

Breaking it Down: Engineering Student STEM Confidence at the Intersection of Race/Ethnicity and Gender

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Abstract It is generally accepted that engineering requires a strong aptitude for mathematics and science; therefore, students' judgments regarding their competence in these areas as well as engineering likely influence their confidence in engineering. Little is known about how self-confidence in science, mathematics, and engineering courses (STEM confidence) varies at the intersection of race/ethnicity and gender. To fill this gap, this study examined the STEM confidence of multiple groups in undergraduate engineering programs. Results indicated that although some underrepresented groups may have lower STEM confidence overall, this finding no longer applies to all groups after controlling for personal, environmental, and behavioral factors. Specifically, African-American and Hispanic men report higher average STEM confidence than White men after controlling for these associated measures. In addition, White women continue to report lower average STEM confidence than White men after controlling for these measures, while other groups do not differ from White men. Further, many elements of student perception, including student views of professors, comparisons to peers, perceptions of the field as rewarding, and desirability of chosen major are positively associated with student STEM confidence. The changing patterns of significance for race/ethnicity and gender groups between the two models indicate that personal, environmental, and behavioral factors have different relationships with STEM confidence levels for different groups. This study contributes an understanding that gender differences in STEM confidence are not indifferent to racial and ethnic context. Social-cognitive theory provides a valuable framework for studying student academic confidence and would improve future self-confidence research.

Keywords Engineering students · Self-confidence · STEM confidence · Intersectionality · Race/ethnicity · Gender

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Currently, the U.S. has a shortage of skilled domestic workers; and jobs requiring knowledge and skills in the areas of science, technology, engineering, and mathematics (STEM) continue to grow (Jiang and Freeman 2011; Marra et al. 2012; May and Chubin 2003; Terrel 2007). In fact, the Bureau of Labor Statistics projects that STEM occupations will increase by 22 % between 2004 and 2014 (Terrel 2007). At the same time these types of jobs are increasing, studies indicate that the ethnic make-up of the workforce is rapidly changing (Cole and Espinoza 2008; May and Chubin 2003). In fact, underrepresented groups are estimated to increase from about a quarter of the workforce to almost half by 2050 (Cole and Espinoza 2008; May and Chubin 2003). While the need for STEM workers, particularly engineers, is on the rise, women and minorities also make up an increasing proportion of the labor pool; yet these groups continue to receive proportionally fewer engineering degrees than White men (Anderson et al. 2006; Brown et al. 2005; Cole and Espinoza 2008; French et al. 2005; Johnson 2007; Kissinger et al. 2009; Marra et al. 2012; Tate and Linn 2005). Research focused on attracting and retaining a diverse population of students is crucial to the continued development, innovation, growth, and maintenance of STEM-related industries, such as engineering (French et al. 2005; Jiang and Freeman 2011; May and Chubin 2003).

Multiple studies indicate that self-confidence and self-efficacy influence college students' academic achievement (Brown et al. 1989; Hackett et al. 1992; Lent et al. 1986; Pascarella et al. 1987; Santiago and Einarson 1998). Further, numerous studies demonstrate a strong link between student self-confidence and persistence in engineering undergraduate programs (Brainard and Carlin 1998; Burtner 2004; Goodman et al. 2002; Huang and Brainard 2001; Metz et al. 1999; Seymour and Hewitt 1997; Tate and Linn 2005). Research also indicates that strong correlations exist between self-efficacy and persistence (Bandura 1986; Brown et al. 1989; Cordero et al. 2010; Hackett et al. 1992; Lent et al. 1986; Marra et al. 2012; Multon et al. 1991; Pajares 1996; Santiago and Einarson 1998; Schunk 1989; Seymour and Hewitt 1997). A close relationship exists between self-confidence and self-efficacy, whereby self-efficacy informs self-confidence (Schunk 1991). While various studies assess students' self-confidence and/or self-efficacy beliefs and various outcomes associated with these beliefs, much still needs to be understood, especially regarding how self-confidence in science, mathematics, and engineering courses (STEM confidence) varies across the intersection of gender and race, in addition to how student experiences influence STEM confidence.

Because women and particular minority groups, including African Americans, Latinos, Native Americans, and Pacific Islanders, continue to be underrepresented in the engineering field, this study seeks to unpack how the undergraduate engineering experiences of these students influence their STEM confidence. Data from the Project to Assess Climate in Engineering (PACE) enables analysis of these underrepresented groups because of the large number of student respondents across multiple schools. The close relationship between self-confidence and self-efficacy points to social cognitive theory as an appropriate framework for examining: (1) how student STEM confidence levels vary by racial/ethnic group and gender, and (2) how STEM confidence is affected by personal, environmental, and behavioral factors. Personal factors include perceptions of the engineering field and major desirability; environmental factors include perceptions of professors, comparisons with other students, and interactions with other students; and behavioral factors include student performance as measured by grade point average (GPA). In order to better understand how these aspects of engineering undergraduate experiences influence and impact student STEM confidence, the article starts by unpacking social cognitive, self-efficacy, and self-concept theories, followed by a review of existing research focused on

self-confidence and self-efficacy in relation to: gender, race/ethnicity, personal factors, environmental factors, and behavioral factors. The article next describes the research methods used for the study, and culminates with the analysis results, discussion, and finally conclusions and implications.

Social Cognitive, Self-Efficacy and Self-Concept Theories

Social Cognitive Theory, as embodied in Bandura's (1977, 1978, 1986) triadic reciprocal determinism model, emphasizes how human functioning is shaped by (a) personal attributes, such as internal cognitive and affective states, (b) environmental events, and (c) behavior, all interacting to determine motivation and actions (Bandura 1986; Crothers et al. 2008; Lent et al. 1994). Because self-reflection helps move people from knowledge to action, one of the most influential aspects of human motivation and action in people's everyday lives is self-efficacy beliefs (Bandura 1986). Self-efficacy expectations vary in magnitude, generality, and strength, and research indicates that four primary sources of information influence self-efficacy expectations: performance accomplishments, vicarious experience, verbal persuasion, and physiological and affective states, or emotional arousal (Bandura 1977, 1978, 1986, 1997; Byars and Hackett 1998; Vogt 2005). Performance accomplishments refer to the experience of success in performing a task, and this has been shown to increase an individual's self-efficacy with regard to that particular task (Bandura 1977, 1982; Campbell and Hackett 1986; Hackett and Campbell 1987). Vicarious experience refers to seeing others succeed or fail (Bandura 1982; Gist 1987; Gist et al. 1989; Schunk 1981; Schunk 1982). Receiving messages regarding one's ability to perform a task successfully offers an example of verbal persuasion, and emotional arousal often takes the form of anxiety or tension which provides physiological information regarding one's competence (Busch 1995).

