69, 1.05)	1.25 (0.68, 2.31)
Peer	755	35	0.84 (0.69, 1.01)	1.14 (0.78, 1.66)	1.33 (1.07, 1.65)*	0.88 (0.46, 1.71)
Counselor	490	22	0.91 (0.73, 1.13)	1.63 (1.10, 2.43)*	1.47 (1.16, 1.87)*	0.49 (0.19, 1.26)
Club[c]	411	19	0.99 (0.79, 1.25)	1.60 (1.05, 2.42)*	1.10 (0.84, 1.42)	0.71 (0.30, 1.70)
Other[a]	88	4	1.10 (0.70, 1.73)	0.50 (0.15, 1.63)	0.93 (0.56, 1.55)	1.04 (0.25, 4.43)
Network size						
Small[d]	773	37	0.85 (0.70, 1.03)	0.95 (0.64, 1.39)	0.89 (0.71, 1.11)	0.75 (0.38, 1.48)
Medium[e]	587	27	1.26 (1.03, 1.53)*	0.98 (0.66, 1.47)	0.91 (0.72, 1.16)	1.76 (0.94, 3.31)
Large[f]	796	36	0.96 (0.80, 1.16)	1.07 (0.74, 1.55)	1.20 (0.97, 1.49)	0.75 (0.39, 1.46)

OR odds ratio, *CI* confidence interval

*Statistically significant at 0.05 level

[a] Other non-family and non-school related alters, such as celebrity, radio broadcaster, or coworker

[b] Includes high school or middle school teacher

[c] Club/organization contact

[d] Network size is 1 alter

[e] Network size is 2 alters

[f] Network size is 3–7 alters

were significant race/ethnicity differences. Compared to white students, Black students were more likely to identify a school counselor or club/organization contact, and Latinx students were more likely to identify a sibling, peer, and school counselor as being influential.

Respondents could only indicate one person per alter type (e.g., parent/guardian, sibling/other family members, peer/classmate/friend, high school teacher, high school counselor, club/organization contact, or other [to be specified]). Network size (or the amount of different alter types) ranged from 1 to 7 ($M=2.5$, $SD=1.7$; Median $=2$) and was classified as small (1 alter type: 37%), medium (2 alter types: 27%), or large (3–7 alter types: 36%). This classification is consistent with Martin et al. (2011), in which students typically listed 2–3 names of individuals who were influential in their decision to enter or persist in engineering. In our study, responses clustered among 1, 2, or 3 alter types. There were few individuals with network alter sizes greater than three alter types. Thus, we combined group sizes of 3–7 alter types as one category. Women were more likely than men to have a medium-sized network of alter types. No racial/ethnic differences were found in network size of alter types (see Table 4).

How alters influenced women and URM students' decisions to pursue an engineering major

Our analyses of interview data found that parents/guardians and teachers influenced students' decisions to pursue engineering in high school by (1) encouraging their enthusiasm for mathematics and science or problem-solving (primarily parents/guardians), (2) explaining the benefits of becoming an engineer, and (3) providing advice about career and academic pathways (primarily teachers) (RQ3). Of interviewees who identified parents/guardians as alters, 15% reported that their parents/guardians were engineers, whereas 28% reported that their parents/guardians worked with engineers. However, we did not find any themes based on gender or race/ethnicity, likely due to the small sample sizes in the disaggregated data.

Encouraging enthusiasm for mathematics, science, and problem-solving

Interviewees noted that parents/guardians directly connected their aptitude for mathematics and science and their enthusiasm for problem-solving to the engineering profession. First, they encouraged students' pursuit of engineering by explaining what engineers do, providing engineering-related materials/toys, and supporting their participation in engineering-related activities. For example, a white woman at a PWI explained that she did not know what career to pursue but decided on engineering after consistently hearing from her parents and others in her social network: "Oh, you're good at science and math; you should do engineering." Another white woman at a PWI reported that her parents connected her enjoyment of mathematics and science to engineering:

> *My parents actually said that I've always liked math and science. I would take extra math classes earlier, so they suggested [engineering]. I looked more into it and we did those career testing things in high school, where you do the personality test and what career would fit you. Engineering was actually never on it. So I'm glad they had mentioned, 'you should check this out,' because it was something that I really had never thought of before that.*

In general, parents encouraged students to enter a major/career where they could "do what they love" and something "they're good at." Because they had an aptitude for mathematics and science and enjoyed problem-solving, engineering was viewed as a suitable career choice.

