THE INTERSECTION OF GENDER AND RACE: EXPLORING CHEMICAL ENGINEERING STUDENTS' ATTITUDES

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Diversity in engineering is needed to contribute to innovative engineering solutions, provide access to the economic and social capital afforded by an engineering degree, and create an engineering workforce representative of the U.S. population.[1,2] Engineering as a career provides a route for diverse students to enter the workforce in a lucrative and socially respected position, and pathways into and through engineering should be open to a wider range of students.[3] Approximately 20% of engineering bachelor's degrees are awarded to women and only 14.7% to racial/ethnic minorities in the United States.[4] In chemical engineering, the numbers are higher for women with 32.4% of bachelor's degrees awarded to women but are lower (10.3%) for racial/ethnic minorities.[4,5] Moreover, the number of students at the intersections of both gender and race/ethnicity are not reported in American Society for Engineering Education or National Academy of Engineering reports.

Because of these numbers, the findings of studies in engineering that do not examine the intersections of gender and race/ethnicity overrepresent differences between groups for particular majorities. In studies of gender, findings for women are overwhelmingly representative of white women, and studies of racial/ethnic minorities disproportionally represent men. This lack of an intersectional approach continues to reify a gap in our understanding of how chemical engineering students at the intersections of both gender and race/ethnicity navigate their engineering pathways, thus reducing our capability to effectively support and retain entire groups within the scope of the chemical engineering field.

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The notion that social categories and markers of identity (*i.e.*, gender and race/ethnicity) operate independently of each other has been rejected by decades of work that examines the intersection of multiple diversity markers.[6] An intersectional lens "focuses on the difference *among* women, moving beyond simply the differences *between* men and women."[7] These differences among women can be understood through race/ethnicity, class, or other variables unique to the individual. Our paper begins the process of examining the intersections of gender and race/ethnicity in chemical engineering; however, it only focuses on one aspect of intersectionality—demographic markers of gender and race/ethnicity. Additionally, our work does not fully capture the stories of chemical engineering students at the intersections of all self-identified gender identities and races/ethnicities due to small sample sizes. Instead, we examine attitudinal differences among women and men by majority and minority race/ethnicity groups. The focus of this study is student perceptions and differences among intersectional groups in a U.S. context. Other countries have similar representation issues, but the history of race in the United States provides a particular context in which to examine these differences. This work begins to provide an understanding of different groups of students in chemical engineering that is vital for moving the field towards a diverse and equitable space.

Three sets of attitudinal measures were examined in this work: belongingness, motivation, and STEM identities. Belongingness examines how a student perceives their fit or integration into an engineering community. Sense of belonging is defined by an individual's self-measure of "fit" within a higher education institution's social and academic systems.[8] Specifically, our operationalization of belongingness examines how students perceive their fit within engineering as a discipline and their engineering classes. Work in belongingness has shown that racial/ethnic minority groups are more likely to experience a lack of belongingness when compared to majority peers due to campus climates, concerns about finances, and perceived isolation.[9-11] Seymour and Hewitt[10] highlight the results of this limited belongingness for racial/ethnic minorities when discussing why students leave STEM majors.

Motivation has been shown to influence student performance and learning within engineering.[12,13] Here, we measured student motivation through examination of student expectations of success (expectancy),[14] connections between future goals and present actions (connectedness),[15] and the amount of work the student will exert to achieve a desired result (work avoidance).[16] Expectancy is related to an individual's perception of success on a current task to their past experiences,[14] while connectedness measures the strength with which they can relate current tasks with future goals.[15] Work avoidance lays out the approach an individual intends to use on present tasks.[16] Students' refer to their potential for success and future goals when presented with new engineering tasks and use these factors to determine how much effort they dedicate toward completing new tasks.[17]

STEM identities (*i.e.*, mathematics, physics, and engineering) were measured in three ways: how individuals are recognized as the kind of person that can do a particular subject, their beliefs about their ability to understand and perform well in courses (performance/competence), and an interest in the subject. Each of these affective theories has been shown to influence retention, performance, and learning in one way or another and have been shown to be interconnected.[18–21]

