# The Effect of Diversity on Feelings of Belongingness for New Engineering Students

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***Abstract*—This research category full paper seeks to understand if feelings of belonging differ according to student demographics for first-year engineering students. Engineering has maintained a stable profile (i.e., white, masculine, and male) for many years, despite national trends in higher education. Multiple researchers have demonstrated that increased diversity leads to improved communication skills, creativity, and problem-solving capabilities, all goals that directly align with engineering's core values. The lack of diversity within engineering has resulted in a culture which produces engineers that are underprepared and lacking the skills required to work in an increasingly diverse and global engineering market. Engineering's cultural attitude towards diversity has created environments where students, especially underrepresented minorities (URM), feel that they do not belong despite meeting the academic requirements. To better understand feelings of belongingness within engineering education, the research team set out to answer the question: How do feelings of belongingness differ across demographic characteristics for new (second week) engineering students, enrolled in a first-year first-semester engineering course? Our results demonstrate that neither disability status, race or sexual identity significantly affect how new engineers report their perception of belonging. Female students entered engineering feeling that they belong but at a level significantly lower than their male peers. This suggests that there is still much work to be done in the K-12 environment to cultivate female students' interest and confidence in engineering, as well as room for improving the welcoming of all students into engineering education.**

***Keywords—Belonging, Diversity, First-year engineering***

## I. Introduction

"Developing optimal, innovative solutions to real rather than theoretical problems [1, p. 11]" is the dominant objective of engineering practice. Problem-solving and design skills are revered within engineering culture, even more than fellow engineers [1], [2]. In other words, engineering values what you can do (e.g., problem-solving) and not who the engineer is. The intense focus on technical skills has resulted in a system that produces engineers that are underprepared and lacking the skills required to work in an increasingly diverse and global engineering market [3]. Additionally, the disconnect between the technical and the social aspects of engineering has produced an atmosphere that has been described as unattuned, unwelcoming, and chilly to diverse students [2], [4]–[8]. Resulting in an educational environment where students, especially underrepresented minorities (URM), often feel that they do not belong despite meeting the academic requirements of the discipline. This sentiment was epitomized in the pivotal story of Inez [8], a female minority engineering student.

When discussing her engineering education experience, Inez reveals that over the course of her academic career she faced numerous obstacles including being actively deterred from an engineering career. Throughout her story, Inez reveals that engineering creates and maintains an exclusionary mentality of an 'us' vs 'them' [8, p. 110]. This segregation not only separates engineering from other majors but also isolates students within engineering based on a variety of demographic and academic criteria. Inez's story culminates when she expressed that she wished that she "belonged more in the whole engineering group"[8, p. 104].

Multiple researchers have validated the assumption, that having and retaining multiple points-of-view and a diverse cognitive repertoire leads to the development of better engineering solutions and designs [14]. Literatures indicates that cognitive diversity leads to improved communication skills, creativity, and problem-solving capabilities [9]–[11], all goals that directly align with engineering's core values and accreditation requirements [12]. This body of literature, when paired with reports of an unwelcoming culture, highlights the importance of supporting students' sense of belongingness.

While literature has often explored the effects of engineering culture on students' belonging, the literature predominately focuses on belonging for upper-division engineering students. This has left a gap in the literature concerning the belonging of those who are entering engineering programs. Understanding the feelings of belonging for first-year students is especially important as the first year is the "critical year in which decisions to stay or leave are most often made [13, p. 8]." To better understand the feelings of belongingness within engineering education, the research team set out to answer the question: How do feelings of belonging differ across demographic characteristics for new (second week) engineering students, enrolled in a first-year first-semester engineering course?

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## II. Theoretical Foundation

Tinto's model [13] for student retention posits that when students are integrated into and feel they belong to the social and academic environment there is a greater likelihood for them to persist through graduation. Further evidence supporting the importance of students' sense of belonging, Godfrey, Aubrey, and King [14] showed that a sense of belonging was often cited as a reason engineering students left their program or institution. Leveraging an existing, robust body of literature we draw on Self-Determination Theory (SDT) as a theoretical framework to explore belongingness in first-year engineering students. SDT examines the motivation(s) behind and the level to which an individual's actions are self-determined. According to Deci and Ryan [15], there are three innate psychological needs: autonomy, competence, and relatedness. Fulfillment of these needs is essential to psychological health and overall well-being. The drive to satisfy these needs provides the impetus for many of the actions that people undertake. While SDT posits three basics psychological needs, we focus our investigation on a single need, relatedness, which remains the most understudied [16]. Relatedness is a "sense of belongingness and connectedness to the persons, group, or culture disseminating a goal" [15, p. 64]. When considered in engineering education literature, relatedness is often discussed as belongingness. Continuing this tradition will refer to this idea as belongingness in our study.

