GENDER AND RACIAL DISPARITIES IN STUDENTS' SELF-CONFIDENCE ON TEAM-BASED ENGINEERING DESIGN PROJECTS

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Introduction

Students' self-perceptions, their mental models of success in engineering, and how they formulate their identities are critical to their persistence and success in engineering [1,2]. Students from groups who are traditionally underrepresented in engineering, specifically, women, underrepresented minorities (URM, def. non-White and non-Asian), and first-generation college students, are frequently the recipients of subtle messages of non-belonging, thus creating an inhospitable environment which inhibits the formation of professional identity [3]. Disparities may be particularly acute in team-based learning environments, such as engineering design projects, which are widely used in engineering courses [4]. While the intention of team-based design projects is to provide all students with a range of technical and non-technical mastery experiences [4,5], students enter into these experiences with differences – whether real or perceived – in relevant technical skills that undermine individuals' participation and persistence on team-based work. Prior research indicates male engineering students are more confident than females in their math and science abilities, as well as their abilities to solve open-ended problems [6-9]. Lower confidence in women often translates into lower likelihood that they will take an active role in technical tasks and instead relegate themselves to administrative or people-oriented tasks on design projects [10,11].

The goal of this study was to establish a baseline of self-confidence in engineering among majority, women, and underrepresented students, considering gender, race, and first-generation status. This study is part of a larger research agenda aimed at improving recruitment and retention at our institution of historically marginalized groups in engineering. We undertook this preliminary study so as to discern the extent to which the student population at our institution align with previous studies on student self-efficacy in engineering [6, 9-11]. This paper reports these baseline findings; it will serve as the basis on which we compare educational interventions and students supports for improving success and retention in engineering programs at our institution. We anticipate our findings will inform the engineering education community and provide evidence for strategies that improve diversity in engineering fields.

This study builds on the existing literature in two ways. First, prior work has focused on gendered differences in self-confidence [6,9-11], and this is the first study to extend the investigation to URM and first-generation populations. Self-efficacy combined with selected academic self-concept constructs comprise our delineation of self-confidence. This delineation coheres with previous research, which indicates academic self-confidence as a more generalized belief in oneself, with the interplay of self-concept and self-efficacy acting in domain-specific contexts [12,13]. In our study, we focus on self-concept of knowledge and skills related to engineering – in particular, we focus on students' math and science self-confidence, communication/interpersonal self-confidence, and open-ended problem-solving self-confidence as proxies of student self-concept. Self-concept constructs comprise three of five parts of students' overall self-confidence. The other two constructs include tinkering self-efficacy and engineering application self-efficacy. We acknowledge there are additional factors that influence students' overall self-concept; however, we have chosen these because they have been indicated as the most salient mediators of engineering self-concept based on previous research [6,14]. Second, this study utilizes a validated instrument that captures self-confidence across the entire skillset necessary for engineering design, whereas prior work [6,10,15] used instruments that were more narrowly focused on one or a few factors such as problem solving and/or tinkering self-efficacy. The results of this study will help engineering design educators tailor their instructional approach to specific student subpopulations, and the methodology presented in this work can be used as a framework for studying effective intra- and co-curricular interventions to ensure equitable learning outcomes in engineering design courses. Consistent with previously published research studies, we formulated the following hypotheses about students at our institution:

(1) Males would report significantly higher self-efficacy for tinkering and engineering applications than females.
(2) Students from majority groups (i.e., White or Asian) would report significantly higher self-efficacy for tinkering and engineering applications and higher self-confidence in math and science than those from underrepresented minority groups (non-White, non-Asian).

Methods

We developed and validated a composite survey that merged items from the APPLES instrument [6,10,14], which focuses on self-confidence in interpersonal skills, problem solving, and math and science theory, with an established but unvalidated instrument [15] that measures self-efficacy in "tinkering" – that is, prototyping and modeling – and the application of technical engineering skills to solving real-world problems. Our combined, validated instrument was administered as part of class activities during the first week of an introductory engineering course for all first-semester freshmen at a single university. Students completed the survey prior to engaging in any design activity with their assigned peer groups. Demographic information, including race, gender, and first generation and international student status, was collected as part of the survey, with these questions positioned at the end of the instrument to minimize stereotype threat [16,17].

Confirmatory factor analysis and internal consistency tests were performed with the instrument and yielded moderate fit (RMSEA=.058, SRMR= .071, CFI=.857, TLI=.841 and Cronbach's alpha estimates were greater than .70 for each of five factors (α=.77-.84): tinkering self-efficacy, engineering application self-efficacy, self-confidence in open-ended problem-solving, interpersonal/communication self-confidence, and math and science self-confidence. Independent samples t-tests were used to discern differences for females, underrepresented minority students (URM, def. non-White and non-Asian students), international students, and first-generation college students. A two-way ANOVA was conducted to detect differences for underrepresented females as a special group of interest. A Bonferroni adjustment was used to correct for multiple statistical tests conducted on the same data, which reduced the alpha threshold to α=.002.