We included physics identity in this study because physics identity has been found from prior work to significantly predict engineering choice for all engineering students.[19] Additionally, when compared to chemistry and biology identities, physics identity was a significantly better predictor of engineering persistence than either biology or chemistry identities.[22] Our prior work investigating the identities of first-year chemical engineering students compared to their engineering peers also found that chemical engineering students had a higher physics identity than other engineers.[23] Based on the evidence for how physics plays a part in engineering choice and persistence as well as the findings that chemical engineering students (at the beginning of college) have higher physics identities, we included this particular science identity to investigate differences among chemical engineering students. By understanding the multifaceted aspects of engineering students' attitudes and beliefs, we can understand how diverse groups within engineering at the intersections of gender and race/ethnicity may or may not develop attitudes that are positive for learning. We examined these measures to address the following research question, "What are the differences in attitudes and beliefs of chemical engineering students at the intersection of gender and race/ethnicity?"

METHODS

The data for this study came from the Intersectionality of Non-normative Identities and Cultures of Engineering (InIce) survey administered in the fall of 2015 at four land-grant institutions in different regions of the United States. The InIce project is a larger mixed-method project designed to investigate factors related to: (1) how students felt about their place in the engineering community; (2) attitudes towards engineering; and (3) perceptions about their future in engineering.[24] The data collected during this study were measured at one point in time and are cross-sectional. Multiple survey items were used to measure students' attitudinal profiles consisting of belongingness in engineering, STEM identities (*i.e.*, engineering, physics, and mathematics), other affective measures, and demographic information as well as students' career goals and choice of engineering major. Table 1 outlines examples of survey items for the measures

TABLE 1
Examples of Survey Items to Measure Latent Constructs Used in this Analysis

Latent Constructs	Construct Definition	Example Items from the InIce Survey
Belongingness (6 items)	Feelings of fit within engineering	I feel comfortable in engineering. I feel I belong in engineering.
Work Avoidance (3 items)	Motivation to get through a course or task with as little work as possible	Getting a passing grade with as little studying as possible. Getting through the course with the least amount of time and effort.
Expectancy (5 items)	Beliefs that they will do well in a course	I expect to do well in this engineering course. I am certain I can master the skills being taught in this engineering course.
Connectedness (5 items)	Tying current tasks to future goals	I don't think much about the future. I don't like to plan for the future.
Engineering Performance/Competence (5 items)	Beliefs about ability to do well and understand engineering course material	I am confident that I can understand engineering in class. I can do well on exams in engineering.
Physics Recognition (5 items)	Feelings that others see one as the kind of person that can do physics	My instructors see me as a PHYSICS person. I've had experiences in which I was recognized as a PHYSICS person.
Physics Performance/Competence (5 items)	Beliefs about ability to do well and understand physics course material	I am confident that I can understand PHYSICS in class. I understand concepts I have studied in PHYSICS.
STEM Identities (1 item each)	Direct measures of how students saw themselves as a particular kind of person	I see myself as a physics person. I see myself as an engineer. I see myself as a math person.

used in this study. All attitudinal responses were measured on seven-point anchored numeric scales.

The survey was administered to students enrolled in introductory engineering courses via a paper-and-pencil format. In this paper, we examined the responses of students who indicated they were interested in chemical engineering. Students who rated their interest in chemical engineering above 4 on a scale of "0 - not at all interested" to "6 - extremely interested" and did not indicate a higher interest in another engineering discipline were included in the analysis; all other students were removed from the present study. Of the 2,916 students who participated in the survey, 342 indicated a strong interest in chemical engineering. This approach was taken as all surveyed institutions had a first-year engineering program or delayed matriculation process that could affect how students would respond to a single question about engineering major choice. By allowing students to indicate their interest on a list of all potential engineering disciplines, we were better able to understand students who were strongly interested in one discipline or students that were generally interested in engineering but undecided as to which discipline they would choose.