Second, parents/guardians supported students' enthusiasm for building and problem-solving by buying them engineering-related materials/toys, such as LEGO, and enrolling them in engineering-related programs and activities, such as engineering camps and fairs. Gaining access to these resources allowed students to engage in some of the traits associated with engineers (e.g., curiosity, creativity, and problem-solving at an early age), making engineering a viable and exciting career choice. A Latinx man at a PWI explained how the LEGO his parents purchased for him contributed to his decision to pursue engineering:

> *I think it was my parents who told me about what an engineer does.... I was always playing with LEGOs. That was really big in my childhood, and I had a friend who was like me...who liked to build different things...build forts and build cool things.... So that's when I first decided that doing something like that, building something, would stimulate my interest.*

A Black man at a PWI described how his mother piqued his interest in engineering by enrolling him in an engineering-related camp at an early age:

> *I guess it really started at a very early age for me. My mom put me in...[a] summer camp/afterschool activity program where you go every Saturday during the school year. ...They even have camps during the summer too. They spark your interest in engineering at an early age. Basically, I learned...about engineering, simple machines, stuff like that at an early age.... That's how I got interested, and then I*

started doing things like robotics.

Another student, a white woman at a PWI, credits her parents for encouraging her interest in engineering by taking her to an engineering fair:

I became interested when my parents took me to the…engineering fair…in 8th grade. I realized I really like math and science. So, what they were presenting was actually really interesting. So I decided to take an engineering class in high school and that's when I really was like, 'I really want to do this. I really like it.' I just continued with the engineering class in high school and did it in college.

A white woman at a PWI recalled how her father actively encouraged her interest in engineering when she was a child by purchasing a "circuit set" and taking her to engineering-related events:

I was a Girl Scout…they do a lot of activities with the Society of Women Engineers. So, I did activities like that. My dad would take me to those, which were pretty fun…most of it would be like chemical [engineering]. A lot of SWE is chemical because it's [mostly] women in chemical engineering or it's [at least a] pretty large [number] of women…. One reason why I'm interested in it [is] just because I did so much of those types of experiments when I was younger.

Overall, students had vivid recollections about playing with LEGO sets and participating in engineering-related activities when they were young. These experiences were overwhelmingly positive, and students connected them to their desire to pursue engineering as a major.

Although teachers, compared to parents/guardians, were less frequently identified as sources of information on the survey, interviewees described how they also connected students' aptitude for mathematics and science or enthusiasm for problem-solving to engineering. For example, a Black man at an HBCU described the critical role of his chemistry teacher in making him aware of engineering as a career.

Nobody from where I'm from…knows any engineering majors. I couldn't talk to anybody about what an engineer does. I didn't even know who to contact or anything like that. It was, 'Hey, I really like math and science.' They ask you, 'Well, what do you want to do?' I say…, 'I want to learn to build stuff or make things better, innovate stuff. I have these little ideas and stuff like that.' [My chemistry teacher] was, 'Hey, maybe you should look into engineering.' I had no idea what it was. Luckily, once I came closer to college, and I started learning a lot more about what they do and…the different majors and stuff like that, I knew this is the one for me.

A Black woman at a PWI reported that her biology teacher was instrumental in connecting her aptitude for mathematics to engineering:

The one who influenced me was my biology teacher. She asked me, 'If there's one subject that you would do for the rest of your life, what would it be?' I said, 'Math.' She goes, 'So why are you pursuing nurse practitioner?' I said, '…You have a good point.' So that's when she helped me see different areas and just explore…. She told me, 'Okay now do some research about engineering and what type of engineer you'd like to be.' So, I just did the research and I liked electrical the most.

Overall, we found that parents/guardians and teachers were critical sources of knowledge, encouragement, and resources that connected students' enthusiasm for mathematics, science, and problem-solving to engineering, thereby making it an attractive career for them to pursue. Having alters who were engineers, worked with engineers, or with STEM knowledge particularly helped students access information supportive of declaring an engineering major.

Benefits of becoming an engineer

Interviewees shared that parents/guardians and teachers stressed the career opportunities and financial benefits of becoming an engineer. Parents often explained that they did not want their children to work as hard as they had to in their own employment. This motivated some students to pursue engineering as a career, because it offered steady employment with high salaries. In other cases, parents who did not provide specific advice about engineering strongly supported students' pursuit of a college degree, regardless of the major, because they wanted them to have a good and stable career path. Those who described advice given from parents included a Latinx man at a PWI, he explained:

[My mother] instilled in me [that] if I'm going to college that I need to choose a good career that will provide enough money for…my family and…for me to be stable…. She knew that I liked math and science and…she told me about engineering and I just researched…it on the internet and…that's why I chose it.

A Black woman at a PWI described her desire for financial stability as one of her reasons for choosing engineering as a college major.