These sources of information can be categorized into the three broad areas of Bandura's triadic reciprocal determinism model (Bandura 1986). They take the form of personal attributes, such as beliefs and attitudes; behavior, or the responses one makes in given situations; and environmental events, such as the role that people in the environment play (Bandura 1986; Lent et al. 1994). For example, performance accomplishments would be considered behavior, whereas vicarious experiences and verbal persuasion would both fall under environmental events. Although the theory asserts that the aforementioned factors inform and influence self-efficacy, the social cognitive model also assumes ongoing, reciprocal interactions among factors (Byars and Hackett 1998).

Self-concept, an individual's collective self-perceptions, encompasses self-esteem, self-confidence, stability, and self-crystallization (Rosenberg and Kaplan 1982; Schunk 1991). Experiences with and interpretations of the environment, as well as external assessments and reinforcements, all work to form and influence an individual's self-concept (Shavelson and Bolus 1982). Further, an individual's perceptions of specific behaviors likely influence *subarea*, or domain-specific self-concepts, such as mathematic abilities. These subject-specific beliefs or self-concepts combine to form an individual's academic self-concept (Schunk 1991). Important to understand, however, is that within academics, a high self-concept does not necessarily mean that students are highly confident in all areas.

Self-efficacy, which is closely related to self-confidence, plays a role in academic self-concept (Schunk 1991). Longstanding definitional and measurement problems for both self-efficacy and self-confidence have muddied our understanding of the importance of each (Pajares 1996). Self-confidence can be defined as an individual's general belief that he

or she has the ability to produce results, accomplish goals, or perform tasks competently, and perceptions of self-confidence can vary by domain (Pajares 1996; Schunk 1991; Vogt 2008; Vogt et al. 2007). Student self-confidence is understood to be informed by self-esteem as well as general self-efficacy (Schunk 1991), and typically an individual bases these confidence beliefs on “memories of past experiences or upon people’s judgments of their capabilities to organize and execute courses of action to attain specific goals” (Vogt et al. 2007, p. 341).

General self-efficacy refers to a person’s beliefs in his/her capacity to complete certain tasks required to reach specific attainments within a particular domain (Marra et al. 2012). What distinguishes self-efficacy from self-confidence is the task and domain-specific nature of self-efficacy. An individual’s perception of self-efficacy may vary from one domain to another or from one task to another (Pajares 1996; Schunk 1991; Vogt 2008). An individual may exhibit high levels of self-efficacy within one domain, while at the same time exhibiting low levels of self-efficacy within another domain (Cassidy and Eachus 2002).

Because self-efficacy informs self-confidence, social cognitive theory provides a useful framework for understanding how various factors found to influence academic self-efficacy also may influence academic self-confidence, and in the case of this study, STEM confidence (Bandura 1989; Schunk 1989). The concept of STEM confidence represents students’ academic confidence within science, engineering, and math domains; it is domain-specific but not task-specific, so it measures confidence rather than efficacy. Given the relationship between self-confidence and self-efficacy, the literature review offers insights from both of these bodies of research.

Self-Confidence, Self-Efficacy, Gender, and Race/Ethnicity

Evidence indicates that in some cases gender and ethnicity differences may exist with regard to self-confidence, self-efficacy, and persistence (Besterfield-Sacre et al. 2001; Brainard and Carlin 1998; Goodman et al. 2002; Huang and Brainard 2001; Metz et al. 1999; Pajares and Kranzler 1995; Santiago and Einarson 1998; Seymour and Hewitt 1997; Tate and Linn 2005). For example, female students often cite self-confidence as a reason for their decision to abandon engineering (Brainard and Carlin 1998; Huang and Brainard 2001; Kissinger et al. 2009; Metz et al. 1999; Seymour and Hewitt 1997).

Both self-confidence and self-efficacy have been found to play important roles in the academic and career development of women in STEM (Betz and Hackett 1997; Cech et al. 2011; Hackett and Betz 1981; Hackett et al. 1992; Huang and Brainard 2001; Vogt 2003). They are particularly critical to the success of women pursuing non-traditional careers, such as engineering (Betz 2001; Cech et al. 2011; Lapan et al. 1989; Marra et al. 2005; Marra et al. 2009; Nauta et al. 1998). In male-dominated professions such as engineering, women tend to be less likely to develop professional role confidence because of the need to overcome cultural biases that men are naturally fit for and better at these professions (Cech et al. 2011). In addition, women often exhibit significantly lower levels of self-efficacy than men (Betz and Hackett 1981; Hackett and Betz 1981; Lindley 2006).

In male-dominated fields, women’s self-confidence and self-efficacy beliefs can be heavily influenced by social persuasion and vicarious experiences (Cech et al. 2011; Cordero et al. 2010; Huang and Brainard 2001; Hutchison et al. 2006; Zeldin and Pajares 2000). Male faculty and peers may perceive women pursuing these professions as unfit simply because they deviate from the conventional image of such professionals (Cech et al.

2011). Therefore, women often bear the burden of proving that, despite gendered expectations, they are skilled in male-typed professions (Cech et al. 2011). Frequently, women engineering students lack a sense of inclusion due to negative social cues from both students and faculty regarding their presence in engineering (Marra et al. 2009; Zeldin and Pajares 2000). These types of messages function as the kind of social persuasion that can influence one's self-confidence and self-efficacy beliefs (Huang and Brainard 2001; Zeldin and Pajares 2000).

Generally, women tend to underestimate their abilities in math and science, which can lower their confidence and self-efficacy perceptions (Betz 1997; Huang and Brainard 2001; Seymour and Hewitt 1997). Also, women studying engineering compare themselves unfavorably to male peers and judge themselves more harshly than the men judge themselves (Hawks and Spade 1998), which often leads them to express lower levels of confidence than men with regard to their abilities (Besterfield-Sacre et al. 2001; Cech et al. 2011). Further, women are more likely than men to attribute their failures to low ability and less likely to attribute their successes to high ability (Colbeck et al. 2006). As a result, women may develop different levels of career confidence in engineering than men, which may lead to different rates of persistence (Cech et al. 2011).

A lack of role models and little encouragement can result in women having lower self-confidence and self-efficacy than men (Betz and Hackett 1981; Cordero et al. 2010; Gainor 2006; Huang and Brainard 2001; Lent et al. 1996; Marra et al. 2012). Marra et al. (2009) contend that this phenomenon may be amplified for underrepresented minority women studying engineering due to their small numbers. All students of color, regardless of gender, tend to lack role models and frequently have their self-confidence undermined by the perception that white faculty and students regard them (especially black students) as possessing lower ability (Seymour and Hewitt 1997).