Because the data could not be analyzed by each gender and race/ethnicity category in the survey due to a small sample size, we examined the intersections of majority race/ethnicity groups (*i.e.*, white, Asian, and Middle Eastern) and minority groups (i.e., black, Latino/a, and Native American, Alaska Native, Pacific Islander) along with gender (*e.g.*, male and female). Students were allowed to mark multiple race/ethnicity categories on the survey; therefore, 4% of students who were categorized in the majority were included in the minority group. Multiple linear regression was used to examine how students' attitudes were predicted by membership in different demographic groups. The analysis method was chosen to understand differences among students and allowed for comparisons of non-independent samples, thus mitigating any potential issues of this categorization. The majority/minority grouping was selected based on a National Science Foundation report that indicated women, overall, earn a lower proportion of degrees in engineering than men, and white and Asian women and men earn a higher proportion of engineering degrees in comparison to their representation in the U.S population when compared to other race/ethnicities.[25] Therefore, four distinct categorical variables were created to group students as majority male, majority female, minority male, and minority female to predict the outcomes for each group. Multiple regression predicting the attitudinal outcomes (*i.e.*, belongingness, motivation constructs, and STEM identity constructs) with each of the four demographic groups accounted for the effect of being in a majority or minority group in comparison to the other groups in the analysis upon predicting students' attitudinal outcomes. All statistical analyses were conducted in the R programming language and statistical software system.[26]

RESULTS

Of the 342 students who indicated interest in a chemical engineering major, 55% were majority men (n = 187), 29% were majority women (n = 98), 11% were minority men (n = 38), and 9% were minority women (n = 30). Our sample contained mostly domestic students, 85% (n = 291)—whereas 13% (n = 41) were international and 3% (n = 10) were non-reporting. These numbers are similar to national demographic distributions in chemical engineering.[4] The international student breakdown across the different demographic groups was: 5% were majority men (n = 16); 3% were majority women (n = 11); 2% were minority men (n = 5); and 3% were minority women (n = 9).

TABLE 2
Standardized Estimates of Multiple Regression Analysis

Predictor Variables	**Majority Women**	**Minority Women**	**Majority Men**	**Minority Men**
Belongingness	**-0.20***	0.04	-0.11	-0.02
Work Avoidance	**-0.19***	-0.03	-0.09	-0.05
Expectancy	**-0.27****	0.03	-0.07	0.02
Connectedness	**0.22***	**0.14***	0.08	0.09
Engineering Performance/Competence	**-0.26****	0.18e-04	-0.11	-0.07
Physics Recognition	-0.15	**-0.18****	-0.05	-0.05
Physics Performance/Competence	-0.16	**-0.13***	-0.03	-0.05
I see myself as a physics person.	**-0.20***	**-0.18****	-0.05	-0.04
I see myself as an engineer.	-0.09	**0.14***	-0.04	0.03
I feel like an engineer now.	-0.22	**-0.22***	-0.18	-0.06
I see myself as a math person.	0.09	0.07	**0.20***	0.02

*p < .05, **p < .01

We compared students on multiple latent variables (*i.e.*, sense of belonging in engineering, motivation, STEM-related identities) to understand underlying attitudinal differences across the intersections of both gender and race/ethnicity. The items used to measure students' attitudes in our analysis have high internal consistency with Cronbach's alpha values of $\alpha = 0.91$ for belongingness, $\alpha = 0.94$ for physics identity, $\alpha = 0.90$ for physics recognition, $\alpha = 0.92$ for physics performance/competence, $\alpha = 0.86$ for engineering performance/competence, $\alpha = 0.92$ for expectancy, $\alpha = 0.91$ for work avoid, and $\alpha = 0.77$ for connectedness. These statistical measures indicate that the questions used to score each latent construct did, in fact, measure one underlying attitude.

In predicting the different attitudinal outcomes by gender and race/ethnicity, we found significant differences in students' attitudes in chemical engineering, as shown in Table 2. Below, we discuss our findings by each demographic group.

Majority women were significantly lower on their self-reported belongingness in engineering ($\beta = -0.20$, $p < .05$), work avoidance ($\beta = -0.19$, $p < .05$), expectancy in engineering courses ($\beta = -0.27$, $p < .01$), and performance/competence beliefs in engineering ($\beta = -0.26$, $p < .01$). These results indicate that majority women were less likely than their peers to feel a sense of belonging in engineering, were less likely to avoid doing difficult tasks, and were less likely to believe they can perform well in engineering. Participants in the majority female group had negative beliefs about performing well in engineering; they also demonstrated lower beliefs on work avoidance indicating their willingness to put effort into an academic task despite lower confidence in their ability to succeed.