My parents want me to…, once I graduate, get a

> *job, be independent.... I don't want to [rely] on anyone to take care of me. Engineering was one of those things..., you'll definitely have a job in it.... You'll have options, but you will still...make money and support yourself.... That was very comforting to me.... Honestly, growing up, I didn't have to struggle. I had a very nice life and I was like, 'Okay, I want to provide that for myself and then eventually later [for] my children.'*

Another student, a Latinx man at a PWI, linked his interest in biomedical engineering to his desire for a financially secure future in a job with prestige:

> *Math and science [have] always interested me and I know that [biomedical engineers] make good salaries. The idea of being known as a biomedical engineer, I feel like people respect you because... it's a hard career.... I'm proud that I'm taking a hard career and, not like I couldn't do other stuff, but I like the challenge of being a biomedical engineer.*

In addition to parents, interviewees described how teachers represented engineering as "one of the best fields to go into" because it had good job security since society would always need engineers. For example, a Latinx man at a PWI stated that his biology teacher advised him:

> *Biomedical engineering was the future.... A lot of advances are going to take place in the next coming years, and it has to do a lot with the medical field.... The medical field's always reinventing itself.... This is where the future [is] going to be.*

This student further explained that his teacher's advice was so influential because she was "caring," "inspiring," and would "go above and beyond for her students." He continued, "That's why I really considered what she had to say, and I think she ultimately [was] a big part of why I chose to do what I did." Similarly, a Black man at a PWI also explained the advice his teacher provided him that influenced his decision to major in engineering: "I would say... [my teacher told me about] 'doing something that involves...your interest. Understand that engineering isn't something that's particularly easy but...it's still something that would pay off in the end.'"

In sum, interviewees considered a career in engineering to be a path to financial stability, career advancement, and social mobility. Students' beliefs were directly influenced by knowledge and resources obtained from their parents/guardians and teachers. While parents talked to students about financial stability, teachers tended to speak to students about the advantages of a career in engineering, such as job security. Students acted on these insights by learning more about the benefits of entering the engineering profession.

Advice about career and academic pathways

Recognizing their aptitude for mathematics, science skills, and/or enthusiasm for hands-on activities, teachers (primarily those of mathematics, science, and engineering) counseled students about how to pursue a career in engineering, encouraging them to attend college. A Black man at an HBCU discussed his experiences with his chemistry teacher as he considered going to college.

> *I was always trying to be the best in the class and what not, and they recognized that. So, they were really big on wanting me to do better. Especially from where I came, you know, not many kids go to college and stuff like that. So...they were a pretty big influence. They were always...pushing me to get work done, apply for scholarships, ... apply to schools, and make sure my GPA is up.*

Similarly, another Black man at an HBCU indicated that a teacher encouraged him to get good grades and attend college. He said: "I can't say I was the best engineering student in the class but [the teacher] always [saw] that I was actually working hard just to get my grade... and just to go to college. And he always told me to go to college...he'd come to me and tell me to go to college."

Teachers advised students about mathematics, science, and other classes that would prepare them academically to pursue an engineering degree and succeed in college. Teachers encouraged students interested in engineering to take more rigorous and advanced mathematics and science courses, such as physics, while in high school. Students who benefitted from such advice revealed how they embraced the challenge of advanced courses, thereby improving their academic preparation for engineering programs. For example, a Latinx woman at an HSI described how her physics teacher influenced her decision on which courses to take and took an interest in her education. She said, "I would talk to him.... I was trying to tell him that I was going to take the easy science class. He's like, 'No.... You take physics.' I took physics and I loved physics. So that kind of got me into the mindset of taking on challenges." A white woman at a PWI similarly noted that her engineering teacher pushed her to enroll for a second year in his class.

> *My engineering teacher in high school, he was [a] very no-nonsense guy.... He was very hard on everybody. So when he [said] that I was doing well and he actu-*

> *ally wanted me back for the second year, he was like, 'Are you taking second year? I really want you to come. I really want you to take it.' That's when I was like, 'I must be doing well at it…and since I liked it…this should be what I would do.' So I think really freshman year [of high school]…is when I was deciding more and more that I wanted to be [an engineer].*

Besides suggestions related to mathematics and science academic preparation, students shared how supportive teachers motivated them to do well in high school and supported their college preparation. A white woman at a PWI said: "My chemistry [teacher]…was like one of the best teachers I've ever had still to this day. He was so supportive and really wanted us all to succeed, and then also he was just a really good teacher and got the material across." A Latinx man at an HSI also had a supportive teacher:

> *She would just encourage me to find new information and just learn new stuff. She would present me with problems…. She would send me to teachers' rooms just to fix their computers, just to see if I could do it. So I was kind of like, well it was me and my friend, but we were kind of like protégés, so we would like just go around and fix everyone's computers in the school.*

A white woman at a PWI followed the example of her supportive teacher:

> *She was my A.P. [Advanced Placement] chem teacher, then my A.P. environmental science teacher, so I knew her for several years. And to me, she seemed very successful and happy with the things she had done, and she thought I'd be good at engineering. You know, when you get encouragement from someone you look up to, that really drives you forward.*

She explained this teacher's advice: "'Work hard, study hard.' She, of course, knew it was difficult, so…she tried to warn me what I was getting into. I don't think any high schooler is truly prepared for coming into college no matter how many warnings you get."