According to SDT, the degree to which a student's psychological needs are met can predict their level of motivation and persistence. Additionally, belongingness is positively correlated with, increased motivation, improved academic performance (e.g., grades), feelings of joy, and overall student health [17]–[20]. However, when a feeling of belonging has been left unsupported research has demonstrated both academic and personal consequences. "Research indicates that individuals who report a lesser sense of belonging are more likely to report higher levels of depression" [21, p. 3]. Furthermore lacking a sense of belonging is associated with anger and sadness [20], [22]–[24]. Supporting a sense of belonging is multifaceted and can be achieved through both direct intervention and through social interactions. Walton, Cohen, Cwir, and Spencer [19] claim that minimal social cues are "sufficient to create a sense of social connection to a field of study and that this social connection can cause people to internalize motivation for the field [19, p. 521]."

Additionally, in a longitudinal study designed to bolster first-year students' sense of belonging, Walton and Cohen [20] found that a brief belongingness intervention during the first year had lasting effects. "The intervention aimed to lessen psychological perceptions of threat on campus by framing social adversity as common and transient; [20, p. 1447]" this message encouraged students to attribute adversity to the college transition period and not fixed deficits unique to themselves or their ethnic group. Three years after the intervention Walton and Cohen reported that participants on average reported improved health and overall well-being, as well as "raised their grade-point average relative to multiple control groups and halved the minority achievement gap" [20, p. 1447]. Their intervention was particularly successful for African American students, a group that is often marginalized within engineering. This study also highlights that interventions intended to target a specific group often benefit all participating students.

Investigations of the engineering education experiences of underrepresented students tend to show that the climate of engineering is unwelcoming [4], [25]. An alternative way to express this sentiment is that students that do not adhere to the stereotypical definition of an engineer (i.e., a white male) often feel that they do not belong or are not fully included into engineering culture. As students experience the unwelcoming environment, they may start to internalize the adversity and attribute it to personal characteristics (e.g., gender, race/ethnicity, sexual identity) [26]; this internalization is then reinforced externally through the lack of similar peers and can decrease their belonging in engineering. As Tinto [13] posits and Godfrey, Aubrey, and King [14] confirmed, lacking a sense of belonging can lead to attrition from engineering. Therefore, it is critical to understand how engineering education influences students' sense of belonging, especially early in their academic career.

## III. Methods

### A. Study Population and Environment

A first-year, first-semester engineering design course at a Western land-grant institution was studied, to understand the feelings of belonging for new engineering students. Six hundred and sixty students were registered in the course, of which 525 (80%) identified as first-year students (no previous college experience). The 525 first-year students in the course represent 95.5% of all first-year students enrolled in the College of Engineering. Therefore, not only does this course reflect many national first-year engineering programs, but also is representative of the incoming class of engineering students.

The first-year course being studied utilized an open engineering lab (OEL). The OEL is multi-use space open to all engineering students; however, it is used primarily for the first-year design course. Within the OEL there is a computer classroom, several open workstations, open access computers and a supply desk where the students can get materials required for their semester-long design project. During regular operation approximately 50 students would use the space at any one time, however, the research team observed (as part of the larger study) upwards of 150 students simultaneously in the OEL [27], [28]. As part of the opening weeks of the semester course materials included lectures on teaming skills and creating an inclusive environment.

### B. Belongingness Survey

This study focuses on the feelings of belonging for new engineering students. To accomplish this an online survey was administered during the second week of the semester ($n$ = 608, 92.1% response rate). Six belongingness questions

were asked as part of a larger survey examining student attitudes, beliefs, and perceptions of diversity. The belongingness questions create two factors that explore how the students perceive their fit in engineering (belonging to engineering; e.g., "I feel comfortable in engineering.") and then more specifically their feelings of belonging within the engineering classroom (belonging within engineering; e.g., "I feel that I am part of my engineering class."). When combined they provide an insight into the feelings of belonging for new undergraduate engineering students.

