AC 2008-768: SAME COURSES, DIFFERENT OUTCOMES? VARIATIONS IN CONFIDENCE, EXPERIENCE, AND PREPARATION IN ENGINEERING DESIGN

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Same courses, different outcomes? Variations in Confidence, Experience, and Preparation in Engineering Design

Abstract

There is evidence in the literature that women have lower confidence in their skills and knowledge than men, particularly in areas considered crucial for engineering, like math and science. This difference has been linked to gender gaps in engineering enrollment and persistence. Our study of engineering students extends research on gender differences by examining how confidence with design interacts with academic preparation and the frequency of design experiences in engineering coursework. We also compare patterns of gender differences within the racial/ethnic majority and minority groups. Our findings reaffirm prior research on the gender gap in engineering students' academic confidence, where men tend to report higher levels of confidence. In particular, the analysis showed that the gender differences in confidence and perceived academic preparation to engage in design are primarily accounted for by the gender gap within the racial/ethnic majority group, while these differences were not as strongly expressed among underrepresented minorities. We also saw differences in how well women and men think their courses are preparing them to engage in these design activities. The study contributes new insights by examining the link between design confidence and course experience, as well as the relevance of other factors.

Introduction

Despite years of research and intervention, women and some racial/ethnic minority students continue to be underrepresented in engineering [1]. For instance, women earned less than one fifth of the Bachelor's degrees in engineering and engineering technologies granted in the U.S. in 2004 [2]. While underrepresented minority (URM) students are closing the gap between their participation and that of their majority counterparts, women's enrollment in engineering education remains the same as it was about a decade years ago [3]. URM success in engineering education has been correlated with improved academic preparation for college, financial assistance, and recruiting and programmatic interventions in higher education. While some institutions have excelled at recruiting and retaining women and URM students though preparatory and programmatic interventions [4-6], women overall continue to lag behind men in choosing and continuing with engineering education, despite there being no differences in ability or engagement [2, 7].

One reason for the gender and URM gaps that has been explored by researchers is a gap in self-confidence. Self-confidence is an affective construct referring to the strength of belief in one's abilities. Previous research indicates that self-confidence plays an important role in gendered academic experiences in the science, technology, engineering, and mathematics (STEM) fields [8-10]. Self-confidence in math and science has been found to be positively associated with the likelihood of entry into science and engineering majors in postsecondary education, and persisting in science and engineering majors later in college [11-15].

While higher self-confidence in one's abilities in a given discipline has been associated with enhanced performance and persistence in the field, research has uncovered that gender and racial/ethnic background mediate students' confidence levels in some disciplines. There is evidence that women exhibit lower confidence in their skills and knowledge than men, particularly in areas considered crucial for engineering, like math and science. Higher confidence levels among men relative to women have been found for physics and engineering background knowledge, problem-solving, and overall engineering abilities [16], preparation and ability to perform in specific engineering courses (e.g., chemical engineering) [17], as well as engineering-related technical and mechanical abilities [18].

Math and science education are important foundations for becoming a competent engineer, but another area central to engineering practice is design. Teaching and learning good design skills are important aspects of engineering education in colleges and universities [19, 20]. ABET has recognized this need by including "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability" in the *Criteria for Accrediting Engineering Programs*, as one of the eleven learning outcomes that students should attain before graduation [21].

Because design is central to engineering, we focus our analyses here on engineering students' confidence to do design. Few studies have looked at students' confidence with specific skills or activities associated with engineering design and the relationship between confidence and academic preparation in applying these skills. While examples of such work exist [16], they have not addressed the range of activities that formally constitute the design process.

Another important question for research concerns the antecedents of self-confidence. Academic preparation is one factor whose relationship with confidence deserves attention. Interestingly, research indicates that high school preparation does not appear to be significantly related to attrition of women in engineering majors [14]. In another study, women's performance in first-year chemical engineering courses did not account for their lower self-confidence and grades in later courses compared to men [17]. In addition, a survey of engineering faculty also found that "both male and female faculty members perceive that the 'academic preparation' and 'study habits' of female engineering undergraduates are as good as, if not better than, those of their male peers" [7]. At the same time, little is known regarding the relationship between perceived academic preparation to practice design and self-confidence in design-related abilities at a given time during engineering study. This potential relationship seems particularly worthy of longitudinal investigation, where more external and transitory feelings of preparation based on current coursework can be juxtaposed with more internal and (presumably) enduring notions of confidence in one's intellectual abilities.

Because the outcome of preparatory and programmatic interventions has been largely positive for URM students while remaining neutral in the aggregate for women, we seek to extend inquiry beyond replication of previous results in the literature. While much of prior research has tied differences in confidence to different trajectories of academic study, such as selecting a major or switching out of STEM majors, we wanted to investigate the interaction among self-confidence, gender, and majority or URM status for those who "stuck with it," choosing to remain in engineering from sophomore to senior years. To inform this analysis in the context of design education, we will also consider the perceived frequency of design experiences and preparation to engage in design.

First, we will explore confidence to do design with respect to gender and then, URM status. Do our findings replicate past research showing a gender gap in confidence? Is confidence a factor for URM students, as it has been shown to be for women? Does confidence remain a factor for students throughout the college years? This important line of inquiry directly addresses differences between women and URMs as categories of students.

Second, we will explore students' beliefs about the design education they are receiving. Are there differences between what women and men, or what URM and majority students believe about the design education they are receiving in their engineering coursework? Do students believe they are receiving the same quantity of design education? Are these beliefs linked to perceptions of preparation to engage in design activities? Do these beliefs change over time, through the college years? This line of inquiry is important because it addresses a potential source of confidence: the perceived quantity and quality of the coursework itself.

The specific research questions we address are as follows:

RQ 1: Does confidence to do design vary with the gender, URM status, and/or class standing of engineering students?

RQ 2: Do students' beliefs about the quantity of design they are exposed to in their engineering education coursework vary with gender, URM status, and/or class standing?

RQ 3: Do students' beliefs about how well their courses are preparing them to do design vary with gender, URM status, and/or class standing?

An analysis of these aspects of students' attitudes toward design should further our understanding of the relative effects of gender and underrepresented racial/ethnic minority status on college experiences of engineering students.

Methods

The Academic Pathways Study (APS), part of the NSF-funded Center for Advancement in Engineering Education (CAEE), focuses on students' experiences as they move into, through, and out of engineering education [23]. Longitudinal data were collected from 40 students at each of four diverse institutions: Technical Public Institution, a university specializing in teaching engineering and technology; Urban Private University, a historically black mid-Atlantic institution; Large Public University, a university in the Northwest U.S.; and Suburban Private University, a medium-sized university on the West Coast. The analysis here describes results from three related questions that were part of a larger, web-based APS survey administered to the cohort of study participants over four consecutive years [24]. The comparisons reported here are based on data collected in the second and fourth years, in the spring of 2005 and 2007.