Underrepresented minority students in engineering also tend to lack peers, with whom they share a common ethnic and cultural background (Anderson et al. 2006; Bonous-Hammarth 2000; Brown et al. 2005; Johnson 2007; May and Chubin 2003; Seymour and Hewitt 1997). This can result in students' social identity being characterized by feelings of difference and lack of a sense of belonging (Cole and Espinoza 2008; Tate and Linn 2005); sense of belonging has been associated with students' confidence in their ability to complete an engineering degree (Huang and Brainard 2001; Marra et al. 2012). As is the case for women, these kinds of contextual factors could influence the STEM confidence of underrepresented minority students.

Understanding the application of academic confidence and self-efficacy across diverse groups is critical, given the variability that can exist (Lindley 2006). In their study of graduate students in science and engineering, Santiago and Einarson (1998) found that U.S. minority students reported significantly higher academic self-efficacy than Anglo students, despite lower GRE scores and indications that they felt less prepared by their undergraduate experiences. In another study, African American high school students, in particular, reported above average confidence in their math capability, yet they demonstrated lower mathematics self-efficacy than their peers (Pajares and Kranzler 1995). In other studies, no self-efficacy differences emerged between White and African American undergraduate students with regard to their perceptions of mathematics and investigative abilities (Betz and Gwilliam 2002; Gwilliam and Betz 2001; Lindley 2006). Similar to women, forms of social persuasion have been found to be a strong predictor of self-efficacy among Black undergraduate students; however, unlike with women, its impacts are similar to performance in strength (Gainor and Lent 1998).

One study found that Mexican American engineering students had lower levels of self-efficacy than European Americans with regard to requirements in their academic program (Hackett et al. 1992). Asian American undergraduate self-efficacy scores were found to be the lowest when compared to Black, Latino and White undergraduates, and significantly lower than the average score for Latino undergraduate students, who demonstrated the highest level of academic self-efficacy in this particular study (Greenstein 2000). Focus group data provided additional support for these findings, and suggested that low academic self-efficacy scores could reflect Asian American undergraduates feeling that they were not living up to model minority expectations (Greenstein 2000). While some literature touches on the confidence, self-efficacy and persistence of students of different racial and ethnic backgrounds, the data tends to be limited, or show mixed results, and does not delve deeply enough into these areas. Specifically, more research is needed to understand how controlling for student perceptions and other demographic variables can influence STEM confidence differently across groups. More research is also needed with regard to similarities and differences across race/ethnicity and gender, with particular attention on how race/ethnicity and gender intersect.

Self-Confidence, Self-Efficacy, and Personal Factors

Student perceptions of the engineering field function as personal factors, or beliefs and attitudes that can serve as one source of information for self-confidence and self-efficacy beliefs. Although very little research examines how student perceptions of the engineering field relate to student self-efficacy, student perceptions of the engineering field have been found to play a role in student confidence levels as they progress through engineering programs (Besterfield-Sacre et al. 2001; Burtner 2004; Cech et al. 2011; French et al. 2005; Seymour and Hewitt 1997).

Students who switch out of engineering majors express concerns about the kinds of work that will be available to them in engineering and the corresponding lifestyles of those careers (Seymour and Hewitt 1997). For example, some students believe that the careers they would be eligible for post-graduation would not be fulfilling, enjoyable, or have a worthwhile purpose, and they anticipate that they would have to develop and embrace a persona very different from their own personality (Seymour and Hewitt 1997). In addition to the mastery of core intellectual skills, professional success requires the cultivation of confidence in, identification with, and commitment to the profession, or professional role confidence (Cech et al. 2011). The more confident students are that they will find engineering work satisfying and aligned with their interests and values, the greater their intentions to remain in engineering beyond graduation (Cech et al. 2011). While one study found that Hispanic students had significantly higher ratings than White students regarding general impressions of engineering (Besterfield-Sacre et al. 2001), more research focused on the perceptions of underrepresented minority engineering students is required to inform and improve retention efforts. For example, how, if at all, do student perceptions of the engineering field influence underrepresented students' STEM confidence?

Student satisfaction with their chosen major and the extent to which they want to be in their major function as personal factors that can serve as a source of information for self-confidence and self-efficacy. Major satisfaction relates to identification with the major, technical interest, and perceptions of a positive climate (Ngambeki and Evangelou 2011). Ngambeki and Evangelou (2011) found a strong positive correlation between students' satisfaction with their major and their confidence in their ability to complete engineering

tasks. This study also found that students' self-efficacy negatively correlated to compliance motivation, indicating that being pushed into a particular major could have detrimental effects on self-efficacy (Ngambeki and Evangelou 2011).

Self-Confidence, Self-Efficacy, and Environmental Factors

Student perceptions of faculty function as environmental factors that inform academic confidence and self-efficacy beliefs. Student-faculty interactions play an important role in success for all students (Huang and Brainard 2001; Marra et al. 2012), and faculty efforts can have important influences on student self-perceptions (Colbeck et al. 2006). In one study, students who expected positive interactions with program faculty demonstrated higher levels of academic self-efficacy (Santiago and Einarson 1998). Faculty activities, such as sharing with students, showing an interest in them, and providing them with opportunities, all relate positively to self-efficacy (Marra et al. 2009; Vogt et al. 2007). Distant faculty relationships, on the other hand, have been associated with lower self-efficacy, confidence, and GPA (Huang and Brainard 2001; Marra et al. 2012; Vogt 2008). Through forms of social persuasion, faculty can enhance self-confidence and self-efficacy by letting students know that they are capable of particular skills (Marra et al. 2012; Ponton et al. 2001).

Comparing oneself to others acts as an example of a vicarious experience and functions as another source of information in one's environment. When students face a situation in which they have little or no experience, perceptions of outcomes that others have achieved when performing similar tasks may influence their self-efficacy beliefs (Hutchison et al. 2006). For example, students who observe peers performing a task will likely believe that they can also accomplish the same task simply because they have seen others do it (Colbeck et al. 2006; Schunk 1989). When students work in teams with other students, or seek help from them, they often shape their beliefs about their own abilities based on the outcomes of other students (Hutchison et al. 2006). Students' self-confidence and self-efficacy beliefs can also stem from verbal feedback they receive through interactions with peers (Colbeck et al. 2006; Hutchison et al. 2006; Schunk 1991). This verbal feedback functions as another form of social persuasion, which can be particularly salient for women's self-confidence and self-efficacy beliefs (Marra et al. 2012; Ponton et al. 2001).