Interviewees revealed that teachers supported and encouraged them in a caring manner and as individuals as they traversed the high school experience and prepared for college. In addition, teachers were key sources of information about the steps necessary to pursue an engineering career. For example, they advised students to take more rigorous mathematics and science classes. They also provided opportunities for more general academic development and opportunities for students to become familiar with the academic culture of universities. Students reported that they acted on this advice as they progressed through high school and decided to major in engineering.

Discussion

This study, which focused on students' pre-college admission social capital, provides insights about the timing of engineering career decisions, the most influential alters in such decisions, and how this influence occurs among women and URM students. Our primary findings are that most women and URM students decide to pursue engineering as a college degree major while in high school. They identified parents/guardians and teachers as the alters in their social networks who played critical roles in their decision. These alters often had engineering or STEM career knowledge and/or took an interest in the students. They provided information about engineering as a potential career, as well as information about opportunities to access various engineering-related resources.

Timing of engineering career decision by women and URM students: high school or earlier

We found that URM students are more likely than white students to decide to pursue engineering after high school, which can add obstacles to their academic preparation. A student who decides they are interested in engineering in the later years of high school may have missed opportunities to take the requisite and rigorous mathematics and sciences courses that position them for success in an engineering program. According to Maltese and Tai (2011), students who indicate interest in STEM as early as the eighth grade are more likely to earn an undergraduate degree in STEM. Students who show an early interest in STEM have more time to seek information and guidance (e.g., information about courses to complete in preparation for college and career) and engage in STEM-related activities to narrow down the areas of specific interest they would like to pursue.

Consistent with other studies (Hardie, 2015; Lundy-Wagner et al., 2014; Perna, 2000; Puccia et al., 2021; Stanton-Salazar, 2011), we found that survey respondents more often reported that their parents were the most influential alters in their engineering major declaration. This finding was bolstered by interviewees who explained that parents sparked their initial interest in engineering, but noted that teachers provided important advice about what it takes to be an engineering major in college. This suggests that students with familial alters (particularly those who are not engineers themselves) but without school-based alters have less social capital with which to rely on to guide their college matriculation once they decide to pursue engineering as a major. Having less social capital may contribute to a lack of access to the needed academic preparation; knowledge about the college application process, including financial aid; insider knowledge about navigating college experiences successfully; and the inability to achieve their educational and career goals. This finding is important: students without access to school-based alters may have less access to resources these alters might have provided, which could also negatively affect their later STEM persistence.

Previous research suggests that having less social capital may be more detrimental for Black students (Skvoretz et al., 2020), particularly Black girls whose social networks are lower status or smaller and who rely on school alters for information about college (Hardie, 2015). This is particularly important given the academic climate faced by women and URM students generally (Campbell-Montalvo et al., 2022c; McGee, 2021).

Perna (2000) concluded that more research is needed to determine race/ethnicity group differences in college enrollment processes. We attempted to tackle one aspect of this by examining when students decided to pursue an engineering major. Our results suggest implications for interventions designed to foster interest in engineering. Most survey respondents indicated that they considered engineering as a major while in high school. In addition, we found that women and URM survey respondents made decisions about majoring in engineering between high school and college enrollment. This suggests that there might be opportunities to influence students' decisions earlier in their academic preparation, including in middle school. For example, it might be essential to examine the type of exposure to engineering, including engineering career options, that students receive while in middle school, with particular attention given to the type of exposure women and URM receive at the various stages of their academic preparation (i.e., middle school, high school, and pre-college experiences).

Most influential alters on the engineering major decision: parents and teachers

Consistent with previous research that revealed parents and teachers are initial sources of social capital (Coleman, 1988; De Graaf et al., 2000; Goldrick-Rab, 2006; Hardie, 2015; Martin et al., 2020; Means, 2019; Puccia et al., 2021), we found that parents/guardians and teachers are the most frequently identified alters in women and URM students' academic and career decision processes. They helped students see that engineering might be something they could do. Breaking it down by students who are first-generation and continuation-generation in college, Martin et al. (2020) noted that both groups had similar alters who influenced their decision to enter engineering: teachers, STEM program personnel, and family members, although the role of family members differed markedly for the two groups. Like Martin et al. (2020), we found in Puccia et al. (2021) that during the first year of their engineering major, students relied heavily on the expressive social capital of parents when considering whether to stay in engineering. In addition, and consistent with Martin et al. (2013), we found that parents encouraged their children to pursue engineering to maintain a financially stable life (Puccia et al., 2021).