Sample and Procedure

In the three survey questions, engineering students at four institutions were asked to (a) rate their confidence in the ability to engage in each of eight engineering design activities, (b) indicate the frequency of engagement with these activities in their courses, and (c) rate how well their courses are preparing them to engage in each activity. The design activities listed for each set of questions are drawn from previous research, such as [25-27]. Figure 1, Figure 2, and Figure 3 contain the text of the three questions. The first question is hereafter referred to as the *confidence question*, the second as the *perceived course experience question*, and the third as the *perceived course preparation question*.

For the following engineering design activities, please indicate your level of confidence. For example, if you have little or no confidence in your ability to model engineering solutions, then mark poor. If you are extremely confident in your ability, mark excellent.

	Poor	Fair	Good	Very good	Excellent
Defining what the problem really is	☐	☐	☐	☐	☐
Searching for and collecting information needed to solve the problem	☐	☐	☐	☐	☐
Thinking up potential solutions to the problem	☐	☐	☐	☐	☐
Detailing how to build the solution to the problem	☐	☐	☐	☐	☐
Assessing and passing judgment on a possible or planned solution to the problem	☐	☐	☐	☐	☐
Comparing and contrasting two solutions to the problem on a particular dimension such as cost	☐	☐	☐	☐	☐
Selecting one idea or solution to the problem from among those considered	☐	☐	☐	☐	☐
Communicating elements of the design in sketches, diagrams, lists, and written or oral reports	☐	☐	☐	☐	☐

Figure 1. The *confidence* survey question, as administered.

For the following engineering design activities, please indicate how often you engaged in the activity in your coursework in the current academic year.

	Never	1–2 times per term	1–2 times a month	Once a week	2–3 times a week	Daily
Defining what the problem really is	☐	☐	☐	☐	☐	☐
Searching for and collecting information needed to solve the problem	☐	☐	☐	☐	☐	☐
Thinking up potential solutions to the problem	☐	☐	☐	☐	☐	☐
Detailing how to build the solution to the problem	☐	☐	☐	☐	☐	☐
Assessing and passing judgment on a possible or planned solution to the problem	☐	☐	☐	☐	☐	☐
Comparing and contrasting two solutions to the problem on a particular dimension such as cost	☐	☐	☐	☐	☐	☐
Selecting one idea or solution to the problem from among those considered	☐	☐	☐	☐	☐	☐
Communicating elements of the design in sketches, diagrams, lists, and written or oral reports	☐	☐	☐	☐	☐	☐

Figure 2. The *perceived course experience* survey question, as administered.

For the following engineering design activities, please indicate how well you think your courses are preparing you to engage in the activity. For example, if you think they are not preparing you at all, then mark poor. If you think they are preparing you extremely well, then mark excellent.

	Poor	Fair	Well	Very well	Excellent
Defining what the problem really is	☐	☐	☐	☐	☐
Searching for and collecting information needed to solve the problem	☐	☐	☐	☐	☐
Thinking up potential solutions to the problem	☐	☐	☐	☐	☐
Detailing how to build the solution to the problem	☐	☐	☐	☐	☐
Assessing and passing judgment on a possible or planned solution to the problem	☐	☐	☐	☐	☐
Comparing and contrasting two solutions to the problem on a particular dimension such as cost	☐	☐	☐	☐	☐
Selecting one idea or solution to the problem from among those considered	☐	☐	☐	☐	☐
Communicating elements of the design in sketches, diagrams, lists, and written or oral reports	☐	☐	☐	☐	☐

Figure 3. The *perceived course preparation* survey question, as administered.

To investigate students' perceptions of their design experiences, we employed a previously developed framework of eight key activities in the engineering design process (Table 1). This set of design activities is based on a content analysis of seven freshman engineering design texts [28], and has been previously used in studies of engineering students' design cognition [27, 29].

Abbreviated name	Full wording as presented in questions
Problem definition	Defining what the problem really is
Gathering information	Searching for and collecting information needed to solve the problem
Generating ideas	Thinking up potential solutions to the problem
Modeling	Detailing how to build the solution to the problem
Feasibility analysis	Assessing and passing judgment on a possible or planned solution to the problem
Evaluation	Comparing and contrasting two solutions to the problem on a particular dimension such as cost
Decision	Selecting one idea or solution to the problem from among those considered
Communication	Communicating elements of the design in sketches, diagrams, lists, and written or oral reports

Table 1. Abbreviated names and full wordings of the eight design activities. Charts will use only abbreviated names.

Because students participated in the APS for four years, the survey data permit a longitudinal comparison of responses from the same participants. While the survey was administered to a larger sample, we limited the present analysis to students who self-identified as studying towards an engineering major in both years and who answered at least two of the three design questions. The final longitudinal sample included responses from 110 students, across the four institutions.

Demographic information was gathered from students in the first year of the APS. Gender was determined based on students' self-reports. Reflecting the oversampling of women in the APS study, 37% of the participants in this sample were women (n = 41).

Students also were identified in terms of what we refer to as *representation status* in this paper—that is, belonging to either the majority or the underrepresented minority group, based on their responses to a more detailed question about racial/ethnic background. Students who self-identified as White/Caucasian, Asian American/Asian, or selected both of these categories were included in the racial/ethnic majority group (n = 73). Of these students, nearly three-quarters (72%) selected White/Caucasian, 27% selected Asian American/Asian, and 1% chose both categories.