Self-Confidence, Self-Efficacy, and Behavioral Factors

Performance accomplishments, also known as mastery experiences, function as behavioral factors informing self-confidence and self-efficacy beliefs. Bandura (1997) describes this source of information as the raw knowledge, skills, and experience required for successfully completing a specific task or goal. In academic environments, such as engineering programs, this translates into successful completion of particular courses, which is typically measured using GPA. Much of the research focused on performance and its relationship to self-confidence and self-efficacy looks at GPA as an outcome, indicating that self-confidence and self-efficacy beliefs impact GPA (Burtner 2004; French et al. 2005; Huang and Brainard 2001; Jiang and Freeman 2011; Meece and Courtney 1992; Multon et al. 1991; Pajares and Miller 1994; Reichert and Absher 1997; Seymour and Hewitt 1997). However, some studies examine how mastery experiences, such as demonstrated understanding and learning of course material, influence students' self-efficacy. For

example, in one study, students demonstrated higher self-efficacy when they felt they understood and learned course material (Hutchison et al. 2006). While the aforementioned studies offer a glimpse into the relationship between student GPAs, confidence, and self-efficacy in engineering programs, more research is needed to understand how GPA influences STEM confidence, particularly for specific underrepresented student groups.

Existing literature regarding student persistence in undergraduate engineering programs demonstrates a strong link between student confidence, self-efficacy, and academic persistence, yet it does not offer a great deal of insight into the experiences of underrepresented groups, especially ethnic minority men and women. This is particularly true with regard to what influences, both negatively and positively, students' STEM confidence. Due to small numbers of participants, those studies that do examine underrepresented student perceptions and beliefs offer limited results (Besterfield-Sacre et al. 2001; French et al. 2005; Marra et al. 2012; Vogt 2008). This study aims to address some of these literature gaps by examining social cognitive influences on engineering student STEM confidence, with a particular focus on women and underrepresented minorities.

Method

Sample

The data for this research came from a large-scale 2008 online survey of 10,366 undergraduate engineering students for the PACE study, funded by the Alfred P. Sloan Foundation. The 21 participating PACE schools were chosen from a list of 351 schools that granted bachelor's degrees in engineering. PACE schools were chosen from this list based on a variety of criteria. Enrollments of women and/or underrepresented minorities that were above or below the national average were used to create a distribution of schools that were doing well and doing poorly recruiting/graduating women and minorities. Invited schools also had to have enrollments of at least 1,000 engineering students. In addition, to reduce variation across sites, PACE schools were restricted to programs that either enroll students directly from high school into the College/School of Engineering and/or provide an engineering advisor during the first year to students who indicated an interest in engineering on their college application form. The majority of the 21 engineering schools involved with PACE are public schools (81 %), although some small and private schools are included. In addition, 14 % of the PACE schools are minority-serving institutions, 52 % are in the top 50 US News engineering rankings, and 57 % are classified by Carnegie as having very high research activity (RU/VH).

The list of all enrolled undergraduate engineering students age 18 or older was stratified by race/ethnicity and gender prior to sampling. Due to the low representation of women and particular minorities (African-Americans, Hispanics, Native Americans and Native Hawaiian/Pacific Islanders) in engineering, these groups were intentionally oversampled, to ensure they would be well-represented among survey respondents. The size of the population of women and underrepresented minority men was matched by a random sample of White, Asian, and International men.

Because women and underrepresented minorities were oversampled, they were expected to represent a higher proportion of respondents compared to the population of engineering undergraduate students in 2008. Within the PACE data, schools varied with respect to the percent of female respondents, ranging from 21 % female to 63 % female,

with a mean of 43 %. In 2008, 18 % of the engineering undergraduate student population was female (Commission on Professionals in Science and Technology 2009).

The population of engineering undergraduates in 2008 was 5 % African American, 1 % Native American, 7 % Hispanic, 70 % White, and 12 % Asian (Commission on Professionals in Science and Technology 2009). The percentage of each racial/ethnic group among respondents varied in the PACE schools. Table 1 shows the representativeness of PACE respondents in this analysis by race and ethnicity. The PACE analytic sample is relatively representative of the national population of engineering undergraduates except that Hispanic students are overrepresented and Asian students are underrepresented among respondents, which was somewhat expected given the oversample of underrepresented groups. International students were excluded from this analysis.

The proportion of the PACE respondents in various majors was compared with the population of undergraduate engineering students in 2008 in those majors (Gibbons 2008). The difference in percentages ranges from 4 % (biomedical engineering and environmental engineering) to less than 1 % (electrical/computer engineering) indicating that the PACE data is generally representative of the population with regard to the distribution of majors.

Students were recruited for the online survey via email. Three strategies were used to address and reduce the low response rate typically associated with web-based surveys. First, students received up to four total emails. Second, each email was sent from the local engineering dean or site liaison. Third, schools were given 100 dollars to use as an incentive which they could supplement with their own funds, and some did. Because the survey was anonymous, reminders were not sent to those students who filled out the incentive drawing page or who requested no more emails. The mean school response rate for the online survey was 29 %; the median was 28 % with a minimum and maximum of 7 and 53 %, respectively. The response rate is similar to other web-based surveys (Kaplowitz et al. 2004; Kwak and Radler 2002).

A total of 21 schools and 7,833 students were included in the analysis after listwise deletion. Listwise deletion was chosen as the best method among conventional methods for handling missing data to minimize the potential for biased estimates (Allison 2002). In total, these 21 schools enrolled about 18 percent of the full-time undergraduate engineering students within the United States in 2008 (ASEE 2008), meaning that although schools were not randomly sampled, it is possible to generalize these results with caution to similar types of schools.

Instrument

The PACE survey was designed to measure the engineering educational climate at universities in the United States. Questions on the survey drew from previously administered and tested surveys (Brainard et al. 1999; Laanan 2004). The PACE survey instrument was pre-tested on undergraduate engineering students at a non-PACE university, subsequently modified based on the feedback, and reviewed by a panel of science and engineering diversity experts. The survey was analyzed for internal consistency and found to have a mean α of 0.77 (Litzler and Young 2012).