Both majority and minority women were significantly more likely than their peers to connect current engineering tasks with their future goals (connectedness; $\beta = 0.22$, $p < .05$ and $\beta = 0.14$, $p < .05$, respectively); all women in our sample demonstrated a stronger ability to see how particular engineering assignments, homework, and courses were related to their future goals. All women, both majority and minority, also had significantly lower physics identity than their male peers ($\beta = -0.20$, $p < .05$ and $\beta = -0.18$, $p < .01$, respectively).

We found that minority women were less likely than their peers to feel recognized by parents, instructors, and peers as a "physics person" ($\beta = -0.18$, $p < .01$) and were more likely than their peers to have lower physics performance/competence beliefs ($\beta = -0.13$, $p < .05$). Minority women also felt less confident in their abilities to do well in physics courses and understand physics concepts (*i.e.*, performance/competence beliefs). However, minority women also reported stronger engineering identities or seeing themselves as the kind of people that can do engineering ($\beta = 0.14$, $p < .05$). Despite a strong response to the question of seeing oneself as an engineer, minority women also were less likely to indicate that they felt like an engineer now ($\beta = -0.22$, $p < .05$). Prior work on identity with early career college students indicates that the reasons for not claiming an engineering identity now but seeing an engineering role as a future identity is because students do not feel that they "know enough" yet.[18] Students, especially women, most often perceive engineering as a title to be taken on after they have earned the requisite knowledge to fully participate in the community of practice.[27] However, it is important for students to develop identities early on as it shapes their motivation and persistence in engineering.[22,28]

Majority men had a significant positive estimate for seeing themselves as a "math person" or having stronger mathematics identities ($\beta = 0.20$, $p < .05$). No other attitudinal variables were significantly different for the majority male group. Similarly, no variables were significantly different for the minority male group.

DISCUSSION

We sought to understand ways in which chemical engineering students' intersecting social identities (*i.e.*, being in gender and racial majority or gender and racial minority groups in chemical engineering) influenced their sense of belonging, motivation, and STEM-related identities. Prior work has traditionally disregarded the intersection between students' social identities, by labeling students strictly into gender or racial/ethnic categories, thus theoretically erasing results for individuals who reside at these intersections.[29,30] This phenomenon is often true in engineering[31] due to the overwhelmingly large number of white and male students.[4] Our work shows that even a simple approximation of these multiple identities shows differences in majority and minority racial/ethnic groups by gender. Below, we discuss our findings in relation to prior literature for our attitudinal outcomes focusing on how these results expand existing knowledge from studies that examine only gender or race/ethnicity.

Belongingness

Consistent with prior literature on women, in general, we found that women in the majority group (*i.e.*, white, Asian, and Middle Eastern women) were less likely to feel a sense of belonging in engineering.[32-34] Despite similar findings in prior work, the results of our work indicated that majority women, not women as a whole, experienced limited belongingness in chemical engineering. This finding indicates that previous work likely overrepresents the experiences of majority women in engineering. We hypothesize that majority women who are choosing chemical engineering are not selecting this major because of their sense of belongingness in engineering; rather, they are selecting this major for other unexplored reasons.

Additionally, the finding that minority women did not have significantly lower levels of belongingness was also consistent with prior work on minority women. Work tracking students from 1987 to 2010 showed that the number of minority women drawn into chemical engineering was low compared to majority women.[35] Even though chemical engineering attracts a higher number of women overall than other engineering disciplines, the numbers of racial/ethnic minority women in chemical engineering is consistently lower than the average of other engineering disciplines.[4] However, those who do matriculate into engineering "may already be filtered as hav[ing] a higher predilection towards successful persistence."[31] This filtering process may remove women who would be unlikely to feel an affiliation with chemical engineering and subsequently favors those already possessing a strong sense of belonging. Understanding how majority women feel that they do or do not belong in chemical engineering (rather than all women) is important, as previous studies have suggested that many women leave the field of engineering from a lack of belongingness as opposed to a lack of talent.[33,35] Our finding indicates that it may be majority women who are most at risk of leaving engineering and thus may need more support to foster their belongingness within chemical engineering. We emphasize the importance of belongingness here as it has been cited as one of the main reasons—over academic performance or other career interests—why women leave engineering.[10,35] Of our sample, 29% were majority women; if their low belongingness is not addressed, chemical engineering could be at risk for significant losses in the numbers and diversity of students either in college or in the transition to industry.