Students who self-identified as African American/Black, American Indian/Alaska Native, Native Hawaiian/Pacific Islander, Mexican American/Chicano, Puerto Rican, Other Latino, or a combination of these categories (or any of these along with a majority category) were included in the URM group (n = 37). More than half of this group (54%) was comprised of students who self-identified as African American/Black. Of the remaining 46% of the URM group, 19% were Latino (participants who selected Mexican American/Chicano, Other Latino, Puerto Rican, or a combination of these) and 27% were Multiracial/Multicultural (participants who selected other race/ethnicity categories, or a combination of any URM and majority categories). The majority and URM groups were characterized by nearly equivalent

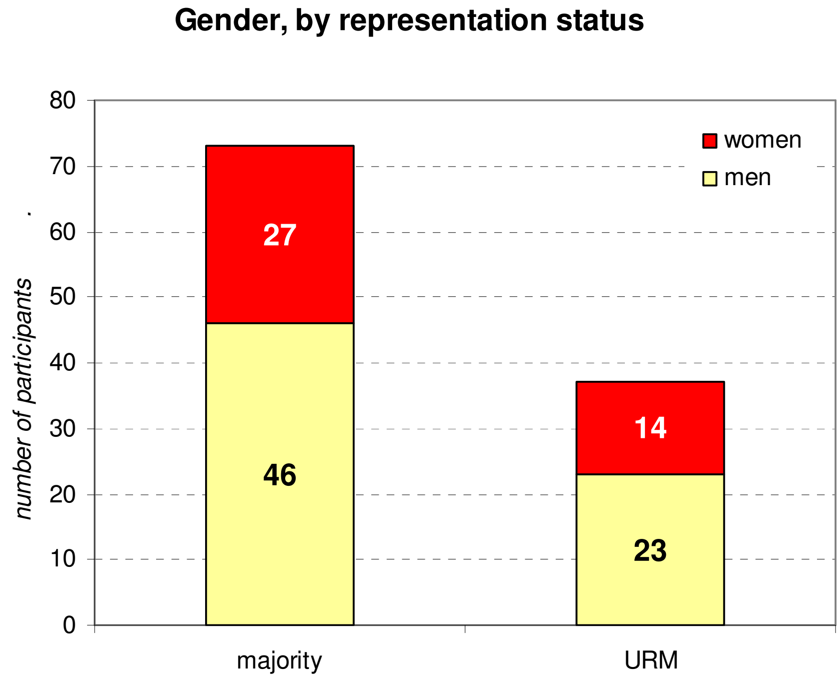

Figure 4. Sample size and demographics by representation status and gender. Gender distribution within the majority and URM groups was nearly identical (37% and 38% women, respectively).

gender percentages. Figure 4 illustrates the composition of the sample by gender and representation status.

Although the participants' institutional affiliation was not an explicit factor in our analysis, we were concerned that institution would present a complicating factor in the analysis, given that members of the URM group were not evenly distributed across the campuses. Students from Urban Private University accounted for about half of the URM group (51%), and the remaining half was distributed across Suburban Private University (19%), Technical Public Institution (16%), and Large Public University (14%). On the other hand, the majority group was entirely comprised of students from Suburban Private University (29%), Technical Public Institution (35%), and Large Public University (36%). While at least 75% of students from these institutions belonged to the majority group, no majority students came from Urban Private University. Also, Urban Private University's sample comprised 80% of all "African American/Black" students, the largest racial/ethnic category in the URM group. Thus, there is significant overlap between institutional affiliation and URM designation. Potential implications of these properties of the sample are addressed in greater detail at the conclusion of this paper.

Analysis

Our analysis explored differences in students' confidence to do each of the eight design activities, perceived frequency of course experience with the design activities, and perceived preparation to engage in the design activities. The comparisons were carried out by gender, URM status, and class standing (Year two *vs.* four). Students responded to the confidence question and the perceived course preparation question using the following scale: Poor=0, Fair=1, Good/Well=2, Very Good/Well=3, Excellent=4. Responses to the perceived course experience question were measured using the following scale: Never=0, 1–2 times per term=1, 1–2 times a month=2, Once a week=3, 2–3 times a week=4, and Daily=5.

In both years, students' average ratings of confidence to do each of the design activities ranged from "good" to "very good." On average, students reported engaging in each design activity as part of their coursework approximately 2–3 times per week to 1–2 times per month. Finally, students' average ratings of their academic preparation in each of the design activities ranged from "good" to "very good."

Since each of the three survey questions provides a different prompt for rating eight distinct design activities, each design activity constitutes a separate variable, for a total of 24 design activity variables in the study. Because our analysis involves multiple comparisons, Bonferroni adjustment was applied to the significance value of $p \leq .05$ to account for increased likelihood of Type I error. Observed correlation among the responses to the eight design activities on each question was factored into the adjustments [30]. The adjusted values used in our analyses were $p \leq .014$ on the *confidence* question, $p \leq .023$ on the *perceived course experience* question, and $p \leq .020$ on the *perceived course preparation* question.

From a theory-building and practical standpoint, it is useful to generalize from significant outcomes on individual design activities to the construct represented in the survey question (e.g., to discuss gender differences in "confidence to engage in engineering design"). In the case of the *confidence* question, running separate tests for the eight design activities also contributes to an understanding of students' overall *confidence in doing design*. Thus, in interpreting the analyses we paid attention to results which pointed to consistent differences between the groups on the general constructs of confidence, preparation, or frequency of engaging in engineering design activities.

Results

Results from the analyses are organized by research question. Our goals were to focus the discussion on the most significant findings and to integrate these findings in ways that are most interesting and meaningful in terms of their implications. Considering that the Bonferroni correction is a conservative statistical approach, results with p-values near or below the uncorrected $p \leq .05$ level are reported in tables. Findings that are significant are indicated with an asterisk. This approach allows us to identify potential trends in the results and provides a useful context for interpreting the significant findings.

Confidence to do design

RQ 1: Does confidence to do design differ, depending on the gender, URM status, and/or class standing of engineering students?

As shown in Table 2 and Figures 4 and 5, there was a gender gap in confidence to do design in Year 2. Indeed, we found significant differences in confidence levels for three of the eight design activities. By Year 4, the gender gap had mostly closed, with only one item showing a significant difference between men and women.

Year 2

Question	Gender	Mean	Mean rank	*p*-value
Confidence in ability to perform design activities				
1. Defining what the problem really is*	M	2.90	61.37	0.003
	F	2.43	44.01	
3. Thinking up potential solutions to the problem*	M	2.90	63.01	0.000
	F	2.28	41.18	
4. Detailing how to build the solution to the problem*	M	2.57	63.35	0.000
	F	1.90	40.60	
5. Assessing and passing judgment on a possible or planned solution to the problem	M	2.58	59.36	0.042
	F	2.30	47.49	
7. Selecting one idea or solution to the problem from among those considered	M	2.65	59.87	0.026
	F	2.23	46.60	

Year 4

Confidence in ability to perform design activities				
1. Defining what the problem really is	M	3.04	60.76	0.015
	F	2.66	46.65	
3. Thinking up potential solutions to the problem	M	2.80	60.50	0.019
	F	2.46	47.09	
4. Detailing how to build the solution to the problem*	M	2.49	62.78	0.000
	F	1.93	42.10	

Table 2. Years 2 and 4 gender differences in confidence. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; n = 41 women + 69 men).