Measures

The outcome of interest was student STEM confidence. Three survey items were averaged and then standardized ($M = 0$, $SD = 1$) to create the STEM confidence variable. The three items asked about confidence in a student's ability to succeed in college engineering

Table 1 Percentage of undergraduate engineering population and PACE respondents by race/ethnicity

PACE respondent data based on the analytical sample of 7,833 students

Race/ethnicity	Population	PACE respondents
African American	5	4
Native American	1	2
Hispanic	7	13
Asian	12	9
White	70	72

courses; college science courses; and college math courses (See Table 2 for details). These three items were combined into one variable since the literature indicates that engineering is closely tied to science and math skills in public perception (Sinkele and Mupinga 2011), and the public generally assumes that students must excel in science and math in order to succeed in engineering (Committee on Public Understanding of Engineering Messages, National Academy of Engineering 2008; Sinkele and Mupinga 2011). Further, it is common to combine multiple survey items to reduce the risk of using an unreliable or invalid measure (Silvey 1975). Students responded to each item on a five-point rating scale (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree). The Cronbach's Alpha estimate of reliability for this STEM confidence variable is 0.83 (Cronbach 1951), which was estimated using the multilevel package (Bliese 2012) in R (R Development Core Team 2011).

A set of predictor variables drawn from social cognitive theory were included in the models (See Table 3). Since this paper examines STEM confidence by race/ethnicity and gender, the main predictor of interest is called race/gender and includes 12 distinct groups. White men were the reference category, and each intersection of race/ethnicity and gender was included as a dichotomous variable; for example, Hispanic women compared with White men is one variable and Asian men compared with White men is another race/gender variable.

Six predictor variables represent the three areas hypothesized by social cognitive theory to have a relationship with confidence. Environmental factors include Good Professors, Student Community, and Comparison to Peers; Personal factors are Engineering Rewarding and Major Desirability; the Behavioral factor is cumulative GPA. Of the six measures, four were created from multiple survey items, while Comparison to Peers and GPA were single survey items. Comparison to Peers asked the students "Compared to other students in my classes, I think my academic abilities in my engineering classes are:" with five response choices (far below average; below average; average; above average; far above average). GPA measured the students' self-reported cumulative GPA. Both items were standardized ($M = 0$, $SD = 1$) for analysis.

The four aggregate predictor variables created from multiple survey items included Good Professors (10 items; $\alpha = 0.76$), Student Community (6 items; $\alpha = 0.78$), Engineering Rewarding (6 items; $\alpha = 0.71$), and Major Desirability (4 items; $\alpha = 0.60$). All survey items used to create these aggregates were measured with response categories based on a five-point Likert scale. Selected survey items (See Table 2) were averaged and then standardized ($M = 0$, $SD = 1$) to create the aggregates, and negatively worded items were reverse coded prior to averaging. Good Professors measures the extent to which students have positive interactions with their engineering professors. Student Community is a measure of the extent to which students feel like part of a community. Engineering Rewarding is a measure of one's perceptions of the engineering field, including a student's level of agreement about whether society values the work engineers do or whether an

Table 2 Aggregate variable survey items and Cronbach's alpha estimates of reliabilitySTEM confidence ($\alpha = 0.83$)

I am confident in my ability to succeed in my college engineering courses

I am confident in my ability to succeed in my college science courses

I am confident in my ability to succeed in my college math courses

Good professors ($\alpha = 0.76$)

Do your professors care whether or not you learn the course material?

Do your professors treat you with respect?

Do your professors think you have a lower ability than you actually have?

Do your professors take your suggestions and comments in class seriously?

Are you comfortable meeting with your professors for academic help?

Do your professors inspire you to study engineering?

Engineering rewarding ($\alpha = 0.71$)

Society values the work engineers do

Engineering is boring

Engineering is an occupation that is respected by other people

Engineers help to make the world a better place

I expect that engineering will be a rewarding career

My engineering coursework will prepare me for a job in engineering

Student community ($\alpha = 0.78$)

Are group projects valuable?

Do you feel like you are a part of an engineering community?

Do you like studying with other students in a group?

Are you involved with student study groups?

Do engineering students help each other succeed in class?

Do other students take your comments/suggestions in class seriously?

Major desirability ($\alpha = 0.60$)

I have no desire to declare a non-engineering major

I can think of other majors that I would like better than engineering

It is my choice to study engineering

I intend to complete my engineering degree

Response categories for each item were on a five-point Likert scale

engineering career will be rewarding. Major Desirability includes the desire to stay in engineering and the extent to which the study of engineering is the student's choice.

In order to create these four aggregate predictor variables, along with the aggregate outcome variable, a principal components analysis was conducted for each respective survey subsection based on the polychoric correlation matrix, which is appropriate for use with ordinal data (Garrido et al. 2011). Principal component structure was determined based on a combination of Velicer's MAP criteria (Garrido et al. 2011) and the very simple structure (VSS) criteria (Revelle and Rocklin 1979), and items were retained based on examination of item loadings and communalities. In addition to statistical means, items were considered for inclusion based on theoretical grounds and the content of each item.

The following demographic variables were included as control variables: class year (1st year, 2nd year, 3rd year, 4th year, 5th year, 6th year and beyond); whether the student was a first-generation American citizen or not; whether the student used need-based

Table 3 Descriptive statistics for the variables in the analysis

Variable	N	M	SD	Min	Max
STEM confidence ^a	7,833	4.29	0.72	1	5
Good professors ^a	7,833	3.87	0.57	1.33	5
Student community ^a	7,833	3.53	0.66	1	5
Comparison to peers ^a	7,833	3.57	0.72	1	5
Major desirability ^a	7,833	4.17	0.70	1	5
Engineering rewarding ^a	7,833	4.27	0.54	1	5
GPA ^a	7,833	3.23	0.50	1	4.3
Not first generation	6,341	0.81		0	1
Prior experience	1,168	0.15		0	1
Need-based scholarship	2,703	0.35		0	1
White male ^b	2,946	0.38		0	1
African-American male	167	0.02		0	1
Native American male	73	0.01		0	1
Hispanic male	741	0.09		0	1
Asian male	369	0.05		0	1
Hawaiian/Pacific Islander male	16	0.00		0	1
White female	2,653	0.34		0	1
African-American female	134	0.02		0	1
Native American female	44	0.01		0	1
Hispanic female	329	0.04		0	1
Asian female	343	0.04		0	1
Hawaiian/Pacific Islander female	18	0.00		0	1
First year ^b	1,616	0.21		0	1
Second year	1,760	0.22		0	1
Third year	1,912	0.24		0	1
Fourth year	1,783	0.23		0	1
Fifth year	624	0.08		0	1
Sixth year or more	138	0.02		0	1
Aerospace	452	0.06		0	1
Biomedical	564	0.07		0	1
Chemical	810	0.10		0	1
Civil	1,047	0.13		0	1
Computer science	285	0.04		0	1
Electrical and computer	1,197	0.15		0	1
Industrial	467	0.06		0	1
Mechanical	1,864	0.24		0	1
Other major	1,147	0.15		−1	−1

^a Standardized for analysis (M = 0, SD = 1)

^b Used as reference category

scholarships to pay for college; and the student's major field of study. For class year, 1st year students were the reference category. For the student's field of study, each field was compared to the mean STEM confidence value rather than a reference category. For this

reason, no model coefficient for the “other” field of study category could be estimated. The eight most popular fields of study were used as control variables, while the remaining students were grouped into the “other” field of study category.

