Discussion of Underrepresentation and Bias within Engineering Curricula is Not Sufficient to Improve Women's Career Interest in Biomedical Engineering

Spencer Szczesny[1], Alyssa Salazar[1], Cameron Casasanta[1]
[1]Pennsylvania State University, University Park, PA
ses297@psu.edu

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INTRODUCTION: While gender parity exists at the undergraduate level in biomedical engineering (BME) [1], there is still a significant decline in female representation at the graduate and faculty levels [2]. Research shows that gendered social expectations, bias/discrimination, and a hostile learning environment can make women feel like they don't belong and turn them away from engineering [3,4]. The **objective of this study** was to determine whether improving the climate for women in biomedical engineering would increase their interest in pursuing further education or a career in engineering after graduation. We hypothesized that open discussion of gender inequalities and of implicit bias will enhance a sense of belonging for female students within BME and increase the likelihood of their retention in engineering.

METHODS: All procedures were approved in advance by the Institutional Review Board at Penn State University. At the beginning and end of the semester, an anonymous survey was administered to 4th-year BME undergraduate students in fall 2021 and first- and second-year BME graduate students (MS and PhD) in spring 2022. During each semester, we engaged the students on the topic of gender and racial inequality in engineering through (1) the presentation of data regarding female and racial underrepresentation as well as their causes, (2) multimedia content providing emotive context, and (3) assignments involving self-reflection, assessment of implicit bias, and cataloging of observed discrimination. All surveys were identical and included validated scales of intrinsic engineering interest, identification with engineering, extrinsic engineering utility, engineering self-efficacy, intention to pursue a career in engineering, student perception of compatibility between their gender or race with engineering, sense of belonging in the department, and lack of experience of discrimination [5,6]. Students that took both the pre- and post-surveys were identified using an anonymous identification number to enable individual (rather than aggregate) differences in perceptions over time. Baseline differences in each scale between men and women were assessed using Mann-Whitney tests. Additionally, Mann-Whitney tests were used to assess changes in each scale between the pre- and post-surveys. We also used Mann-Whitney tests to determine if the paired pre/post differences in survey responses for individuals who took both surveys was different from zero. All data are presented using box plots with the whiskers indicating the max/min data. Statistical significance was determined by $p < 0.05$ and a statistical trend by $p < 0.10$.

RESULTS: A total of 63/72 (pre/post) undergraduate students (58% women) and 41/55 (pre-post) graduate students (35% women) completed the surveys. We found that the scores for female undergraduate students were the same as men in nearly every category at the beginning of the semester (Fig. 1A). The only difference was that women perceived their gender as less compatible with engineering. The same was true for the graduate students (data not shown). At the undergraduate level, there was no change in any of the scales over time in the aggregate data (Fig. 1B). Paired comparisons for students that took both surveys showed only a trending decrease in engineering interest for women (Fig. 1C). At the graduate level, there was a significant increase in interest in engineering over time (Fig. 1D); however, there was also a trending decrease in perceived compatibility of gender with engineering and a significant decrease in the lack of discrimination over the semester. Disaggregating the data by gender found that both men and women experienced the same increase in discrimination over time (data not shown). Similar findings were observed in the pairwise comparison for female graduate students (Fig. 1E).

DISCUSSION: Consistent with prior literature [4], female undergraduate and graduate students perceived their gender to be less compatible with engineering than men at the start of the semester. Contrary to our hypothesis, we found that there was no difference between men and women at baseline for sense of belonging or intention to pursue an engineering career and there was no change in these metrics over the semester. Surprisingly, we found that female undergraduate students experienced a slight decrease in engineering interest during the semester. Similarly, there was an increase in the experience of discrimination for female (and male) graduate students. Together, these data suggest that our educational modules on underrepresentation and bias did not improve women's sense of belonging or increase their intention to remain in engineering. The lack of a positive effect for our educational modules on women's interest in engineering careers and sense of belonging was likely because these metrics were already relatively high at baseline. Still, the one metric that was lower at baseline for women (gender compatibility) did not show improvement either. This is likely because a single education module is not sufficient to counter a lifetime of experiences indicating that their gender is incompatible with engineering [8]. It is worth noting that the increase in discrimination observed by graduate students during the semester may not be negative. A goal of the educational modules was to make students more aware of bias, and one of the assignments explicitly asked students to record observations of discrimination throughout the semester in a journal. Therefore, the increased observation of discrimination reported by the students may be due to an increase in awareness of the existing levels of bias around them.

There are a few limitations to this study that are worth noting. First, there were no control student groups that took the pre/post surveys but did not receive the educational modules. This makes it difficult to interpret whether differences in the pre/post survey results were due to the education modules or some other experiences that occurred during the semester. Finally, there were small sample sizes for the paired analyses, which decreased the power of the longitudinal comparisons. Despite these limitations, these data suggest that an educational module on underrepresentation and bias is not sufficient on its own to improve a sense of belonging or retention in engineering for women in biomedical engineering and that more holistic efforts are necessary.

SIGNIFICANCE: Biomedical researchers choose topics to investigate based on their own personal experiences and interests [7]. Therefore, increasing representation of women and racial minorities in biomedical engineering is critical to reduce health disparities and to ensure that the medical needs of all members of society are properly investigated and successfully addressed.

REFERENCES: [1] Eng by Numbers ASEE 2021; [2] Survey of Doctorate Recipients NCSES 2021; [3] Seymour+ Talking about Leaving 1997; [4] Nosek+ Group Dyn Theory Res Pract 2002; [5] Jones+ J Eng Ed 2010; [6] Mamaril+ J Eng Ed 2016; [7] Hoppe+ Sci Adv 2019; [8] Jaeger+ Rev Higher Ed 2017.
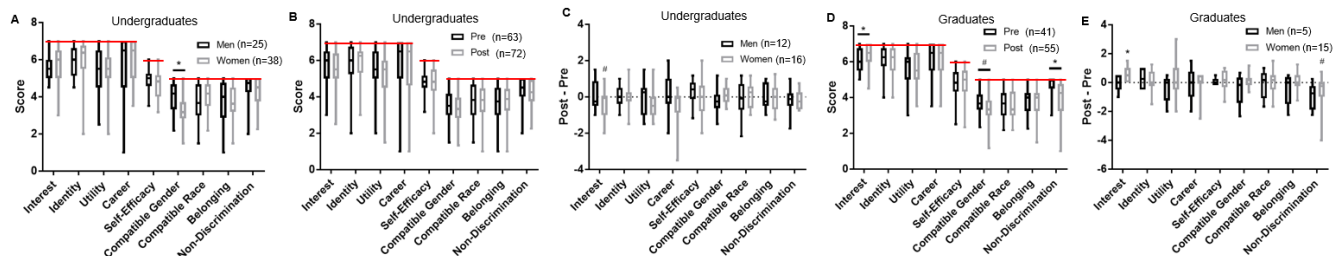
Figure 1: (A) Baseline assessments of male and female undergraduate students at beginning of semester for each scale. (B) Aggregate comparison of undergraduate assessments at beginning (pre) and end (post) of semester. (C) Paired difference in pre/post data for undergraduate students that took both surveys. (D) Aggregate comparison of graduate assessments at beginning (pre) and end (post) of semester. (E) Paired difference in pre/post data for graduate students that took both surveys. Red line indicates maximum/best score for each scale. * $p < 0.05$, # $p < 0.10$.