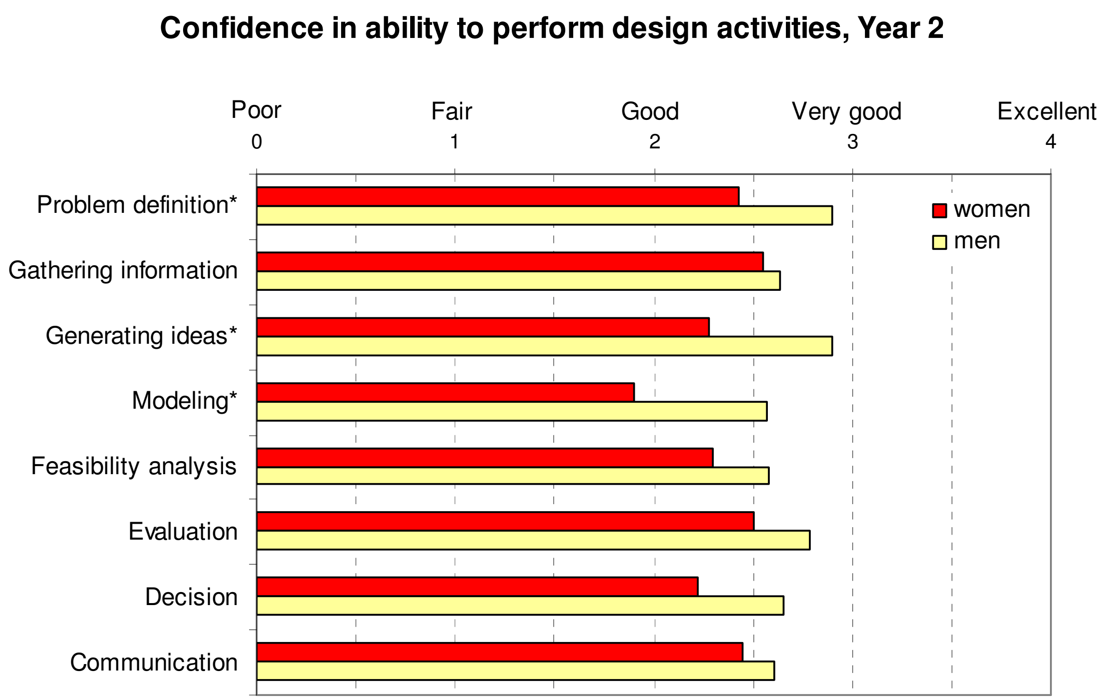

Figure 5. Mean confidence in ability to perform design activities, by gender, Year 2. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; n = 41 women + 69 men).

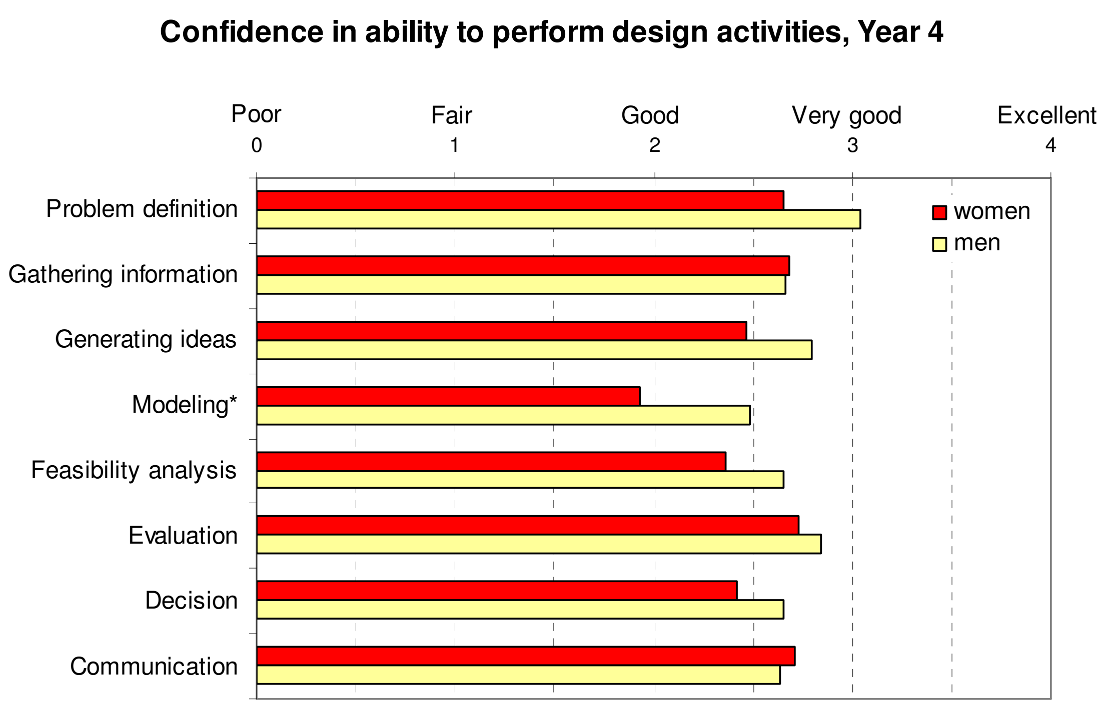

Figure 6. Mean confidence in ability to perform design activities, by gender, Year 4. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; n = 41 women + 69 men).

In contrast, there was little difference in how students reported their confidence to do design, when making a comparison by representation status. With this in mind, we decided to explore gender differences within each representation status group. Table 3 shows significant differences in confidence to do the design activities between majority men and women. In Year 2, there were significant differences for five of the eight design activities. In Year 4, there were significant differences for only two of the activities.

Year 2

Question	Gender	Mean	Mean rank	*p*-value
Confidence in engaging in design activities				
1. Defining what the problem really is*	M	3.04	42.68	0.001
	F	2.41	27.31	
3. Thinking up potential solutions to the problem*	M	2.91	43.88	0.000
	F	2.07	25.28	
4. Detailing how to build the solution to the problem*	M	2.63	43.20	0.001
	F	1.81	26.44	
5. Assessing and passing judgment on a possible or planned solution to the problem*	M	2.67	42.67	0.001
	F	2.11	27.33	
7. Selecting one idea or solution to the problem from among those considered*	M	2.76	41.62	0.011
	F	2.15	29.13	

Year 4

Question	Gender	Mean	Mean rank	*p*-value
Confidence in engaging in design activities				
1. Defining what the problem really is*	M	3.07	42.04	0.004
	F	2.56	28.41	
4. Detailing how to build the solution to the problem*	M	2.46	42.41	0.002
	F	1.85	27.78	

Table 3. Years 2 and 4 gender differences in confidence within the majority group only. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; $n = 27$ women + 46 men).