### C. Data Cleaning and Analysis

For this study, we examine diversity in terms of, race, disability status, non-binary categories of gender, and sexual orientation. While the survey provided an opportunity for the students to indicate how they identify across these categories, student responses created numerous small groups. For example, student responses included 12 unique sexual orientations, while the more inclusive survey questions work to support an inclusive educational environment [29], they create additional challenges during analysis. To maintain participant confidentiality and statistical power, student responses were aggregated (specifics are provided along with the results). Once aggregated groups were created, one-way analysis of variance (ANOVA) was conducted to determine if differences in feelings of belongingness occurred based on demographic categories. List-wise deletion was utilized to address missing data. Initial analysis was conducted on the overall sense of belongingness; when warranted, the analysis was furthered to explore difference among the individual belongingness factors (belonging to engineering and belonging within engineering).

## IV. Results

Table 1: Descriptive statistics for overall belongingness and each belongingness factor.

| | Overall Belonging | Belonging to Engineering | Belonging within Engineering |
|---|---|---|---|
| *N* | 536 | 536 | 536 |
| mean | 4.57 | 4.6 | 4.5 |
| Std. Dev. | 0.98 | 1.04 | 1.02 |
| Median | 4.67 | 4.75 | 4.5 |
| Min. | 0.5 | 0.5 | 0.5 |
| Max. | 6 | 6 | 6 |
| Skew. | -0.03 | -0.42 | -0.22 |
| Kurtosis | -0.38 | -0.27 | -0.48 |

### A. Belongingness

As a first step to understanding the feelings of belonging for new engineering students, descriptive statistics were generated for the overall feeling of belongingness and each factor (Table 1). Through the descriptive statistics the assumption of normality was verified using the criteria of skewness $\leq |2|$ and kurtosis $\leq |7|$ [30]. Confirming the assumption of normality allowed for the use of parametric hypothesis testing methods (i.e., One-way, between subjects ANOVA). From Table 1, it is observed that new students enter engineering education with a relatively high perception of their belonging (scale 0-6).

### B. Disability Status

The research team took the position that like belongingness disability status is based on the students' perception of their disability. Students were asked "How do you describe your disability/ability status?" and subsequently provided an opportunity to indicate both a general classification of their disability status and could indicate their specific disability/ability status. Of the 660 students enrolled in the class, 485 (73.5%) students responded to these questions and 89 (13.5%) students indicated a disability. It is important to note, for this analysis the research team did not differentiate between disabilities. For example, if a student indicated "A temporary impairment due to an illness or injury" or "A history of traumatic brain injury from Afghanistan" in either case they were included in the disability group. Aggregation of the participants resulted in three groups, no disability identified, disability, and prefer not to answer ($n$ = 367, 89, 29, respectively). One-way, between subjects ANOVA was conducted to determine if disability status affected feelings of overall belonging. Results indicated that disability status is not a significant factor for feelings of belongingness [$F(2, 482) = 0.6258$, $p = 0.5353$].

### C. Race

Students were provided an opportunity to self-identify their racial/ethnic background through both a pre-populated list and free-response ($n$ = 504, 76.4% response rate). To be inclusive of how students self-identify they were permitted to indicate all racial and ethnicities with which they identify, resulting in 39 unique racial and ethnic backgrounds. To protect from participant reidentification and maintain statistical power, student responses were simplified into five identifications, two of which include multiple racial identifications. The aggregated groups include multi-racial ($n$ = 98), which included all students that identified with more than a single race. Underrepresented group (URG; $n$ = 50), which includes student identifications of Black, Middle Eastern, American Indian, and Hawaiian or Pacific Islander. In addition to the two aggregated groups, the analysis includes students that self-identified as White ($n$ = 284), Hispanic ($n$ = 59) and Asian ($n$ = 33). One-way, between subjects ANOVA was conducted to determine if racial identity affected feelings of belongingness. Results demonstrated that race is not a significant factor for feelings of belongingness [$F(4, 486) = 2.162$, $p = 0.0686$].