Motivation

We found that both majority and minority women displayed lower expectations for success than did their peers. Prior work, while not explicitly focused on chemical engineering students, found that women in engineering had lower levels of self-efficacy than their male peers did.[35] Similarly, a six-year longitudinal study in engineering and science found that high-achieving women demonstrated a significant drop in academic self-confidence. Rather than becoming more confident as they progress through their degree, "the proportion of women reporting lack of self-confidence nearly doubles by the senior year."[36] The decreased expectations of success for majority women may also fuel their desires to work harder in engineering (*i.e.*, having lower work avoidance). As majority women feel they are less likely to succeed in engineering, they may feel that they have to work harder than their peers to reach their future goals in and out of engineering. The finding that majority women feel less likely to succeed in engineering is concerning considering the growing need for diverse and talented engineers in the engineering workforce.[1,2] Developing ways to support majority women's beliefs about their ability to succeed is important in combatting increasingly low female enrollment in engineering.[37]

Majority and minority women displayed higher levels of connectedness (*i.e.*, planning for the future) which can serve to positively influence performance on present engineering tasks and increase the valuing of these tasks.[12,13,15,38] This result is in contrast to previous work examining connectedness in mechanical and aeronautical engineering that demonstrated no significant difference between the connectedness scores of men and women.[39] When taken together, our results indicate that while women plan for a future in engineering they struggle to see themselves performing in their courses at similar levels to their peers. Noting that women report lower attitudes related to their expected course performance highlights a need to examine the practices that occur within engineering classrooms that foster positive development of these traits.

Identity

Work has shown that seeing oneself as an engineer or having an engineering identity can influence engineering choice.[19] In this work, we found that minority-group women identified with engineering more than their peers on the question, "I see myself as an engineer." Additionally, we found minority women's positive perceptions of seeing themselves as engineers, in general, were in contrast with their negative beliefs about identifying as an engineer in the present ("I feel like an engineer now"). This finding is consistent with work that showed early career engineering students were more likely to see themselves as engineers in the future but had difficulty identifying as an engineer now.[27,40] This combination of findings presents an opportunity to help support minority women in their development of positive identities as chemical engineers within the engineering classroom rather than framing "being an engineer" as a far-off goal. For minority women to become members of the chemical engineering community, they will need to develop an identity that aligns with cultural norms associated with the field. Acquiring the knowledge and skills necessary to become a chemical engineer may not be enough for these women to take on an engineering identity as it has been shown that students need to see themselves and be recognized as legitimate participants in the community of practice.[19] Developing a chemical engineering identity and developing expertise in the discipline "are part of the same process, with the former [developing an identity] motivating, shaping, and giving meaning to the latter, which it subsumes."[41]

Additionally, physics identity has been shown as the most important science identity (among chemistry, biology, and physics) for engineering choice.[22] Our analyses found that both majority and minority women were less likely to describe themselves as a "physics person," and minority women had fewer instances of being recognized as someone who can do physics by their instructors, peers, and family members. These results indicate that women in chemical engineering may struggle more than male peers in developing a physics identity that supports engineering identity development.[19] This finding may also have implications for particular required courses that are gatekeepers to engineering progress, like physics, in which students may be less motivated and more prone to struggle with course material that does not align with how they see themselves.