Average confidence levels for each of the design activities are shown in Figure 7 and Figure 8. Men on average rated their confidence higher than women for all the activities. Although the gap narrowed in Year 4, men's confidence remained higher than women's for every design activity.

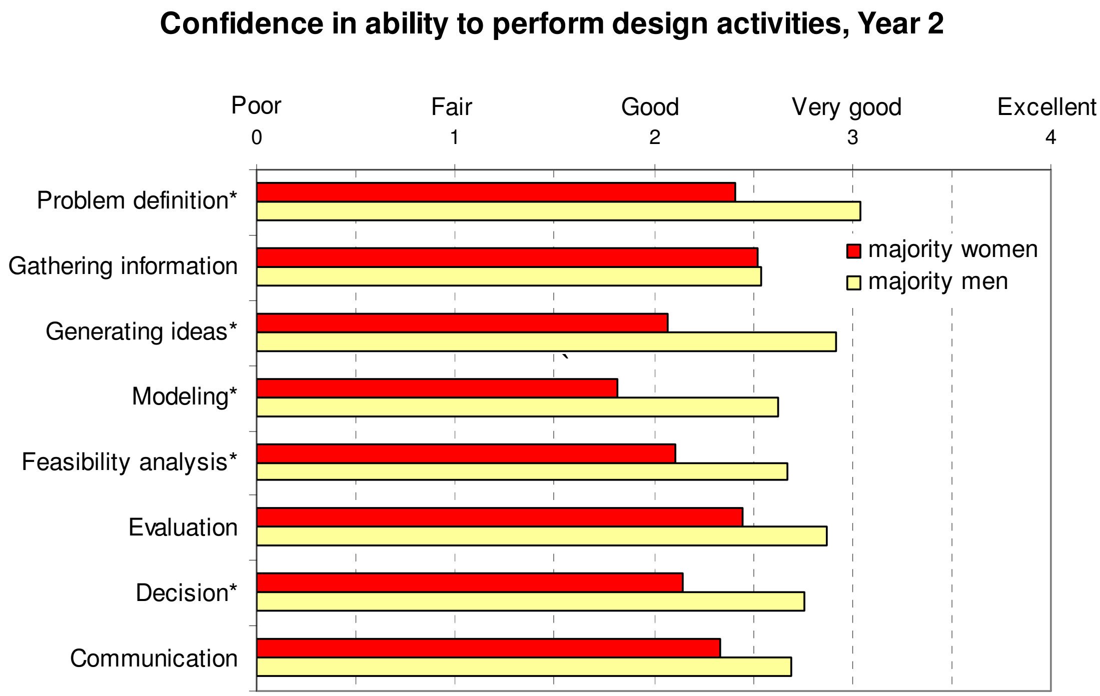

Figure 7. Within majority group, mean confidence in ability to perform design activities, by gender, Year 2. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; $n = 27$ women + 46 men).

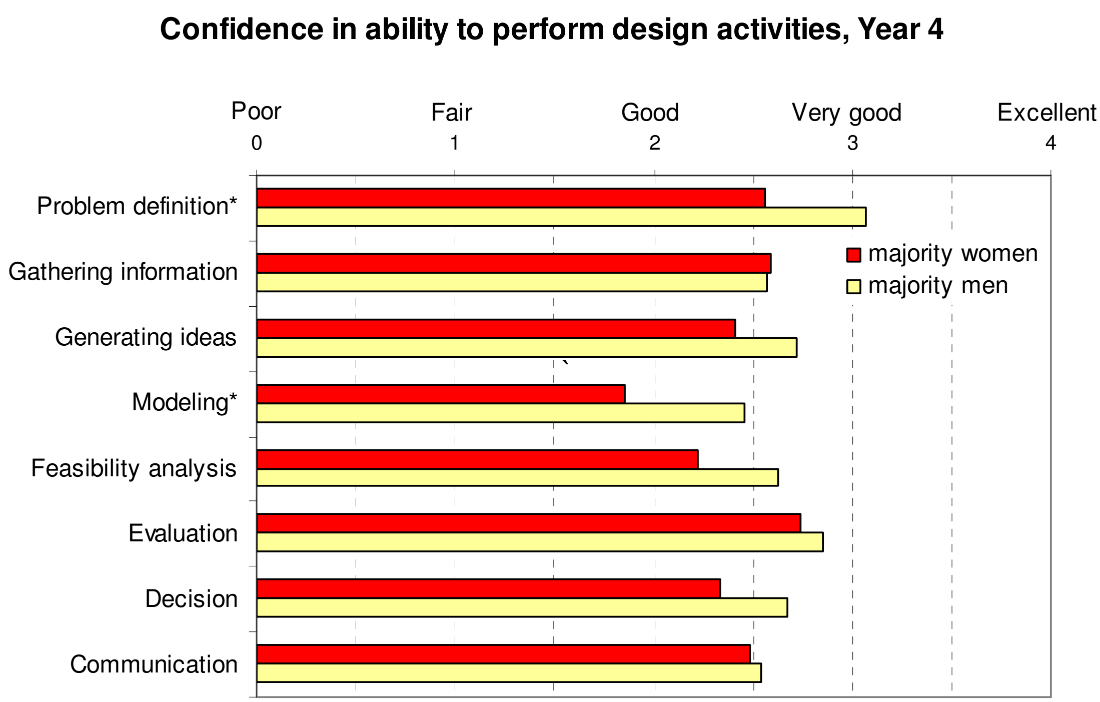

Figure 8. Within majority group, mean confidence in ability to perform design activities, by gender, Year 4. Asterisks indicate significant gender differences ($p \leq 0.014$, Mann–Whitney U; $n = 27$ women + 46 men).

We also explored gender within the URM group. There were no significant differences between men's and women's confidence levels for any of the activities in either Year 2 or Year 4.

In sum, men expressed higher confidence than women in both Years 2 and 4, although the gender gap had narrowed somewhat by Year 4. There were no significant differences between majority students and URM students in confidence to do design. At the same time, there were significant differences in confidence between majority men and women, but there were no significant differences in confidence between URM men and women. Therefore, the gender gap in confidence to do design is primarily accounted for by majority women.

Perceived quantity of design education

RQ 2: Do students' beliefs about the quantity of design they are exposed to in their engineering education coursework vary, depending on their gender, URM status, and/or class standing?

