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Examining the Unique Experiences of Transgender and Gender Nonconforming Students in a Pre-College Engineering Course

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Introduction

Very little research on transgender and gender nonconforming (TGNC) students in engineering has been undertaken to better understand the experiences of this underrepresented and largely ignored population. Pawley et al. 's [1] review of published articles in the *Journal of Engineering Education* between 1998-2012 revealed zero studies mentioning transgender people. Embedded in this review was a clear call to broaden the conceptualization of gender beyond the current binary rhetoric [1]. Using binary terms of gender (i.e., men and women or male and female) has rendered TGNC students invisible in engineering education [2]. Ignoring TGNC student perspectives heightens the already chilly environment of engineering. Nearly one in four TGNC students have reported being verbally, physically, or sexually assaulted on college campuses and 16% left higher education due to the harassment they experienced [3]. The majority of campuses do not even provide TGNC-inclusive resources such as student health centers, and gender-affirming restrooms, or policies and practices that allow for students to be referred to by used names and pronouns [4]. TGNC students need to be included in the conversation as the engineering education community strives to create a growing, diverse body of engineers.

Engineering For US All (e4usa) is a pre-college engineering course that aims to create equitable engineering learning environments for students across backgrounds [5]. This work-in-progress study reports on data collected through pre and post-surveys given to high school students enrolled in the e4usa course during the 2021-2022 academic year. We sought to explore TGNC experiences in e4usa classes through the following research question: In what ways does the e4usa course influence transgender and gender nonconforming (TGNC) students' interests in and intentions to pursue engineering? This paper aims to provide preliminary insights into TGNC students participating in this course by exploring their unique perspectives. An understanding of TGNC student experiences in the e4usa course will help to improve the course, while also exposing the policies and practices in the field of engineering that continue to marginalize these students.

Limitations

We acknowledge our small sample size as a major limitation of this quantitative exploration of TGNC student experiences in a pre-college engineering course. Our sample size is small, but it is also unfortunately reflective of the overall TGNC representation in engineering. The findings were collected from a single course offering taught across the nation and does not account for variation that may occur from different pre-college engineering courses. Our findings do align with available research on TGNC student experiences, but it is important to note that student experiences are influenced by a variety of factors (e.g., course, class structure, classroom climate, and peer interactions). We hope and intend the findings from this study to be the

beginnings of addressing, understanding, and improving experiences for TGNC students in engineering and STEM overall.

Methods

Context

e4usa is a nationwide effort funded by the National Science Foundation (NSF) in 2018. An underlying goal of e4usa is to create equitable pre-college engineering learning environments for students across backgrounds [5]. The course seeks to build the foundational professional skills of students with varying interests toward engineering through engineering design experiences [6]. Ninth through twelfth grade students in the United States can enroll in the course as a one-semester or a full-year course depending on the participating school.

Survey Development and Overview

Pre and post-surveys were given to e4usa students during the 2021-2022 school year to examine pre-college engineering student perspectives in the course. The surveys were developed by the e4usa research team, which includes engineering education and psychology researchers with expertise in using Social Cognitive Career Theory (SCCT) [7]. SCCT explains students' development of vocational and academic interests, career-relevant choices and decisions, and persistence in professional, educational and occupational fields [8]. It specifically suggests that environmental contextual elements combined with learning experiences impact self-efficacy and outcome expectations to advance an individual's interests and commitment decisions. The survey items were adopted from a previously tested model and study by Lent et al. [9] that examined the interplay between interest, satisfaction and students' intentions regarding engineering majors. The pre-survey was given to students within their first month of taking the course and the post-survey was given to students during their last month in the course. The before and after responses were not linked as surveys were intentionally designed to be anonymous to extract honest and truthful information.