### D. Sexual Orientation

Within the literature on belongingness, it has been reported that non-heterosexual students often face issues of acceptance and perceptions of belonging [31]. To understand the inclusiveness of the OEL, students were asked "How do you describe your sexual identity? Mark all that apply" ($n$ = 489, 74.1% response rate). In total students indicated 12 unique sexual identities, which were aggregated into two groups for analysis. Students that identified solely as heterosexual ($n$ = 457) were included in a single group the remaining sexual identities were included in an LGBA+ (lesbian, gay, bisexual, asexual, and additional sexual orientation minorities) category ($n$ = 32). One-way between subjects ANOVA was conducted to explore how feelings of belongingness were affected by student sexual identity. The analysis concludes that feelings of belonging do not significantly vary according to student sexual orientation [$F(1, 487) = 0.8683$, $p = 0.3519$].

### E. Gender

Students were asked "How do you describe your gender identity? (Mark all that apply)." Students responded with 15 unique self-identification, the abundance of identifications required aggregation into groups suitable for analysis. Both male ($n$ = 383) and female ($n$ = 105) gender groups include students that responded with the additional modifier of cisgender. After creating the male and female groups, 14 students from 10 different gender identities were removed from the analysis. While these students have been removed from this analysis, their experiences are included our larger mixed methods study. Allowing for a more nuanced exploration for an understudied portion the population. To understand the effects of gender on students' perception of belongingness, one-way, between subjects ANOVA was conducted on the measure of overall belongingness. The resulting ANOVA demonstrates that female students ($M = 4.38$, $SD = 0.98$) felt significantly less belonging [$F(1,468) = 6.497$, $p = 0.0111$)] than their male peers ($M = 4.65$, $SD = 0.98$).

To further study this phenomena analysis was continued using the two belongingness factors to allow for a deeper understanding of how belonginess is related to gender. The extended analysis has the potential to clarify if female students felt less belonging to engineering holistically or within their classroom. The resulting ANOVA indicates that female students feel significantly less (-0.25) belonging in engineering as a field [$F(1, 486) = 5.094$, $p = 0.0245$] and in the engineering classroom (-0.28) [$F(1, 486) = 6.21$, $p = 0.013$]. In summary female students have a slightly lower, yet significant, perception of their belonging to and within engineering than their male peers.

## V. Limitations

This study has shown that students enter engineering education with strong feelings of belonging within and to engineering. We have also revealed that female engineering students feel significantly less belonging than their male peers. The feelings of belonging that were analyzed were collected during the second week of a first-year first-semester engineering design course using an OEL. The feelings of belonging that new engineers report is likely a combination of engineering specific belongingness as well as feelings of belonging to the college and institution. Additionally, the data analyzed is from students that have yet to have a prolonged exposure to engineering culture and values. While many studies have examined the influence of engineering education on affective traits, such as belongingness, this work set out to understand these initial conditions.

While we have demonstrated demographics have limited influence on feelings of belongingness the analysis performed did not consider intersectionality of the participants. For example, while we can speak regarding the average feelings of belonging for female or African American students, we cannot speak about the feelings of the average African American female, which are potentially different than either of the demographic groups independently.

## VI. Discussion

### A. Belongingness in SDT

Self-determination theory posits that fulfillment of the three basic psychological needs is essential for sustained motivation and overall wellbeing [17]. The strong feelings of belonging that were reported by the new engineers, may potentially supplement the other two psychological needs (autonomy and competence). This 'surplus' may help sustain motivation and increase their likelihood of persistence as they face the challenges of an engineering degree. URM student belongingness may be more vulnerable to degradation than their majority peers. This vulnerability has been noted in literature that examines students later in their engineering education experience [7], [32]–[34]. This study in conjunction with the broader literature bases alludes that students feel like they belong in engineering early on because they were admitted. However, over time their experiences within engineering culture shifts their perceptions of fit. Thus, work is needed on how to maintain and/or further cultivate belonging. Cultivation and maintenance of belonging should become a focal point for engineering educators seeking to improve the student experience. Especially, when considering the growing demand for engineering to become more representative of national demographics [3], [4].

### B. *Overall belongingness*

Students are entering the OEL with strong beliefs regarding their belonging in an engineering environment. This outcome is true across a wide range of demographic markers. Our results imply that engineering education may be fostering an exclusionary environment that exhausts the feelings of belongingness new students enter with. Further this result also suggests that there is a temporal effect (i.e., greater than the two-week period explored in this study) of engineering culture that works to undermine the belief that a student belongs in engineering. While this is concerning,

there is a positive aspect, new engineering students are starting their education believing that they belong. Therefore, engineering education needs to focus efforts on maintaining or at least doing no harm to students' belongingness beliefs.