In both years, no significant differences in perceived frequency of design experiences in coursework were found for the overall sample with respect to gender or majority vs. URM status. Within the majority group, men consistently rated their frequency of course experience with design higher compared to women, yet no significant differences were detected. Differences in ratings on two of the eight design activities approached significance in Year 2, yet this finding appeared too weak to signal a trend toward consistently higher frequency ratings by men. There were no significant gender differences in either year within the URM group.

Perceived quality of design education

RQ3: Do students' beliefs about how well their courses are preparing them to do design vary, depending on their gender, URM status, and/or class standing?

As indicated in Table 4, in Year 2, men's ratings of how well their courses were preparing them to do design were significantly greater than women's on three of the eight design activities. By Year 4, differences in perceived preparation had diminished, and men's perceptions of course preparation were significantly greater than women's on only one of the design activities. Figure 9 and Figure 10 further indicate that on average, men's ratings on all the design activities were higher than women's in both years.

Year 2

Question	Gender	Mean	Mean rank	*p*-value
Perceived course preparation to engage in design activities				
3. Thinking up potential solutions to the problem	M	2.74	60.59	0.022
	F	2.27	46.93	
4. Detailing how to build the solution to the problem*	M	2.57	63.78	0.000
	F	1.73	39.86	
6. Comparing and contrasting two solutions to the problem on a particular dimension such as cost*	M	2.25	62.48	0.002
	F	1.54	43.76	
7. Selecting one idea or solution to the problem from among those considered*	M	2.41	61.26	0.005
	F	1.85	44.61	

Year 4

Question	Gender	Mean	Mean rank	*p*-value
Perceived course preparation to engage in design activities				
7. Selecting one idea or solution to the problem from among those considered*	M	2.40	60.93	0.008
	F	1.83	45.17	

Table 4. Years 2 and 4 gender differences in perceived course preparation. Asterisks indicate significant gender differences ($p \leq 0.020$, Mann–Whitney U; n = 41 women + 69 men).

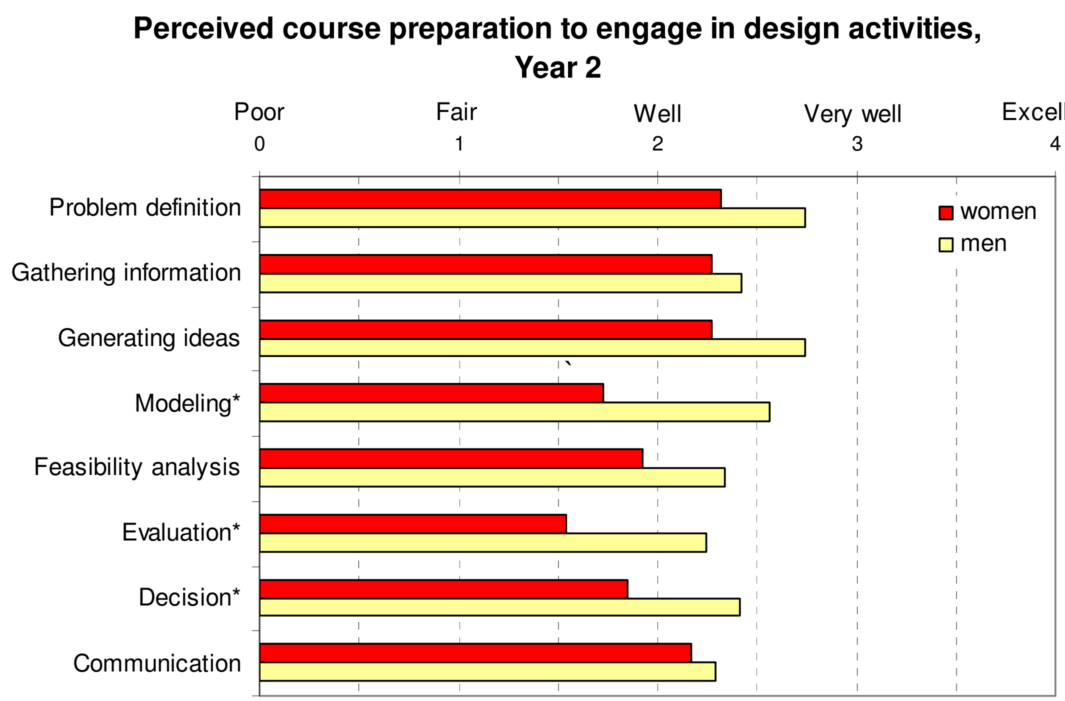

Figure 9. Mean perceived course preparation to engage in design activities, by gender, Year 2. Asterisks indicate significant gender differences ($p \leq 0.020$, Mann–Whitney U; n = 41 women + 69 men).

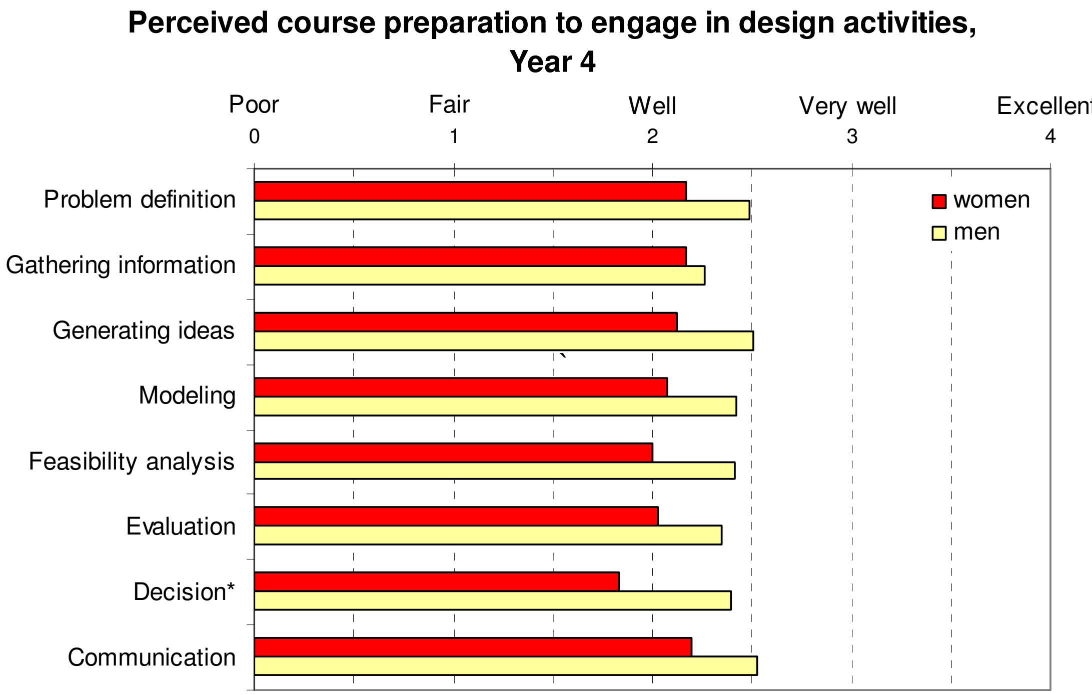

Figure 10. Mean perceived course preparation to engage in design activities, by gender, Year 4. Asterisks indicate significant gender differences (*p* ≤ 0.020, Mann–Whitney U; *n* = 41 women + 69 men).

