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Analyzing Self-Reported Sense of Belonging, Engineering Identity, Intent to Persist, and Stress Levels Among First-Generation and Non-Traditional Students in a First-Year Engineering Program

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Abstract

In this research paper, we provide an analysis of self-reported variable such as sense of belonging, engineering identity, intent to persist, and stress levels among first-generation and non-traditional students in their first year of engineering education. In the context of prevailing stress culture in undergraduate engineering education, substantial efforts are made to improve the condition of these variables to support students' wellbeing and academic success. Utilizing existing social and psychological frameworks, this research intends to support the success of such efforts, especially in the case of minoritized college students (first-generation and non-traditional engineering undergraduates). We offer a detailed understanding of how sense of belonging, engineering identity, intent to persist, and stress interact and impact students' experiences. Quantitative cross-sectional data was collected from first year engineering students (n = 699) in a large Midwestern University in the U.S. through an online survey. The combined sample included 25% female, 49% first generation, and 23% non-traditional students. Independent samples t-tests revealed significant differences between first-generation and continuing-generation engineering students across all variables. First-generation college students reported significantly lower intent to persist (p = .00), engineering identity (p = .01), and higher stress levels (p = .02) compared to continuing-generation study participants. A one-way ANOVA revealed no significant differences based on the above variable among traditional, and non-traditional study participants. Findings from this study emphasize the need for targeted support for first-generation students. Overall, this research highlights the importance of tailored interventions including curricular changes to promote equity and success in engineering education. These findings can help guide strategies to create a more supportive environment that promotes the success and well-being of first year engineering students.

Keywords: first year engineering, sense of belonging, engineering identity, persistence, stress, engineering education

1 | BACKGROUND

The current first-year engineering curriculum is rigid and lacks flexibility, offering students limited opportunities to make choices as they work toward their degree. This rigidity is unappealing to today's students, as it hinders their ability to personalize their educational experience while developing as professionals. Moreover, the structure fails to accommodate diverse learning styles or varying starting points, leaving some students—particularly those from disadvantaged backgrounds—at a significant disadvantage. Many face challenges catching up or may never even begin. Research highlights that institutional barriers like these contribute to lower completion rates among students from underrepresented gender, racial, and ethnic groups [1]. Similarly, the subjects of this study i.e., first-generation college students (FGCS) [2] and non-traditional students (NTS)

[3] also experience lower rates of degree completion compared to their peers due to the similar reasons. First-generation college students (FGCS) are the first in their immediate families to pursue college education (neither of their parents has a bachelor's degree) [2]. The National Center for Education Statistics (NCES) identifies seven key traits that distinguish NTS from traditional ones [4]. They are: postponing college enrollment, being a part-time student, being financially independent, full-time employment while studying, having dependents other than a spouse, being a single parent, and earning a GED or other nontraditional high school credentials instead of a standard diploma.

We argue that engineering curricular rigidity and inflexibility may be among the various causes of mental health and wellbeing (MHW) problems characterized by low levels of sense of belonging, engineering identity, and intent to persist and higher levels of stress for students in their first-year. These problems may then persist throughout their undergraduate studies. Therefore, corresponding to the above calls to bring about positive changes in engineering education experiences, and towards realizing the goals of the Mindset effort, we are in the process to modularize the First-Year Engineering at the University of Cincinnati, providing students with flexibility, choice, and customizability for their first-year experience through an NSF grant [5]. The modules we envision will each be 0.5-1 credit each and will cover a wide variety of topics appropriate for students in a FYE program. We expect the envisioned course modules to improve MHW among first-year engineering students within the above constructs.

This research is part of a larger project [5 - 8]. In this paper, we report on the baseline quantitative data reported by participants in their FYE program in the Fall of 2023 about their sense of belonging, engineering identity, intent to persist, and perceived stress. As part of a larger longitudinal study that will be conducted over the length of the project i.e., 3 years, baseline data prior to the implementation of the proposed course module interventions has been collected to make comparisons with participant data that will be collected after the modules are implemented to assess any changes in the above psychological constructs.