This study focuses on STEM confidence as an outcome due to the critical role it can play in engineering undergraduate persistence (Bandura 1986; Brainard and Carlin 1998; Brown et al. 1989; Burtner 2004; Cordero et al. 2010; Goodman et al. 2002; Hackett et al. 1992; Huang and Brainard 2001; Lent et al. 1986; Marra et al. 2012; Metz et al. 1999; Multon et al. 1991; Pajares 1996; Santiago and Einarson 1998; Seymour and Hewitt 1997; Schunk 1989; Tate and Linn 2005), particularly for women (Betz 2001; Lapan et al. 1989; Marra et al. 2005; Marra et al. 2009; Nauta et al. 1998). Social cognitive theory posits the reciprocal nature of self-efficacy and various variables (Byars and Hackett 1998). Given that self-confidence is informed by self-efficacy, of interest to this study is how particular personal, environmental, and behavioral factors influence engineering student STEM confidence and how, if at all, those influences vary across different race/ethnicity and gender groups.

Data Analysis

Analysis involved two multilevel linear regression models run using the lme4 package (Bates et al. 2011) in R (R Development Core Team 2011). Both models use STEM confidence as the outcome. Multilevel modeling was used to account for the nesting of students within schools in the data (Gelman and Hill 2007; Snijders and Bosker 1999). This model is appropriate even with a school sample size of only 21 (Gelman and Hill 2007). Although the distribution of the outcome measure is negatively (left) skewed, visual examination of the residuals (predicted minus observed) revealed an approximately normal distribution of the residuals for each model, making the assumption of normality tenable. In addition, the normality assumption of the conditional distribution is less important when the sample is large, so linear regression is a good fit for this analysis (Agresti and Finlay 1997).

Two models were used to first isolate any race/gender direct effects on STEM confidence and then assess changes to these effects once additional social-cognitive and control variables were added. Model 1 included 11 binary predictors: each category of race/gender was compared with the reference category of White men. Model 2 included additional predictor variables in order to see how these variables were related to STEM confidence, as well as to understand how the relationship between confidence and each race/gender category changed after controlling for these additional predictors. All predictors were student-level variables; no school-level variables were included.

Results

Students in the sample are approximately evenly distributed between first, second, third, and fourth year students, with an additional 762 students (about 10 %) in their fifth or sixth year or beyond. Students report an average cumulative GPA of 3.23 with a minimum GPA of 1.00 and a maximum GPA of 4.3. Women represent 45 % of the sample. The analytic sample is 71 % White, 4 % African-American, 1 % Native American, 14 % Hispanic, 9 % Asian, and <1 % Hawaiian/Pacific Islander students. In addition, 81 % report not being first-generation Americans; 15 % report taking an engineering course prior to college; and

35 % report using need-based scholarships to pay for college (for more descriptive statistics see Table 3).

Table 4 contains the results for both models. Model 1 shows that all race/gender groups have either lower STEM confidence or confidence not significantly different from White men. Groups with lower STEM confidence than White men include all female race/gender groups, except Hawaiian/Pacific Islander and Native American women, and Asian and Hawaiian/Pacific Islander men. The STEM confidence outcome ranges from one to five, with five being the highest level of STEM confidence. Based on the estimates in this model, an Asian man would be expected, on average, to be about 0.3 standard deviations lower on STEM confidence than a White man. Since the standard deviation of STEM confidence is 0.72, this difference is equivalent to about 0.2 points lower on a rating scale of 1–5. Of the groups included in this model, the largest gap is between Hawaiian/Pacific Islander men and White men, with Hawaiian/Pacific Islander men at over half a standard deviation lower, on average.

Model 2 adds eleven additional covariates. Results indicate that Good Professors, Student Community, Comparison to Peers, Major Desirability, Engineering Rewarding, and GPA all have a significant, positive relationship with STEM confidence. Whether the student is a first-generation American, has prior engineering class experience, or uses need-based scholarships to pay for college are not significant predictors of STEM confidence. Students whose field of study is aerospace engineering or chemical engineering have significantly higher STEM confidence than the average; students whose field of study is computer science have significantly lower STEM confidence than average; while students in biomedical engineering, civil engineering, electrical and computer engineering, industrial engineering, or mechanical engineering did not have significantly different STEM confidence than the average confidence value in the sample.

In addition, race/gender categories show different significance patterns compared to Model 1. In Model 1, African-American and Hispanic males did not have significantly different STEM confidence compared with White males; however, in Model 2, after controlling for associated covariates, African-American and Hispanic males actually have significantly higher STEM confidence. In Model 2, White females continue to have lower STEM confidence than White males while Native American males and females and Hawaiian/Pacific Islander females remain not significantly different on confidence compared with White males. Asian females and males, African-American females, Hispanic females, and Hawaiian/Pacific Islander males all showed lower STEM confidence in Model 1, but in Model 2 none of these groups is significantly different from White males on confidence. Since the aggregate perception variables were standardized for analysis, as was the STEM confidence outcome, the slope coefficients for these standardized variables may be interpreted as standardized coefficients (Snijders and Bosker 1999). For example, the model indicates that experience with supportive, respectful professors is positively related to STEM confidence, with an increase of one standard deviation in students' ratings of satisfaction with their professors associated with a 0.15 standard deviation increase in STEM confidence, after controlling for the effects of all the covariates in the model. Students in their third year or later all show higher STEM confidence than first year students, as expected. Second year students do not show a significantly different level of confidence from those in their first year.