Alter-type network size in high school matters for women

According to the network theory of social capital (Lin, 2000), a large *network size* is associated with access to more information, influence, and resources. We found that alter-type network size differs by gender, with women being more likely to have medium alter-type network sizes when compared to men who have large alter-type network sizes. This finding is consistent with that of Martin et al., (2014a, 2014b), in which women had small, kin-centric networks and men had larger networks with a mix of strong and weak ties. Although we know that gender differences exist by network size, we do not yet know the role that alter-type network size plays in decision-making or other STEM-related experiences of women compared to men. Men's more robust network sizes may provided them with added resources to succeed in engineering.

How the influence occurs

Students learn about engineering and how it relates to their mathematics, science, and problem-solving aptitude from their parents and teachers. Consistent with Martin et al. (2020), students in our study described how their parents took proactive steps to share information about how their aptitude for mathematics and science translated to the pursuit of engineering degrees. Parents also provided resources (e.g., engineering-related materials/toys, opportunities to participate in engineering-related activities, such as programs, camps, and fairs) that encouraged their interest in engineering. Access to such resources is essential in awakening and increasing students' interest in engineering. This finding echoes Coleman's (1988) contention that the transmission of social capital occurs when parents share beneficial knowledge and resources to contribute to their children's academic achievement and career success. We found that by merely reinforcing the connection between their mathematics and science aptitude and enthusiasm for problem-solving to engineering, parents/guardians were able to cultivate their children's interest in learning about engineering, which for some resulted in the decision to pursue an of engineering degree.

Our findings are similar to previous research but diverge from some prior studies. For instance, previous work (and the present study) found that STEM-based teachers, mentors with STEM knowledge, STEM-talented high school friends, guidance counselors, and family members familiar with STEM were influential in students' declaration of STEM majors (Puccia et al., 2021; Strutz & Ohland, 2012). In Strutz and Ohland (2012), STEM-based teachers were the most frequently identified alters—in our study, parents were the most frequently mentioned alter, followed by teachers. In this study, teachers, primarily those in STEM fields, are valuable in identifying students' potential for these fields and providing information about engineering. In addition, they are well-positioned to advise students about career pathways and academic courses needed to prepare for a major in engineering. Teachers also play a vital role in building students' confidence in learning, succeeding, and persevering in advanced mathematics and science classes.

Teacher intervention is particularly beneficial to students with social networks with primary alters that do not include engineers, people who work with engineers, or others with special knowledge of STEM education pathways (Hardie, 2015; Martin et al., 2020; Stanton-Salazar, 2011). For example, in our study, Black survey respondents depended on alters from school more than white and Asian students did. In addition, Black students' networks may include alters who were not sources of insider engineering knowledge, such as parents. At the same time likely because of robust social capital obtained from their social networks, white and Asian students relied less on school alters.

In sum, our finding suggests that it may take the influence of different types of alters to encourage students to declare engineering as a major. For most students, parents offer crucial experiences that encourage their children's early interest in engineering. This, coupled with school-based alter influence, helps the students learn how be successful in engineering. We expect that students with familial alters well-versed in how to successfully navigate the engineering pathway from secondary to post-secondary education (i.e., students whose parents are engineers) are advantaged and may not require the additional support of school-based alters. Similarly, students with only school-based alters who also provide expressive support and experiences may be able to mitigate some of the disadvantages that may come from not having certain types of support from familial alters. Therefore, students who lack the combination of these types of support, regardless of who is providing the support, may be impeded in their (expressive and instrumental) declaration of an engineering major.

Conclusion and implications

Parents, K-12 teachers, career counselors, and supportive peers are important allies in broadening participation for women and URM students. Teacher support and encouragement are primary reasons some students pursue engineering and believe they can succeed. Because many students first consider identifying engineering as a potential major while in high school, STEM interventions, especially outreach and recruitment efforts designed to encourage student engagement, interest, and retention in engineering, should be implemented as part of their secondary education, perhaps beginning in middle school. Indeed, our findings suggest that engaging parents and teachers in early STEM-related outreach efforts may be meaningful to ensure they have the relevant information needed to identify children with an interest in and aptitude for engineering and support them. In addition, because many women and URM students decide to major in engineering sometime between high school and college enrollment, universities should consider implementing interventions to engage students with undeclared majors and academic potential during this critical period. In addition, targeting Black and Latinx students in high school programs designed to increase interest in engineering may provide these students the opportunity to consider engineering as a college major earlier, before they leave high school.

Overall, our study suggests that multi-pronged approaches involving women and URM students and potentially influential alters (i.e., parents, teachers, and counselors) can enhance efforts to support interest in engineering. In addition, such an effort would represent a collective approach to provide guidance and support, potentially increasing the participation of women and URM students in engineering majors. Because women and URM scientists may have specific lived experience related to the bias and discrimination they faced in both the university and the workplace, their advice would be particularly valuable to these students as they navigate the discriminatory climate in STEM fields (Campbell-Montalvo et al., 2022c; McGee, 2021).