Further, the baseline quantitative data will serve as a foundation for our future research, guiding the collection of rich qualitative data through interviews and focus groups with students, faculty, and advisory staff. By triangulating these diverse qualitative methods, we aim to gain deeper, more nuanced insights into the factors that positively or negatively impact the overall wellbeing of first-year engineering students at our institution. Specifically, the FGCS and the NTS population.

This work is unique in its approach to addressing the mental health and wellbeing (MHW) challenges faced by first-year engineering students by directly targeting the structural rigidity of traditional engineering curricula. By modularizing the First-Year Engineering program at University of Cincinnati, we provide students with the opportunity for greater flexibility and customization in their educational experience, which may foster a stronger sense of belonging, improve engineering identity, and alleviate stress. This intervention is aligned with the goals of the Mindset effort (initiatives or research focused on fostering a growth mindset in students, particularly in engineering education) aiming to enhance student outcomes over a longitudinal study, with the potential to create a sustainable impact on the MHW of first-year students through the customization of their learning pathways.

2 | LITERATURE REVIEW

Engineering has earned a reputation as one of the most stressful disciplinary fields of study in higher education [9, 10]. Occurrences of higher than normal levels of stress [11, 12] and higher than the average (compared to other college students) levels of anxiety, depression, and post-traumatic stress disorder (PTSD) [9] are reported by researchers involved in MHW research in undergraduate engineering. Heavy academic workload [12, 13], sleep deprivation due to heavy workload [11, 13], and exam experiences [14, 15] are among the common source of the mentioned MHW problems. What makes the situation even worst is that although engineering undergraduate perceive the condition of their MHW to be inferior to other undergraduates [16], mental health help-seeking among engineering undergraduates is much lower [17].

Realizing the need for a systematic change in undergraduate engineering stress culture, recently, calls have been made for a shift to a wellness culture [18] where students can thrive [19] instead of continuously struggling academically and psychologically. Out of box thinking to seek out new mechanisms to avert the MHW crisis in higher education has been encouraged by educational institutional leaders for positive academic and MHW outcomes [20, 21]. Researchers are also calling for proactive approaches of implementing curricular changes to act as preventive measures against MHW problems that may be caused by engineering curriculum [22].

We expect our envisioned course modules to improve the sense of belonging and engineering identity among first-year engineering students to their college. Sense of belonging at US 4-year colleges has been reported to be a predictor of improvements in MHW, engagement, and persistence [23]. Similarly, identifying ones self (as part of a group) has shown to positively affect achievement and sense of belonging [24].

3 | THEORETICAL UNDERPINNINGS

This study integrates the socio-ecological model, social identity theory, and Tinto's theory of student retention to examine the unique experiences of first-generation and non-traditional engineering students in First-Year Engineering (FYE) programs.

3.1 | Socio-Ecological Model

This model highlights how individual, interpersonal, institutional, and societal factors shape behavior and outcomes [25]. First-generation and non-traditional students often face systemic barriers, such as unsupportive institutional policies, limited peer networks, and challenging classroom climates. These factors significantly influence their sense of belonging, engineering identity, and persistence. Addressing these barriers across multiple levels is critical for fostering their success.

3.2 | Social Identity Theory

Social identity theory explains how group membership shapes self-identity [26]. For first-generation and non-traditional students, developing an "engineering identity" can be complicated by feelings of marginalization or a lack of representation. External validation from peers and instructors plays a vital role in shaping their identity. Inclusive environments that recognize and validate diverse identities are essential to enhancing their belonging and persistence in engineering.

3.3 | Tinto's Theory of Student Retention

Tinto's theory (1993) emphasizes academic and social integration as key to persistence [27]. First-generation and non-traditional students often juggle competing responsibilities, financial pressures, and limited social support, making integration more challenging. These factors can lead to lower belonging and higher stress levels, which hinder retention. Creating supportive academic communities can help mitigate these challenges.