We also found that majority women felt less confident in understanding engineering and performing well in their engineering courses in self-reported measures of performance/competence beliefs. Similarly, our results indicate that minority-group women have lower self-reported levels of their perceived abilities to do well in physics courses. Previous work has shown that female chemical engineering students as a whole (*i.e.*, not separated by race/ethnicity), tended to have higher academic achievement on performance metrics including high school grade point average (GPA), SAT math and verbal scores, and cumulative college GPA compared to other engineers, science majors, and non-science majors.[42] While another study found that irrespective of gender and race/ethnicity, chemical engineering students graduated at comparable rates to other engineering majors.[43]

Taken together, our results suggest that while there is evidence that both majority and minority women succeed in chemical engineering, they may not readily internalize those beliefs and develop an identity as a chemical engineer. This finding is concerning as these attitudes—and not just academic performance—are important for retention within engineering majors and upon graduation in engineering jobs.[44] These results tell a more nuanced story of women in chemical engineering, showing differences by majority and minority racial/ethnic groups.

Noticeably, there was only one difference in the results for majority men and no significant differences for minority men. Majority men were significantly more likely to indicate a higher mathematics identity than their peers were. This finding is consistent with prior work that has shown mathematics identity as being stronger for men than for women (and by default, the comparison between men and women overrepresents majority students).[19] No other differences were found for these groups, which emphasizes the need to address lower belongingness and motivation for majority women and lower physics identity and current identification with engineering for minority women.

IMPLICATIONS

Our results indicate that students by gender or race/ethnicity do not have homogeneous attitudes within chemical engineering. Below, we discuss the implications of examining the intersection of gender and race/ethnicity to better understand and support underrepresented students in chemical engineering. Our findings have implications for engineering education researchers as well as educators in supporting student recruitment, retention, and success in chemical engineering programs.

Instructors should not accept a single story of student attitudes or beliefs. These attitudes are different not only by gender or race/ethnicity as has been explored in prior research on diverse students but also by students who sit at the intersection of these demographics. Additionally, prior research on women in engineering has suggested that women have lower levels of belongingness and beliefs about their ability to perform tasks and succeed in courses.[45,46] These prior findings may overrepresent the attitudes of majority women rather than reflecting the attitudes of all women. Indeed, our results show that these findings are not consistent for minority women.

Additionally, minority students may not have the same attitudes in engineering as their majority peers. We found that minority women have much lower levels of physics identity than their peers but also start college more strongly identifying as engineers than other students. From prior research, we know that STEM identities broadly—including mathematics, physics, and engineering identities—are important for long-term persistence and satisfaction in engineering.[19,27,47-52] Instructors may need to provide additional opportunities for majority women to develop and minority women to sustain these identities in their courses. We list some evidence-based ways to support identity development below.

- *Refer to chemical engineering students as engineers rather than engineers-in-training or future engineers in the classroom. This subtle change in students' role can shape how they view themselves and may provide opportunities for recognition.*[41]
- *Create projects in the class that allow students to choose a set of topics that are more closely aligned with their personal interests. Fostering learning through connecting to students' own interest can promote identity development and increase motivation.*[53,54]
- *Use active-learning strategies, which can develop elements of student interest in engineering environments.*[55,56]
- *Provide positive reinforcement and educational opportunity to all students in the classroom including those who may be struggling. Avoid always calling on the same students or only recognizing the "smart" students in the classroom. For instance, those who are deemed "smart" (by measures of grades and test scores) often are afforded certain educational opportunities and pathways not afforded to those deemed "struggling" (by the same measures).*[57]

From our research, majority women have lower levels of belongingness in engineering. We offer some potential ways to encourage belongingness for women in chemical engineering.

- *Develop positive and caring relationships with students. Research shows that students who perceive that they have even one positive relationship with a faculty member can reduce students' intentions to leave their major or institution. Communicating caring to increase belongingness is influenced by the availability of faculty during office hours; how comfortable students felt when discussing personal problems with their faculty; and the overall ease while discussing career goals with their faculty member.*[58] *Communicating and openness-to-discussing difficult topics and being available can help promote belongingness for all students.*[59]
- *Provide opportunities for community-building experiences. These could include events through disciplinary societies like AIChE, department meals, or other events designed to involve students within the chemical engineering department.*[60]

Majority women may need additional support in developing their beliefs about their ability to succeed in engineering courses. We list some evidence-based ways to support all students' beliefs about their ability to succeed in engineering below.