In addition to implications for practice, our work offers insight into new directions for research. For instance, this study suggests it might be essential to understand how alter-type network size and configuration changes as students transition from middle to high school, from high school to college, and from college to the workforce in ways that link it to engineering major declaration and degree persistence. In addition, more research is needed to examine the longitudinal effects of K-12 STEM programming, including those offered in middle and elementary school, to determine impact on broadening STEM participation. Finally, work like ours, considering binary gender and race/ethnicity, can be augmented by added intersectional lenses attending to the impact of additional identities, such as sexual and gender minority identities (e.g., LGBTQIA+; Campbell-Montalvo et al., 2022a, 2022d). These areas are ripe for investigation by researchers.

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Declarations

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None of the authors share any competing interests.

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References

Alon, S. (2009). The evolution of class inequality in higher education. *American Sociological and Education, 74*(5), 731–755.

Bernard, H. R. (2011). *Research methods in anthropology: Qualitative and quantitative approaches*. Rowman Altamira.

Berry, R. (2008). Access to upper-level mathematics: The stories of successful African American middle school boys. *Journal for Research in Mathematics Education, 39*(5), 464–488.

Borgatti, S. P., Jones, C., & Everett, M. G. (1998). Network measures of social capital. *Connections, 21*(2), 27–36.

Bourdieu, P. (1986). The forms of capital. In J. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). Greenwood Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Burt, B. A., & Johnson, J. T. (2018). Origins of early STEM interest for Black male graduate students in engineering: A community cultural wealth perspective. *School Science and Mathematics, 118*(6), 257–270.

Campbell-Montalvo, R., Cooke, H., Smith, C. A., Hughes Miller, M., Wao, H., Puccia, E., Mayberry, M., & Skvoretz, J. (2022a). "Now I'm not afraid": The influence of identity-focused STEM professional organizations on the persistence of sexual and gender minority undergraduates in STEM. *Frontiers in Education, 7*, 780331.

Campbell-Montalvo, R., Kersaint, G., Smith, C. A., Puccia, E., Sidorova, O., Cooke, H., Wao, H., Martin, J. P., Skvoretz, J., MacDonald, G., & Lee, R. (2022b). The influence of professional engineering organizations on women and underrepresented minority students' fit. *Frontiers in Education, 6*, 755471.

Campbell-Montalvo, R., Kersaint, G., Smith, C. A., Puccia, E., Skvoretz, J., Wao, H., Martin, J. P., MacDonald, G., & Lee, R. (2022c). How stereotypes and relationships influence women and underrepresented minority students' fit in engineering. *Journal of Research in Science Teaching, 59*(4), 656–692.

Campbell-Montalvo, R., Malaykhan, M., Smith, C. A., Hughes Miller, M., Puccia, E., Mayberry, M., Skvoretz, J., & Wao, H. (2022d). Sexual and gender minority undergraduates' relationships and strategies for managing fit in STEM. *PLoS ONE, 17*(3), e0263561.

Coleman, J. S. (1988). Social capital in the creation of human capital. *American Journal of Sociology, 94*, 94–120.

Cooper, K. M., Cala, J. M., & Brownell, S. E. (2021). Cultural capital in undergraduate research: An exploration of how biology students operationalize knowledge to access research experiences at a large, public research-intensive institution. *International Journal of STEM Education, 8*, 1–17.

Crosnoe, R., Riegle-Crumb, C., Field, S., Frank, K. A., & Muller, C. (2008). Peer group contexts of girls' and boys' academic experiences. *Child Development, 79*(1), 139–155.

De Graaf, N. D., De Graaf, P., & Kraaykamp, G. (2000). Parental cultural capital and educational attainment in the Netherlands: A refinement of the cultural capital perspective. *Sociology of Education, 73*(2), 92–111.

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a educational and occupational plans. *Social Problems, 62*(2), 241–245.

Dika, S. L., Green, C. S., Smith, A. C., Pando, M. A., Tempest, B. Q., & Foxx, K. A. (2020). Navigating support networks to reach the prize: Perceptions of success among engineering persisters of color. *Journal of Women and Minorities in Science and Engineering, 26*(6), 579–607.

Dufur, M. J., Parcel, T. L., Hoffmann, J. P., & Braudt, D. B. (2016). Who has the advantage? Race and sex differences in returns to social capital at home and at school. *Research in Social Stratification and Mobility, 45*, 27–40.

Fletcher, T. L., Jefferson, J. P., Boyd, B. N., & Cross, K. J. (2021). Missed opportunity for diversity in engineering: Black women and undergraduate engineering degree attainment. *Journal of College Student Retention: Research, Theory & Practice*. https://doi.org/10.1177/1521025120986918

Frehill, L. M. (2004). The gendered construction of the engineering profession in the United States, 1893–1920. *Men and Masculinities, 6*(4), 383–403.