The combined framework provides a holistic approach to understanding the experiences of first-generation and non-traditional students. The socio-ecological model contextualizes systemic and environmental challenges, social identity theory highlights the importance of belonging and identity development, and Tinto's framework connects these elements to persistence and success. Together, these theories inform interventions that address barriers, foster equity, and promote the wellbeing of diverse student populations in engineering education.

4 | METHODS

Quantitative data was collected in the Fall of 2023 from students in the first semester of the FYE program at University of Cincinnati. In additions to their demographic data (including generational and traditionality status), the study participants also provided their responses to scales investigating on their engineering identity, intent to persist, sense of belonging, and perceived stress. The Engineering Identity scale developed by Godwin (2016) was used to assess students' identification with the engineering field via recognition, interest and performance/competence constructs [28]. Students' intent to persist in engineering was measured using items adapted by Mamaril (2014) [29] from the Persistence in Engineering Survey [30], with the first two items addressing academic persistence and the last two focusing on professional persistence. To evaluate students' sense of belonging within the engineering community, the study employed the scale developed by Verdín et al. (2018) [31], which connects belongingness to academic and professional outcomes. Finally, the Perceived Stress Scale (PSS) developed by Cohen, Kamarck, and Mermelstein (1983) was used to measure students' perceived stress levels [32]. Together, these scales provided a robust framework for examining factors that influence student outcomes in engineering education.

4.1 | Sampling and Participant Recruitment

The study was conducted after IRB approval. Convenience sampling techniques were used for this baseline study to get maximum response to the quantitative research survey. Participants completed this survey as a part of a group of surveys that were posted on their course (ENED 1100) canvas. At the end of the semester, all survey grades were averaged into a single grade. The average survey grade then counted as one Homework assignment. The grade for taking the survey was based on completion, not on specific responses. Study participants were provided an option to either agree or disagree to allow us to use your responses for our research purposes.

4.2 | Participants

Quantitative cross-sectional data was collected from first year engineering students in a large Midwestern University in the U.S. through an online survey. Legible data (n=699) was used for analysis. The combined sample included 25% female, 49% first generation, and 23% non-traditional students. Eleven students did not identify as either a Female or a Male. The FYE programs hosted around 1500 students in Fall of 2023. A good response rate of around 47% (n=699) was achieved that provides an appropriate representative sample for analysis.

4.3 | Data Analysis

Independent samples t-tests were used to assess differences between first-generation and continuing-generation engineering students across all variables i.e., engineering identity, intent to persist, sense of belonging, and levels of stress. A one-way ANOVA was used to assess between the above variable among traditional, and non-traditional study participants. T-tests were used to compare the means between two groups of a categorical independent variable, and ANOVA to assess differences in means across three or more groups of a categorical independent variable.

We used the Benjamini–Hochberg procedure to adjust our significance threshold (α) due to the multiple comparisons performed. This procedure is not as overly conservative as the Bonferroni correction and is generally preferred when there is a large number of comparisons being made [33]. The Benjamini–Hochberg procedure involves ordering the p-values from the tests performed, starting with the smallest value up to the largest. We index them starting at i=1 up to the number of p-values (or equivalently, the number of tests performed, m). For each p-value, we calculate the quantity: $Q(i)=i\alpha/m$. Then, we find the largest p-value that is less than its associated Q(i), called p*. Any p-values smaller than or equal to p* are considered significant [34].

5 | RESULTS

5.1 | First vs Continuing Generation College Students

First-generation college students (FGCS) are the first in their immediate families to pursue college education (neither of their parents has a bachelor's degree) [3].