Results

Survey response was robust (N=632, 85.4% of total population) and reflected class demographics. Females demonstrated lower mean self-efficacy scores in engineering application and tinkering (Table 1a). Both URMs and first-generation students showed slightly lower mean self-confidence in math and science skills (Tables 1b and 1c). Intersectionality of race and gender was examined; and URM females showed marginally lower mean self-efficacy than URM males in tinkering tasks, when controlling for both demographic factors (female URM=3.3, male URM=3.6, $\alpha_{interaction}$=.007). International students demonstrated significantly less professional/interpersonal and problem solving self-confidence (Table 1d).

Discussion

Taken together, these results suggest that there are pronounced disparities by gender and more moderate disparities by race, first-generation, and international student status present *a priori* students' engagement in team-based engineering design projects. Consistent with prior research [6-11], women students were less confident in their tinkering and engineering application skills; and we found that this gap in tinkering was exacerbated by race for women of color in engineering. First generation and URM students were marginally less confident in math and science abilities, but there were minimal to no disparities in other design-related learning outcomes.

These findings mirror that of Besterfeld-Sacre et al. [7] who found that female students consistently began their engineering programs of study with lower confidence in their background knowledge and in their abilities to succeed in engineering. Moreover, multi-institutional, longitudinal data from previous research showed an overall increase in females' self-efficacy in engineering and ability to cope with difficult situations as they progress through their academic programs even though their feelings of inclusion tend to decrease over time [18,19]. Overall, personal characteristics such as self-confidence and self-efficacy students' commitment to their major and commitment to degree completion [20]. Thus, attention to these personal factors, and the design of educational interventions aimed at reducing attrition are key to increasing the racial, ethnic, and gender diversity of in the field of engineering.

Our results suggest targeted areas for intervention, particularly "tinkering" self-efficacy for women, that may be addressed through coaching and instructional interventions designed to address the differences among these groups. The development and evaluation of such interventions to "level the playing field" will be the focus of future work by our group and will build on the baseline findings from this study.

Table 1. Self-confidence and self-efficacy factors (normalized 0-4 scale) by demographic group for each principal factor in the survey instrument. **$p \leq 0.002$ for significant difference, *$p \leq .01$ for marginally significant difference.

(a) GENDER	Males (n=438)		Females (n=194)		
	Mean	St. Dev	Mean	St. Dev	t
Math and science self-confidence	2.842	0.641	2.798	0.690	0.77
Engineering application self-efficacy	2.735	0.664	2.543	0.722	3.25**
Professional and interpersonal self-confidence	3.046	0.620	3.141	0.589	1.79
Tinkering self-efficacy	2.552	0.761	2.239	0.832	4.63**
Problem-solving self-confidence	3.011	0.582	2.941	0.626	1.37

(b) URM STATUS	Non-URM (n=586)		URMs (n=46)		
	Mean	St. Dev	Mean	St. Dev	t
Math and science self-confidence	2.847	0.653	2.583	0.649	2.65**
Engineering application self-efficacy	2.677	0.702	2.661	0.473	0.22
Professional and interpersonal self-confidence	3.077	0.617	3.062	0.555	0.16
Tinkering self-efficacy	2.459	0.806	2.417	0.664	0.35
Problem-solving self-confidence	2.987	0.601	3.018	0.527	0.34

(c) FIRST GEN STATUS	Non-First Gen (n=588)		First Gen (n=44)		
	Mean	St. Dev	Mean	St. Dev	t
Math and science self-confidence	2.852	0.643	2.514	0.745	3.32**
Engineering application self-efficacy	2.689	0.685	2.500	0.711	1.76
Professional and interpersonal self-confidence	3.092	0.610	2.856	0.605	2.48*
Tinkering self-efficacy	2.461	0.793	2.383	0.846	0.63
Problem-solving self-confidence	2.994	0.597	2.936	0.583	0.62

(d) INTERNATIONAL STATUS	Domestic (n=594)		International (n=38)		
	Mean	St. Dev	Mean	St. Dev	t
Math and science self-confidence	2.833	0.649	2.747	0.764	0.78
Engineering application self-efficacy	2.683	0.679	2.574	0.816	0.95
Professional and interpersonal self-confidence	3.106	0.596	2.601	0.667	5.03**
Tinkering self-efficacy	2.476	0.791	2.145	0.824	2.49*
Problem-solving self-confidence	3.011	0.587	2.658	0.646	3.57**

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