Garrett, S. D., Martin, J. P., & Adams, S. G. (2021). Developing nontechnical professional skills in African American engineering majors through co-curricular activities. *IEEE Transactions on Education, 65*(3), 394–401.

Goldrick-Rab, S. (2006). Following their every move: An investigation of social-class differences in college pathways. *Sociology of Education, 79*(1), 61–79.

Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360–1380.

Hardie, J. H. (2015). The best laid plans: Social capital in the development of girls' educational and occupational plans. *Social Problems, 62*(2), 241–265.

Haveman, R., & Wolfe, B. (1995). The determinants of children's attainments: A review of methods and findings. *Journal of Economic Literature, 33*, 1829–1878.

Hoyt, K. B. (1984). Helping parents understand career education. *Journal of Career Education, 10*(4), 216–224.

Joshi, M., Aikens, M. L., & Dolan, E. L. (2019). Direct ties to a faculty mentor related to positive outcomes for undergraduate researchers. *BioScience, 69*(5), 389–397.

Leech, N. L., & Onwuegbuzie, A. J. (2009). A typology of mixed methods research designs. *Quality & Quantity, 43*(2), 265–275.

Lin, N. (1999). Building a network theory of social capital. *Connections, 22*(1), 28–51.

Lin, N. (2000). Inequality in social capital. *Contemporary Sociology, 29*(6), 785–795.

Lin, N. (2001). *Social capital*. Cambridge University Press.

Lundy-Wagner, V., Veenstra, C., Orr, M., Ramirez, N., Long, R., & Ohland, M. (2014). Gaining access or losing ground: Socioeconomically disadvantaged students in undergraduate engineering, 1994–2003. *Journal of Higher Education, 85*, 339–369.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95*, 877–907.

Martin, J. P., Gipson, K, & Miller, M. K. (2011, October). *Developing a survey instrument to characterize social capital resources impacting undergraduates'*