Table 1

Independent Samples T-Test Results (N = 699; FGCS =344; CGCS = 355; df = 697)

Variable	FGCS (M ± SD)	CGCS (M ± SD)	p
Overall Sense of Belonging	25.97 ± 7.47.21	27.06 ± 6.55	.040**
- Major	13.00 ± 4.01	13.50 ± 3.50	.053
- Classroom	12.97 ± 3.77	13.55 ± 3.36	.047**
Overall Engineering Identity	49.08 ± 11.10	60.00 ± 10.04	.017*
- Recognition	13.05 ± 3.33	13.66 ± 2.24	.011*
- Interest	14.30 ± 3.46	14.69 ± 2.80	.095
- Performance	21.74 ± 5.78	22.64 ± 5.37	.033**
Overall Intent to Persist	16.35 ± 3.36	16.98 ± 2.72	.006*
- Academics	8.76 ± 1.78	9.12 ± 1.40	.004*
- Professional	7.59 ± 1.84	7.87 ± 1.62	.031**
Overall Stress	20.25 ± 7.19	18.96 ± 6.95	.017*

Note. M = Mean, SD = Standard Deviation. Values marked with an asterisk (*) indicate significance at p<.05 (two-tailed). Values marked with two asterisk (**) are false positives based on Benjamini–Hochberg procedure.

When compared to their counterparts i.e., continuing generation college students (CGCS), FGCS scored significantly low across all of the main constructs i.e., sense of belonging (p = .04), engineering identity (p = .01), and intent to persist (p = .00), while scoring significantly higher for stress levels (p = .02) (Table 1).

The difference in the overall sense of belonging (p = .04, but not significant based on Benjamini-Hochberg procedure) was primarily due to the contributing construct of "Classroom" experience (survey item example: I feel supported in my engineering class) with the other contributing construct "Major" (survey item example: I feel comfortable in engineering) did not show any significant differences between FGCS and CGCS. In case of engineering identity, there were overall significant differences between the two groups based on sub constructs of sense of "Recognition" (p = .01) (survey item example: My parents see me as an engineer) and "Performance" (p = .03, but not significant based on Benjamini-Hochberg procedure) (survey item example: I am confident that I can understand engineering in class) but not "Interest" (survey item example: I am interested in learning more about engineering). There were significant differences between the two groups in overall intent to persist based in both of its sub constructs of "Academics" (survey item example: I intend to enroll in engineering courses next semester) and "Professional" (survey item example: I intend to practice engineering for at least 3 years after I graduate). Significant differences based on stress levels (survey item example: In the last month, how often have you felt that things were going your way?) were reported. Based on the above analysis, CGCS had higher averages sense of belonging, engineering identity, intent to persist and lower stress levels compared to FGCS.

5.2 | Traditional vs Non-Traditional Students

Students with none of the seven non-traditionality traits (i.e., postponing college enrollment, being a part-time student, being financially independent, full-time employment while studying, having dependents other than a spouse, being a single parent, and earning a GED or other nontraditional high school credentials instead of a standard diploma) are classified as "traditional (TRD) [4].

Table 2

One-Way ANOVA Test Results (N = 695; Traditional (TRD)=542; Minimally Non-Traditional (MNNT) = 119; Moderately Non-Traditional (MDNT)= 34; df = 694)

Variable	TRD (M ± SD)	MNNT (M ± SD)	MDNT (M ± SD)	F	p
Overall Sense of Belonging	26.78 ± 6.56	25.56 ± 8.46	25.94 ± 8.51	1.60	.202
- Major	13.43 ± 3.51	12.74 ± 4.59	12.85 ± 4.49	1.88	.153
- Classroom	13.35 ± 3.42	12.82 ± 4.09	13.09 ± 4.16	1.11	.330
Overall Engineering Identity	50.52 ± 9.85	48.70 ± 12.69	48.20 ± 13.32	2.00	.136
- Recognition	13.50 ± 2.96	12.90 ± 3.95	13.03 ± 4.03	1.84	.159
- Interest	14.63 ± 2.93	14.04 ± 3.91	14.17 ± 3.31	1.89	.152
- Performance	22.39 ± 5.25	21.75 ± 6.53	21.00 ± 6.72	1.49	.226