- *Demonstrate desired behaviors through modeling engineering best practices. Provide more senior student mentors for students or place underrepresented students with similar individuals in teamwork and course-based interactions to observe desired practices.*[33,61,62]
- *Provide students with tasks that can be accomplished and explicitly teach students how to create and utilize sub-goals when approached with difficult tasks.*[61,62]
- *Inform students that stress is normal as skills are developing and train students to use these frustrations as a form of feedback for progress.*[61,62]
- *Ensure that assessment matches the desired and professed learning outcomes of a course so students can self-assess progress.*[33,61]

Not all our findings were negative for women. We found that both majority and minority women had significantly higher connectedness than their male counterparts did. This ability to make links between current engineering coursework and future career goals can provide a useful, alternative perspective in the classroom. Highlighting how particular engineering work in the class connects to industry problems and future careers in chemical engineering has been shown to improve students' desire to learn.[12] Leveraging the strength of female students to make explicit connections in teaching and future work as engineers can improve the engineering classroom for all students.

LIMITATIONS AND FUTURE WORK

Our study provides a useful start to examining student attitudes by both gender and race/ethnicity. We hope that this study begins to challenge some of the commonly held beliefs about women or racial/ethnic minorities, in general. As with any study, we have some limitations that should be acknowledged when discussing our work.

The population of this study comes from four institutions; while geographically diverse, they are not representative of the national engineering or chemical engineering population.

The study population consisted of students who reported an interest in chemical engineering during the first two weeks of their first engineering course but were not declared chemical engineering majors. As such, our survey required students to know what chemical engineering was and to have developed an interest in engineering prior to starting their undergraduate degree. This work does not explain how students in broad, first-year engineering programs can develop an interest in chemical engineering over the course of their first semester.

The data used in the analysis are cross-sectional. No causal inference can be concluded from these results. For example, students' demographic backgrounds could influence their particular attitudes and beliefs in engineering or underrepresented students' experiences in engineering could shape their attitudes and beliefs. Despite this limitation, the results begin to illustrate the need for examining the intersections of gender and race/ethnicity as well as reflecting on the different attitudes that students bring into engineering and the distinct experiences that students may have in their engineering classroom.

Additionally, we report standardized estimates of the overall attitudes of student groups. This analysis can give chemical engineering educators a general understanding of students' attitudes; however, the results should not be generalized to all students. We were not able to represent individual differences in students' background, experiences, and attitudes using quantitative methods. Due to limited sample size, we were also unable to explore fully the intersections of individuals' more nuanced self-identified gender identity and race/ethnicity. Additionally, this limited sample size forced us to ignore other aspects of students' backgrounds including, but not limited to, socioeconomic status, generational status, and disability status. While this analysis does allow for more nuanced examination of students' attitudes, it does not fully explore the full breadth of students' possible demographic differences.

Finally, in this study, we did not have measures for chemistry identity. Physics identity does play a role in how students choose engineering and persist in engineering. Additionally, we did find differences among chemical engineering students at the intersection of gender and race/ethnicity. However, we acknowledge that for chemical engineering students, other science identities may be a stronger predictor of major choice and persistence. Future work could include examining how chemistry identity influences diverse students' pathways in chemical engineering.

CONCLUSION

In this paper, we examined first-year engineering students interested in chemical engineering by gender and race/ethnicity for differences in their sense of belonging, motivation, and STEM-related identities. We chose to examine these attitudes as they impact significant aspects of engineering-student experiences including but not limited to choice of major,[50] persistence,[63] and course-level performance.[12,44] We found significant differences in belongingness, expectations for success, connecting engineering task to future goals, and engineering and physics identities. Our results indicate that majority women may struggle to belong or develop expectations for success in engineering compared to their peers. Additionally, minority women indicated lower physics identity constructs (recognition and performance/competence beliefs) and a lower indication of feeling like an engineer now than their peers. These women also had stronger ability to connect engineering tasks to their future goals. Our findings highlight that the experiences of women in engineering are more complex than just gender and that other background factors, like race and ethnicity, serve to influence students' attitudes and beliefs. Our results also provide some practical implications for supporting underrepresented students in engineering and leveraging their unique strengths in the chemical engineering classroom.

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