### C. Female students' belongingness

Female students entered the OEL feeling that they belong but at a level that is significantly lower than their male peers. Suggesting that there is still much work to be done in the K-12 environment to cultivate female students' interest and confidence in engineering, as well as room for improving the welcoming of all students into engineering education. Engineering education research has documented that engineering tends to produce a negative experience for women [6], [35]. Within engineering the norm is to be male and for females to "be "other"- an accepted and often respected "other", but different nevertheless [1, p. 14]. Powell, Bagihole, and Danity [35], in summarizing Gherardi's work, suggest "that when women are actually accepted into a traditionally masculine environment, they are often made the object of displays that typify the community of men." Resulting in an "implicit devaluation of femaleness [35, p. 413]." This suggests that for females to belong in an engineering environment/culture, they must repress part of their identity and become one of the "guys".

The lower initial feelings of belonging indicate a greater likelihood for attrition from engineering as one of the three basic psychological needs is not being satisfied. Satisfaction of the belongingness need is required for sustained motivation [15], [17]. If this need is not being met there is an increased likelihood for attrition [13], as the student seeks environments in which all needs are satisfied. Students show more interest in majors where they perceive they belong. For example, Tellhed and colleagues [36] reported that part of the reason women are more interested in healthcare, elementary education, and domestic sphere majors than men are, and men more interested in STEM majors than women are, is related to social belonging concerns. Additionally, recent literature suggests that female students have greater choice in major than their male peers [37]. Therefore, one of potential reasons engineering has struggled to improve representation of women is that when faced with struggles to belong female students may opt to change their career path to one that readily meets their psychological needs and career ambitions. This scenario highlights that engineering is creating cultural obstacles that students must navigate in addition to the challenging academic requirements.

## VII. Implications

Students are reporting that initially, they believe they belong in engineering, regardless of demographic characteristics. Literature suggests that students who do not fit the mold of a typical engineer (i.e., white, masculine, and male), the climate is unwelcoming and chilly. When these two observations are considered together, it suggests that engineering education may erode feelings of belonging over time. However, previous work in SDT has shown that pedagogical interventions can build and sustain students' belongingness. For example, Walton and Cohen [20] demonstrated that a belongingness intervention during year one had measurable effects three years later, which included increased GPA, higher levels of reported happiness and halved the minority achievement gap, this was especially prevalent for African American students. Designing interventions to target belongingness within engineering may work to support students in the long-term and potentially the definition of a typical engineer. It is also important to note that while the Walton and Cohen intervention was shown to have tremendous benefits for African American students, all groups of students exhibited positive benefits. That is there is potential for purposefully designed motivation interventions to support all students, including URM.

## VIII. Future Work

Given the results of this work several suggestions for future work have arisen. First, work is needed to understand when students' high perceptions of belonging to engineering begin to drop off. Understanding how these feelings shift over time indicate points when intervention may be most beneficial. This could be done through longitudinal tracking of students or through comparison of first-year to upper division engineering students. Additionally, work is needed to understand how we can increase the belongingness of female students prior to and after they have entered engineering at the college level. Finally, work can expand the connections made in this study by directly exploring how students' initial belonging to engineering influences other affective factors such as their desired futures in engineering, their intentions to persist, and their actual persistence in engineering.

## IX. Conclusions

"Given that SDT is grounded in individuals' pursuit of satisfying needs and not an objective or even subjective reality as perceived by others" [16, p. 251], it is important that engineering educators understand and support feelings of belonging. Through the development of inclusive environments that support students' psychological needs, engineering education will not only support the overall health of its constituents but will increase the likelihood of students persisting through the rigorous academic demands. Often when studying engineering education, the focus is on students who have had an opportunity to be fully immersed in engineering's culture. In contrast, we examined the feeling of belonging to and in engineering for an incoming cohort of new engineering students. We have shown that most students have strong beliefs that they belong in engineering. The observation that female students enter engineering education with slightly repressed feelings of belonging suggests that there is still much work in the K-12 setting to reduce gender basis for STEM fields. While there is still work to be done to allow engineering to become more representative of higher education and national demographics, we have shown that for this institution students are entering college broadly believing that they belong.

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