When comparing majority students to URM students, we found that there were no significant differences between the two groups with respect to how well they believed their courses were preparing them to do any of the design activities, so we decided to take a further look at gender within each representation status group. As shown in Table 5, in Year 2, among majority students, men's ratings were significantly higher than women's for five of the eight design activities. In Year 4, the gap in beliefs about academic preparation had closed, with no significant differences between majority men and women.

Year 2

Question	Gender	Mean	Mean rank	*p*-value
Course-based preparation to engage in design activities				
1. Defining what the problem really is	M	2.76	41.08	0.026
	F	2.07	30.06	
3. Thinking up potential solutions to the problem*	M	2.80	42.42	0.003
	F	2.00	27.76	
4. Detailing how to build the solution to the problem*	M	2.48	43.35	0.001
	F	1.52	26.19	
5. Assessing and passing judgment on a possible or planned solution to the problem*	M	2.30	41.26	0.020
	F	1.63	29.74	
6. Comparing and contrasting two solutions to the problem on a particular dimension such as cost*	M	2.17	42.37	0.004
	F	1.30	27.85	
7. Selecting one idea or solution to the problem from among those considered*	M	2.38	42.27	0.002
	F	1.56	26.89	

Year 4 *-- no significant differences --*

Table 5. Year 2 gender differences in perceived course preparation within majority group only. Asterisks indicate significant gender differences ($p \leq 0.020$, Mann–Whitney U; n = 27 women + 46 men).

Figure 11 and Figure 12 show, however, that on average, majority men's beliefs about how well their courses were preparing them to do design were greater than majority women's for all of the design activities in both years. This trend could be tested with a larger sample of students.

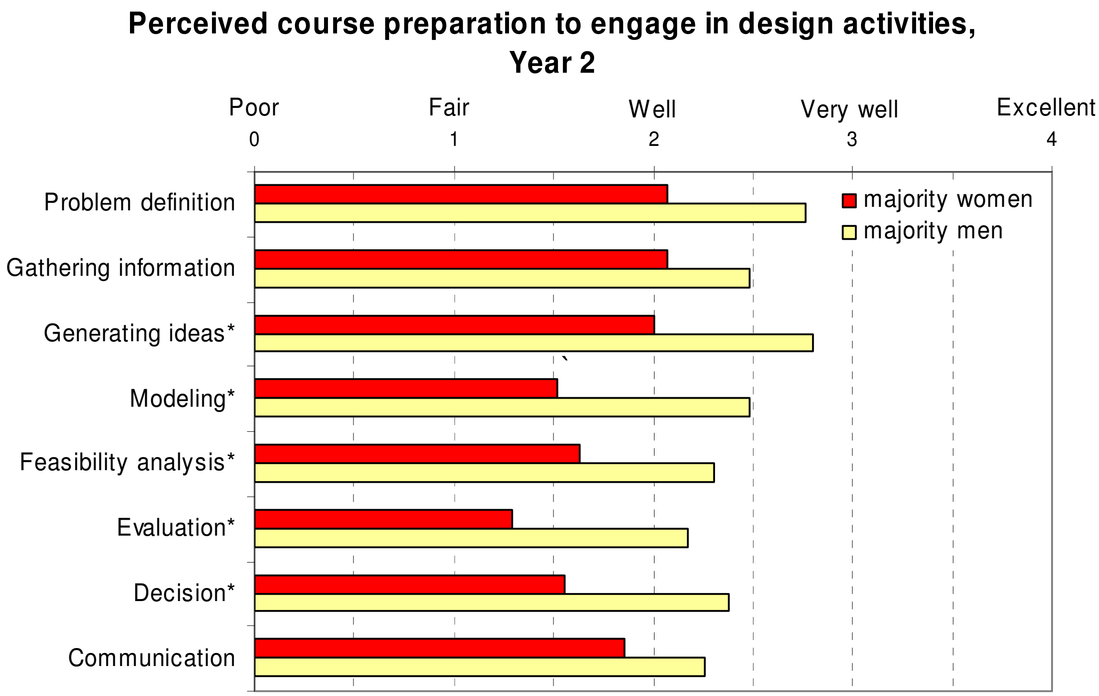

Figure 11. Within majority group, mean perceived course preparation to engage in design activities, by gender, Year 2. Asterisks indicate significant gender differences ($p \leq 0.020$, Mann–Whitney U; $n = 27$ women + 46 men).