Overall Persistence	16.77 ± 2.85	16.28± 3.84	16.36 ± 3.51	1.41	.244
- Academics	9.01 ± 1.50	8.67 ± 1.97	8.61 ± 1.82	2.91	.055
- Professional	7.75 ± 1.64	7.61 ± 2.11	7.73 ±1.89	0.33	.714
Overall Stress	19.23 ± 6.90	20.94 ± 7.49	19.15 ± 7.05	2.95	.052

Note. *M = Mean, SD = Standard Deviation. Values marked with an asterisk (*) indicate significance at p<.05 (two-tailed).*

While those with one trait are considered "minimally non-traditional (MNNT)," those with two or three are "moderately non-traditional (MDNT)," and those with four or more are classified as "highly non-traditional (HGNT)" [4].

In our analysis, HGTD participants who were only four in number were not included. As can be seen in Table 2, no significant differences for the studied variables (sense of belonging, engineering identity, intent to persist, and stress levels) were noticed based on the traditionality status of the participating first year engineering students.

6 | DISCUSSION AND CONCLUSIONS

In the case of FGCS participants from our first-year engineering (FYE) program, findings from our research are similar to outside research that suggests minoritized groups in undergraduate engineering have lower sense of belonging, engineering identity, intent to persist, and higher stress compared to majority groups. Sense of belonging has been identified as a "gateway for learning in first year engineering [35]. Yet, FGCS are reported to have less sense of belonging throughout their engineering education. Consistent with our findings, FGCS expressed similar feelings of not belonging in their engineering classrooms in external research [36]. FGCS persist less to attain degrees compared to their CGCS [37] with higher dropout rates [38]. First-generation status may even be more central to shaping engineering identity compared to gender or race [39].

Non-traditional undergraduate students often face unique challenges that hinder their academic experiences and sense of belonging. Research highlights that these students frequently encounter institutional barriers, such as rigid course schedules and limited access to childcare, making it difficult to balance academic and personal responsibilities [40]. In this study, no significant differences for the studied variables (sense of belonging, engineering identity, intent to persist, and stress levels) were noticed based on the traditionality status (TRD vs MNNT vs MDNT) of the participating first year engineering students. Due to their lower participation (4), highly not-traditional students (HGNT) who possess 4 or more non-traditionality traits were not included in our main analysis. Descriptive analysis of these 4 participants suggested they had the lowest sense of belonging, engineering identity, intent to persist, and highest stress averages compared to other study participants. Future research may highlight the unique experiences of the HGNT students if they could be included in significant numbers.

Sense of belonging at US 4-year colleges has been reported to be a predictor of improvements in MHW, engagement, and persistence [23]. Similarly, identifying ones self (as part of a group) has shown to positively affect achievement and sense of belonging [24]. Prior research has consistently

demonstrated that cultivating an engineering identity and a sense of belonging within an academic engineering pathway significantly influences students' persistence [41, 42].

As highlighted in the above discussion, due to their overall importance for student wellbeing and success, we selected sense of belonging, engineering identity, intent to persist, and stress as key parameters for evaluating the quality of our FYE program course modularization project. We expect our envisioned course modules to significantly enhance not only the learning experiences of FGCS and non-traditional students but also create a more inclusive and supportive environment for all first engineering students. By addressing these critical factors, our approach aims increase retention rates, and equip students with the tools they need to thrive both academically and personally in their future engineering pathways.

The baseline findings provide essential insights that directly shape the design and execution of the new modular program for first-year engineering students. For example, the notable gaps in sense of belonging, engineering identity, intent to persist, and stress levels between first-generation and continuing-generation students highlight the pressing need for focused interventions. Existing research emphasizes that customized academic frameworks and adaptable learning opportunities can address these issues by strengthening a sense of belonging and identity among underrepresented groups [43].

Based on these insights, the modular program is being developed to offer students increased flexibility, choice, and relevance in their first-year experiences, in line with evidence that personalized and inclusive curricular approaches improve student engagement and retention [44]. Furthermore, the higher stress levels reported by first-generation students indicate the importance of incorporating wellness strategies and academic resources into the program, reflecting the broader call for holistic methods in engineering education [45].

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