decision to enter and persist in engineering. Paper presented at the Frontiers in Education Conference (FIE), Rapid City, SD.
Martin, J. P., Miller, M. K., & Simmons, D. R. (2014a). Exploring the theoretical social capital "'deficit'" of first generation college students: Implications for engineering education. *International Journal of Engineering Education, 30*, 822–836.
Martin, J. P., Simmons, D. R., & Yu, S. L. (2013). The role of social capital in the experiences of Hispanic women engineering majors. *Journal of Engineering Education, 102*(2), 227–243.
Martin, J. P., Simmons, D. R., & Yu, S. L. (2014b). Family roles in engineering undergraduates' academic and career choices: Does parental educational attainment matter. *International Journal of Engineering Education, 30*(1), 136–149.
Martin, J. P., Stefl, S. K., Cain, L. W., & Pfirman, A. L. (2020). Understanding first-generation undergraduate engineering students' entry and persistence through social capital theory. *International Journal of STEM Education, 7*(1), 1–22.
Mau, W. J. (2016). Characteristics of U.S. students that pursued a STEM major and factors that predicted their persistence in degree completion. *Universal Journal of Educational Research, 4*(6), 1495–1500.
McGee, E. O. (2021). *Black, brown, bruised: How racialized STEM education stifles innovation*. Harvard Education Press.
Means, D. (2019). Crucial support, vital aspirations: The college and career aspirations of rural Black and Latinx middle school students in a community- and youth-based leadership program. *Journal of Research in Rural Education, 35*(1), 1–14.
Nardi, C. L. (2021). Antiracist opportunities in the Journal of Microbiology and Biology Education: Considerations for diversity, equity, and inclusion. *Journal of Microbiology & Biology Education, 22*(2), e00151-e221.
National Science Board. (2018). *Science & engineering indicators 2018*. National Science Board. Retrieved September 5, 2021, from https://www.nsf.gov/statistics/2018/nsb20181/assets/901/projected-growth-of-employment-in-s-e-occupations.pdf
Otto, L. B., & Call, V. R. A. (1985). Parental influence on young people's career development. *Journal of Career Development, 12*(1), 65–69.
Perna, L. W. (2000). Differences in the decision to attend college among African Americans, Hispanics, and Whites. *The Journal of Higher Education, 71*, 117–141.
Peterson, K. & Stroh, H. (2004). *Thinking about college: Results of the college awareness survey among achievers high schools in Washington*. Technical report #8. Washington School Research Center. Retrieved November 28, 2021, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.499.4495&rep=rep1&type=pdf
Puccia, E., Martin, J. P., Smith, C. A., Kersaint, G., Campbell-Montalvo, R., Wao, H., Lee, R., Skvoretz, J., & MacDonald, G. (2021). The influence of expressive and instrumental social capital from parents on women and underrepresented minority students' declaration and persistence in engineering majors. *International Journal of STEM Education, 8*(1), 1–15.
Rincón, B. E., & Rodriguez, S. (2021). Latinx students charting their own STEM pathways: How community cultural wealth informs their STEM identities. *Journal of Hispanic Higher Education, 20*(2), 149–163.
Roy, J. (2019). *Engineering by the numbers. Technical Report*. American Society for Engineering Education. Retrieved November 28, 2021, from https://ira.asee.org/wp-content/uploads/2019/07/2018-Engineering-by-Numbers-Engineering-Statistics-UPDATED-15-July-2019.pdf
Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field Methods, 15*, 85–109.
SAS Institute Inc. (2011). *Base SAS® 9.4 procedures guide*. SAS Institute Inc.
Sellers, V. B., Martin, J. P., & Seraphin, M. (2022). A narrative inquiry approach to community cultural wealth of Black men in engineering. *Journal of Women and Minorities in Science and Engineering, 28*(4), 69–95.
Shekhar, P., & Huang-Saad, A. (2021). Examining engineering students' participation in entrepreneurship education programs: Implications for practice. *International Journal of STEM Education, 8*, 1–15.
Skvoretz, J., Kersaint, G., Campbell-Montalvo, R., Ware, J. D., Smith, C. A., Puccia, E., Martin, J. P., Lee, R., MacDonald, G., & Wao, H. (2020). Pursuing an engineering major: Social capital of women and underrepresented minorities. *Studies in Higher Education, 45*(3), 592–607.
Slaton, A. E. (2010). *Race, rigor and selectivity in U.S. engineering: The history of an occupational color-line*. Harvard University Press.
Smith, C. A., Wao, H., Kersaint, G., Campbell-Montalvo, R., Gray-Ray, P., Puccia, E., Martin, J. P., Lee, R., Skvoretz, J., & MacDonald, G. (2021). Social capital from professional engineering organizations and the persistence of women and underrepresented minority undergraduates. *Frontiers in Sociology, 6*, 671856.
Smith, C. A., Wao, H., Martin, J. P., MacDonald, G. T., Lee, R. S., & Kersaint, G. (2015, June). *Designing a survey for engineering undergraduates using free listing—An anthropological structured technique.* In 2015 ASEE annual conference & exposition (pp. 26–476).
Snijders, T. A. B. (1999). Prologue to the measurement of social capital. *La Revue Tocqueville, 20*, 27–44.
Solanki, S., McPartlan, P., Xu, D., & Sato, B. K. (2019). Success with EASE: Who benefits from a STEM learning community? *PLoS ONE, 14*(3), e0213827.
Stanton-Salazar, R. D. (2011). A social capital framework for the study of institutional agents and their role in the empowerment of low-status students and youth. *Youth & Society, 43*(3), 1066–1109.
Strayhorn, T. L. (2010). The role of schools, families, and psychological variables on math achievement of Black high school students. *The High School Journal, 93*(4), 177–194.
Strutz, M. L. & Ohland, M. W. (2012). *Low-SES first-generation students' decision to pursue engineering*. Paper presented at the American Society for Engineering Education (ASEE AC 4515).
Swail, W. S., & Hosford, S. (2007). *Missouri students and the pathways to college*. Virginia Beach: Educational Policy Institute. http://www.educationalpolicy.org/pdf/Missouri_Pathways.pdf
Tabachnick, B. G., & Fidell, L. S. (1996). *Using multivariate statistics*. Harper Collins Publishers.
Thomas, D. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation, 27*, 237–246.
Trenor, J. M., Miller, M. K., & Gipson, K. G. (2011, June). *Utilization of a think-aloud protocol to cognitively validate a survey instrument identifying social capital resources of engineering undergraduates.* In 2011 ASEE annual conference & exposition (pp. 22–1656).
Trusty, J., & Watts, R. E. (1996). Parents' perceptions of career information resources. *The Career Development Quarterly, 44*, 242–249.
Van der Gaag, M., & Snijders, T. A. B. (2005). The resource generator: Social capital quantification with concrete items. *Social Networks, 27*, 1–27.
von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., Vandenbroucke, J. P., for the STROBE Initiative. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. *Annals of Internal Medicine, 147*(8), 573.
Wao, H. O., Lee, R. S., & Borman, K. M. (2010). Climate for retention to graduation: A mixed methods investigation of student perceptions of engineering departments and programs. *Journal of Women and Minorities in Science and Engineering, 16*(4), 293–317.
Weller, S. C., & Romney, A. K. (1988). *Systematic data collection* (Vol. 10). Sage.
Wright, B. L., Counsell, S. L., Goings, R. B., Freeman, H., & Peat, F. (2016). Creating access and opportunity: Preparing African-American male students for STEM trajectories PreK-12. *Journal for Multicultural Education, 10*(3), 384–404.

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