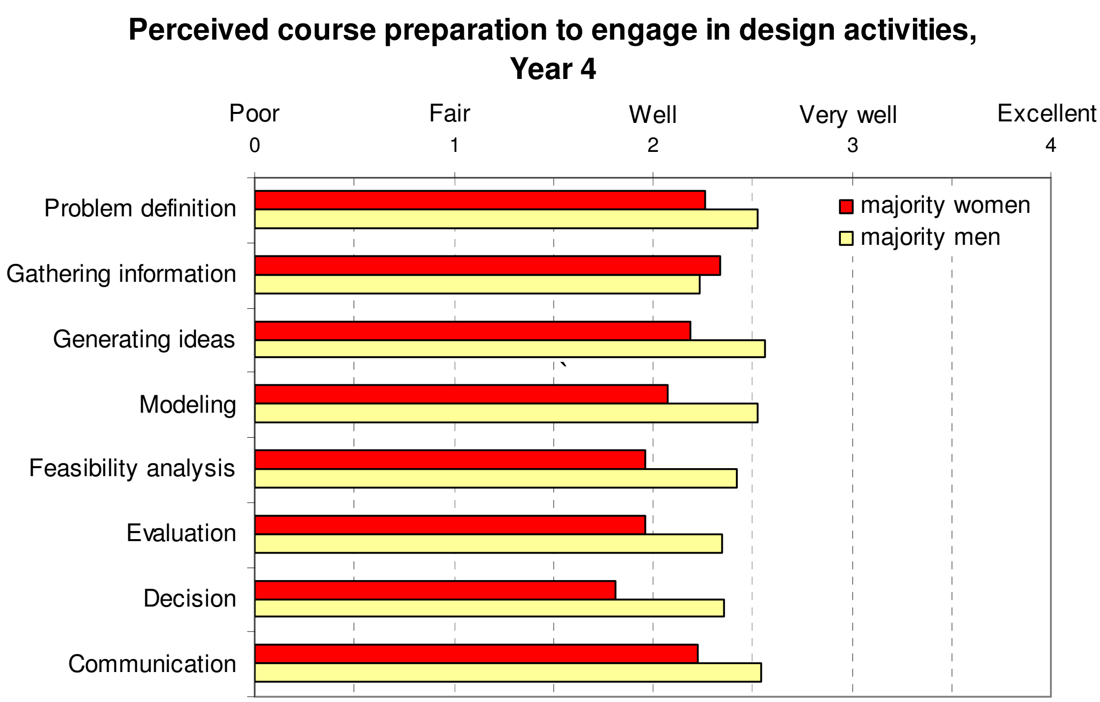

Figure 12. Within majority group, mean perceived course preparation to engage in design activities, by gender, Year 4. Asterisks indicate significant gender differences ($p \leq 0.020$, Mann–Whitney U; $n = 27$ women + 46 men).

Among URM students, there were no significant differences in perceived course preparation between men and women in either Year 2 or Year 4 ($p \leq .02$). A pattern of gender differences seemed to emerge in Year 4, with URM men's average responses exceeding those of URM women on all of the design activities. Further testing with a larger sample would confirm or disconfirm a speculation that, among URM students, a gender gap in perceived course preparation to do design forms through the college years.

Men reported significantly higher level of academic preparation to engage in design compared to women on three of the eight design activities in Year 2 and on one activity in Year 4. This pattern of gender differences complements that observed for ratings of confidence in design. Although the differences between men's and women's perceived preparation for doing design appear to diminish by Year 4, the overall pattern of these differences remains, with men providing more positive responses on all eight activities, on average, in both years. Also, analysis within representation status group revealed significant gender differences on five of the eight design activities within the majority group in Year 2, while no differences were found within the URM group. While the pattern of differences in the average preparation scores within the majority group persisted in Year 4, no significant differences were found for that year. This suggests a narrowing of the gender gap among upperclassmen in terms of perceived preparation to engage in design.

Similar to the findings for confidence in design, differences in perceived preparation between majority men and women account for the gender gap within the overall sample. At the same time, while no gender differences surfaced within the URM group, a visual comparison of average responses of men and women in Year 2 and Year 4 signals a potential emergence of a gender gap in perceived preparation within this group at a later stage of engineering study.

Discussion

Overall, the analysis by gender and majority vs. URM status undertaken in this study provides insights into students' confidence to engage in engineering design activities, and their perceptions of the quantity and quality of design education they receive in their coursework. While corroborating some findings from earlier studies, our analysis has also uncovered longitudinal differences in the development of student attitudes during undergraduate study.

The analysis revealed that in both the second and fourth year, men generally indicated significantly higher levels of confidence as well as course preparation for engaging in engineering design activities. Although the number of activities with statistically significant differences decreased in Year 4, the general pattern of responses changed little, with averages of men's responses consistently exceeding women's in both years. At the same time, no significant gender differences were found in either year with regard to how often the students said they engaged with each design activity in their courses.

The analysis also showed that the gender differences in confidence and perceived academic preparation to engage in design are primarily accounted for by the gender gap within the majority group. It was encouraging to see this gap diminish toward the fourth year of engineering study. However, it should also be noted that, while the magnitude of the gender effect diminishes, the general pattern of responses, where men's perceptions are slightly more positive compared to women's, persists across the majority group through the senior year. Finally, there is some, albeit statistically insignificant, suggestion of an emerging gender difference within the URM group by the fourth year, in terms of students' perceptions of academic preparation.

Perhaps the most potentially impactful finding is the localization of the gender gap within the majority group. Several researchers have argued that gender ought not be studied without consideration for race and ethnicity (e.g., [4, 31]), and this study demonstrates that, at least for our sample and with respect to design, a commonly held understanding about gender differences in confidence does not extend to URM men and women. This has programmatic implications, in that the marginal outcomes of programs designed to improve students' confidence to do design may be greater for majority women than for URM women.

The absence of any significant difference in how frequently students perceive they are being exposed to design in their coursework indicates that students in this sample all perceived they were receiving the same *quantity* of design education. At the same time, men rated their courses more highly with respect to preparing them to do design, indicating that there is a gender difference in the *quality* of design education that students in this sample believed they were receiving. There are several potential explanations for this combination of findings. First, the difference in perceived quality of design education may mirror differences in courses and majors that students tend to choose, with gendered patterns arising in these differences that our analysis would not detect. Further analysis of the students in the sample, incorporating data from their academic transcripts, and/or a comparison of men and women within specific engineering majors, would test this explanation.

Alternatively, there may be a gender difference in what students understand course preparation to be. Women may tend to have a different standard than men, contributing to their different feelings of how well their courses are preparing them to engage in design. Further qualitative inquiry into how men and women define academic preparation may test this explanation.

A third explanation is that the women in this sample perceived that their preparation to do design comes more from extracurricular activities and/or work experiences than from their engineering coursework, and their answers to the survey questions reflected this difference in attribution. Further study incorporating data on these students' non-course-related educational activities may test this explanation.

Finally, the design experiences that men and women have in their engineering courses may, indeed, be qualitatively different. In this scenario, both men and women are engaging in the same design activities in their courses, but perhaps in different ways. For example, men may have different qualities of interaction with faculty and teaching assistants than women, or may tend to take different roles than women in team design projects. This explanation has implications for instructors who aim to provide all students with equal opportunities to learn design. For example, instructors may want to pay greater attention to the individual roles that students play in their design teams and encourage students to take on different roles from time to time. With respect to research, analysis of ethnographic data gathered in APS may provide some insight into the ways that men and women engage with their engineering courses, and more specifically, with the design component.

As discussed earlier in this paper, the explanatory power of our findings is limited by the significant overlap between representation status and institutional affiliation. It is possible that other factors influence perceptions and attitudes regarding self-confidence and preparation design, including characteristics of individual institutions or programs. A study within an institution with substantial representation of all categories of student (men, women, majority, URM) would be an important test of our findings.

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