The multilevel model indicated very little evidence of school effects on STEM confidence. The intra-class correlation coefficient (ICC) was computed to be 0.02 from the unconditional model (a model with no predictors) with STEM confidence as the outcome. The ICC can be interpreted as the correlation among students within the same school

Table 4 Multilevel linear regression model results, STEM confidence outcome (PACE 2008 Survey Data)

Variable	Model 1			Model 2		
	b	SE	t	b	SE	t
Intercept	0.13***	0.03	4.10	−0.12**	0.04	−3.22
African-American male	−0.11	0.08	−1.41	0.19**	0.06	2.95
Native American male	−0.16	0.12	−1.36	0.08	0.09	0.86
Hispanic male	−0.03	0.04	−0.66	0.11**	0.04	3.16
Asian male	−0.30***	0.06	−5.40	−0.03	0.05	−0.71
Hawaiian/Pacific Islander male	−0.57*	0.25	−2.30	−0.16	0.20	−0.78
White female	−0.18***	0.03	−6.65	−0.07**	0.02	−3.25
African-American female	−0.34***	0.09	−3.89	0.09	0.07	1.26
Native American female	−0.28	0.15	−1.87	0.03	0.12	0.24
Hispanic female	−0.23***	0.06	−3.84	0.03	0.05	0.52
Asian female	−0.37***	0.06	−6.39	−0.08	0.05	−1.68
Hawaiian/Pacific Islander female	−0.10	0.23	−0.42	0.16	0.19	0.88
Good professors ^a				0.13***	0.01	12.26
Student community ^a				0.04***	0.01	3.66
Comparison to peers ^a				0.33***	0.01	30.32
Major desirability ^a				0.12***	0.01	11.34
Engineering rewarding ^a				0.13***	0.01	11.93
Not first generation				0.01	0.03	0.33
Prior experience				−0.01	0.03	−0.22
Need-based scholarship				−0.01	0.02	−0.28
Second year				0.04	0.03	1.28
Third year				0.16***	0.03	5.71
Fourth year				0.24***	0.03	8.57
Fifth year				0.35***	0.04	9.08
Sixth year or more				0.30***	0.07	4.11
Aerospace				0.08*	0.03	2.16
Biomedical				0.06	0.03	1.83
Chemical				0.07**	0.03	2.62
Civil				−0.04	0.02	−1.63
Computer science				−0.10*	0.04	−2.23
Electrical and computer				0.00	0.02	−0.09
Industrial				−0.04	0.03	−1.22
Mechanical				0.00	0.02	−0.12
GPA ^a				0.17***	0.01	15.49
BIC	22,217			19,080		
Percent variance explained	2 %			37 %		

All models based on a sample of 7,833 students and 21 schools. STEM confidence dependent variable standardized ($M = 0$, $SD = 1$). White male used as reference category for race/gender variables; freshmen used as reference category for class year variables

^a Standardized for analysis ($M = 0$, $SD = 1$)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

(Gelman and Hill 2007). This small value indicates that although students are nested within schools in the dataset, very little of the variance in STEM confidence outcomes is actually happening at the school level.

The Bayesian Information Criterion (BIC) was used to assess model fit (Raftery 1995). A lower BIC value indicates a better model and a difference of greater than 10 indicates very strong evidence for the more complex model (Raftery 1995). The BIC values for these two models are 22,217 and 19,080, respectively, with the value decreasing by more than 10 points. This indicates that the inclusion of the various demographic, student perception, and GPA variables in Model 2 provides a better fitting model as compared with Model 1.

Results indicate that Model 1 explains 2 % of the variance in individual outcomes and Model 2 explains 37 % of the variance in individual outcomes. These quantities were computed based on the level one explained proportion of variance formula (7.2) in Snijders and Bosker (1999).

Discussion

Research has shown that the academic confidence of engineering students is influenced by a variety of factors and related to particular outcomes (Besterfield-Sacre et al. 2001; Brainard and Carlin 1998; Burtner 2004; Goodman et al. 2002; Huang and Brainard 2001; Metz et al. 1999; Santiago and Einarson 1998; Seymour and Hewitt 1997; Tate and Linn 2005; Vogt et al. 2007).

The extant literature sheds some light on self-efficacy and self-confidence for engineering students in general, yet little is known about how academic confidence, and particularly, STEM confidence varies across the intersection of gender and race/ethnicity. Given the underrepresentation of women and minorities in engineering, and continued concerns about these students' retention, this research study is unique in that it examines how outcomes such as STEM confidence vary by specific student demographic group. It also unpacks how STEM confidence is affected by other factors, including environmental factors, such as experiences with professors and other students; personal factors, such as perceptions of engineering as a field and major desirability; and behavioral factors, such as student GPA.

After controlling for various perception and demographic variables in Model 2, we found that two groups, with respect to race and gender, are significantly more confident than White men; one group is still significantly less confident than White men; the remaining groups are not significantly different from White men on STEM confidence. When examining only the relationship between race/gender and STEM confidence (Model 1), the vast majority of the race/gender groups reported significantly lower STEM confidence than White men. But once the effects of student experiences, perceptions, GPA, and other demographic characteristics, such as year in school, are partialled from the model, interesting findings regarding race/gender emerge.

African American and Hispanic men report higher levels of STEM confidence than White men, after controlling for the other variables in the model. STEM confidence for African American and Hispanic men is conditional on variables in Model 2, since these groups did not have higher confidence than White men in Model 1. It is possible that these students may have entered their engineering programs with significantly higher levels of self-confidence and self-efficacy than students who did not choose engineering. That is, there may be a selection effect occurring here. Given the disproportionate academic, economic, and social disadvantages these students often face in high school, overcoming

these challenges and being selected to enroll in engineering could indicate that they already had high levels of STEM confidence.

African American men report higher STEM confidence than White men, but African American women report similar levels to White men, after accounting for student experiences and GPA. Similarly, Hispanic men report higher STEM confidence than White men, but Hispanic women are no different than White men on reported STEM confidence. White women, on the other hand, were lower on STEM confidence than White men, even after controlling for various demographic and perception variables. This indicates that there are key STEM confidence gender differences among particular race and ethnicity groups: African American, Hispanic, and White.

Gender differences in self-confidence, specifically in the STEM fields, are not a new finding in the education literature. Research indicates that females in engineering generally report lower self-confidence and self-efficacy than males (Brainard and Carlin 1998; Cech et al. 2011; Kissinger et al. 2009; Metz et al. 1999; Seymour and Hewitt 1997; Tate and Linn 2005). Our results indicate that the gender difference in STEM confidence is primarily located among White, African American, and Hispanic students. This study contributes an understanding that gender differences are not indifferent to racial and ethnic context. In fact, prior research that failed to make distinctions between different races and ethnicities yielded findings that may have been erroneously generalized to all women. Even after controlling for Comparison to Peers, White women still have lower STEM confidence than White men. That is, even if a White woman and a White man both feel they are doing relatively well compared to their peers, the woman generally has a lower belief in her ability to succeed in STEM domains (STEM confidence).

Some research indicates that the self-confidence and self-efficacy of students of color, particularly African American students, regardless of gender, may be undermined by the perception that White faculty and students regard them as of lower ability, and this may be exacerbated by the typical dearth of minority engineering faculty and students (Anderson et al. 2006; Bonous-Hammarth 2000; Brown et al. 2005; Johnson 2007; May and Chubin 2003; Seymour and Hewitt 1997). However, the findings here do not necessarily reflect this. To understand the findings from this study regarding African American STEM confidence, the broader literature on African American students in college is instructive. For example, Griffin (2006) suggests that African American high-achieving students have a high sense of self-efficacy and draw on mostly internal sources of motivation for their academic effort. Further, another study demonstrates that African American men in college report feeling the need to work harder to prove their skills and overcome negative impressions that others at the university might have of them (Davis et al. 2004). This suggests that, especially for African American men, the need to over-perform might realistically be associated with an increased sense of confidence.

A post hoc explanation for the Hispanic versus White men STEM confidence finding also comes from the literature about Hispanic/Latino men. Specifically, some research suggests that the second most common coping response of Latino men in college is to utilize self-reliance and examination of past experiences (Gloria et al. 2009). This differs from research suggesting that utilization of one's social network of trusted others is the primary method used by Latino men to get through difficult times (Vázquez and García-Vázquez 1995). The findings regarding self-reliance (Gloria et al. 2009) are supported by other literature, which indicates that in Latino culture, men are often expected to solve problems on their own and provide for their families (Aranda et al. 2001; Gloria and Segura-Herrera 2004). These cultural expectations of self-reliance could help explain why Hispanic men demonstrated higher levels of STEM confidence.

Several perception and demographic variables were related to academic STEM confidence. Consistent with research showing the importance of faculty relationships for student self-confidence and self-efficacy (Huang and Brainard 2001; Marra et al. 2012; Vogt 2008), this study found the environmental variables: Good Professors, Student Community, and Comparison to Peers, were all significantly positively related to STEM confidence. This was also the case for the personal variables, Engineering Rewarding and Major Desirability, and the behavioral variable, GPA. Additional demographic variables, including class year and field of study, were also significantly related to STEM confidence. The class year relationship was expected; as students progress in their engineering programs they should become more confident in their ability to succeed in their chosen field.

Conclusion

Distinct from other research, this study uses a social cognitive framework to examine how student confidence in science, mathematics, and engineering courses, or STEM confidence, varies across race/ethnicity and gender. The results demonstrate that although some underrepresented groups may have lower STEM confidence than White men overall, this finding no longer applies to all groups after controlling for personal, environmental, and behavioral factors. Specifically, African-American and Hispanic men report higher average STEM confidence than White men after controlling for student experiences, perceptions, demographics, and GPA. In addition, White women continue to report lower average STEM confidence than White men after controlling for these associated measures, while other groups do not differ from White men. The results also demonstrated that many elements of student perceptions, including those of professors, ability relative to peers, extent to which the field is rewarding, and the desirability of chosen major, are all positively associated with student STEM confidence. As illustrated by the changing patterns of significance in the two models, these perceptions and demographic variables have different relationships with confidence levels for different groups. This study shows the utility of the social cognitive framework for research related to domain-specific self-confidence.

Existing research demonstrates clear connections among self-confidence, self-efficacy, and persistence (Bandura 1986; Brainard and Carlin 1998; Brown et al. 1989; Burtner 2004; Cordero et al. 2010; Goodman et al. 2002; Hackett et al. 1992; Huang and Brainard 2001; Lent et al. 1986; Marra et al. 2012; Metz et al. 1999; Multon et al. 1991; Pajares 1996; Santiago and Einarson 1998; Schunk 1989; Seymour and Hewitt 1997; Tate and Linn 2005; Vogt et al. 2007); however, the literature on URM self-confidence and self-efficacy offers mixed findings regarding differences between URM groups and majority groups (Betz and Gwilliam 2002; Betz 2001; Gainor and Lent 1998; Pajares and Kranzler 1995; Santiago and Einarson, 1998). Understanding differences in student STEM confidence for different racial/ethnic and gender groups within engineering can help educators and policy-makers improve retention among underrepresented groups in the field. For example, African American and Hispanic men report higher levels of STEM confidence than White men, and African American and Hispanic women report similar levels of STEM confidence as White men, after accounting for student experiences, perceptions and performance. This signifies that personal, environmental, and behavioral factors play a critical role in students' confidence that they will be successful in STEM courses; educators can exert influence over some of these factors. In contrast, White women maintain lower average STEM confidence than White men, even after controlling for all variables in the models. This indicates that unmeasured factors may be the reason White women

continue to have lower average confidence in their ability to be successful in science, mathematics and engineering courses. These results highlight critical areas for administrators, professors, and researchers to explore further in order to develop strategies that can improve engineering climates, help increase the STEM confidence of all students, and contribute to student persistence in engineering.

This data came from 21 selected schools within the United States. Although these schools represent a large proportion of enrollments in undergraduate engineering programs, the sample of schools was not random and results should be generalized with caution. In addition, although students were randomly sampled, certain groups were oversampled in order to have sufficient numbers of women and minorities for analysis. As a result, the proportions in the sample are not fully representative of the engineering undergraduate population. In addition, the sample of Native American and Hawaiian/Pacific Islander students in this study was not large enough to have the statistical power to make many claims about these groups. Future research, perhaps qualitative in nature, that focuses on these groups could provide evidence to deepen our understanding of their experiences in relation to STEM confidence and potentially improve the retention of these students.

This analysis was limited by the survey items available. Ideally, additional associated measures would be included, such as variables related to physiological and affective states, also known as emotional arousal. This could help us understand if and how stereotype threat might come into play with regard to STEM confidence, specifically for women and underrepresented minority students (Marra et al. 2009). Given that vicarious experiences have been found to be particularly influential on women's self-efficacy (Cordero et al. 2010; Hutchison et al. 2006; Zeldin and Pajares 2000), additional variables measuring this concept could help illuminate how these experiences impact women's confidence. Further, outcome measures of STEM confidence specific to each domain (i.e. math, science, and engineering) could have been used if multiple survey items were available for each domain, which would allow for more nuanced outcomes without suffering the reliability and validity limitations of using single-item measures (Silvey 1975). This study was not able to measure any persistence outcomes directly and instead relied on claims from the literature regarding links between confidence, self-efficacy, and persistence (Brainard and Carlin 1998; Burtner 2004; Goodman et al. 2002; Huang and Brainard 2001; Metz et al. 1999; Schunk 1991; Seymour and Hewitt 1997; Tate and Linn 2005).

Although this study extends the collective understanding of academic confidence, specifically STEM confidence, for various underrepresented groups, there are still unanswered questions. In the future, research should investigate why some of these relationships exist and attempt to explain causation. For example, interview data could be used to further investigate why certain groups might feel more or less confident with respect to their success in STEM courses. In addition, the relationships between student experience variables and STEM confidence should be further investigated for each group to gain a more nuanced view into how these relationships vary by group.

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