The survey consists of 70 questions, including 6 questions related to demographic information and 64 questions for the eight major constructs - (1) engineering-related self-efficacy, (2) engineering coping efficacy, (3) outcome expectations, (4) interest in engineering, (5) intentions and commitment, (6) support and barriers, (7) engineering curiosity, and (8) engineering identity. All survey questions were measured using a Likert scale of 0 (strongly disagree) to 4 (strongly agree.) Before analyzing each construct, the construct items were averaged for each participant so

Table 1: *Demographic Information*

	TGNC	Female	Male
n	9	103	242
Percent (%)	2.54%	29.10%	68.36%
Participated in a previous engineering class or activity			
Yes	3	46	102
No	6	53	118

that the constructs could be treated as an averaged score. Example survey items can be found in the Appendix.

Data Collection and Participants

A total of 1,418 students participated in e4usa during the 2021-2022 school year. A sample of 371 completed the post-survey. Of those who completed the post-survey, nine students identified as transgender or gender non-conforming (TGNC). One-third of these students reported having participated in an engineering class or extracurricular activity prior to taking this course (Table 1).

Data Analysis

Several tests were conducted to understand if this course influenced TGNC students' perspectives of engineering and their intent to pursue engineering. Survey data were analyzed using two-tailed t-tests to determine if there were significant changes in students' level of interest and intentions to pursue engineering after taking the course by comparing pre and post-survey response data. Two survey measures were used to test intentions and commitment (three items) and interest in engineering (five items).

Two measures were performed to address the validity of the data due to the small sample size. First, a post-hoc power analysis was performed using the G*Power 3.1 software to ensure there was enough statistical power to detect changes [10]. We found that there was enough reliability to detect a medium-large effect size (i.e., $d \geqq 0.6$) for the t-tests. Second, Mann-Whitney U Tests were used to validate the distribution of data due to the smallness of the sample size [11]. We found that TGNC students' intentions and commitments were statistically significantly different than their male and female peers after taking this course.

Table 2: *Post-Hoc Power Analyses*

	Mean (*M*), Std. Dev. (SD)	Change (MΔ)	Two-tailed t-test	Cohen d
Intentions and Commitment (Future Plans)	**TGNC (Post): *M* = 1.70, SD = 1.47** TGNC (Pre): *M* = 2.17, SD = 0.85	↓ 0.42	$t(8) = 3.46$, $p = .009$	1.48
	Female (Post): *M* = 2.42, SD = 0.93 Female (Pre): *M* = 2.27, SD = 0.91	↑ 0.15	$t(102) = 26.38$, $p < .001$	.93
	Male (Post): *M* = 2.65, SD = 0.97 Male (Pre): *M* = 2.66, SD = 0.86	↓ 0.01	$t(240) = 42.402$, $p < .001$	.97
Interest in Engineering	**TGNC (Post): *M* = 2.08, SD = 0.67** TGNC (Pre): *M* = 2.35, SD = 1.02	↓ 0.27	$t(8) = 9.23$. $p < .001$	.68
	Female (Post): *M* = 2.62, SD = 0.76 Female (Pre): *M* = 2.60, SD = 0.81	↑ 0.02	$t(102) = 34.83$, $p < .001$	.81
	Male (Post): *M* = 2.82, SD = 0.75 Male (Pre): *M* = 2.81, SD = 0.78	↑ 0.01	$t(241) = 57.79$, $p < .001$	.78

Results

Normality assumptions were evaluated using QQ plots with 95% confidence intervals; all values were found to be within acceptable ranges. We also analyzed the data's distribution by looking at each group's skewness and kurtosis values. It was determined that data was normally distributed for each group, as all

items were within acceptable ranges (i.e., ± 2 and ± 7, respectively).

We hypothesized that students' intentions to pursue engineering and interest in engineering would increase after taking the course. TGNC students reported decreased intentions to pursue engineering after the course (M = 1.70, SD = 1.47) compared to before the course (M = 2.17, SD= 0.85). This change was significant, $t(8) = 3.46$, $p = 0.01$, $d = 1.48$. TGNC students also reported decreased interest in engineering after taking this course (M = 2.08, SD = 0.67) compared to before the course (M = 2.35, SD = 1.02). This change was also significant, $t(8) = 9.23$, $p < 0.001$, $d= 0.68$.

Discussion

TGNC youth are likely to experience a difficult environment in high school [12 – 15]. Xavier Hall et al.'s [16] analysis of national survey data on pre-college students who identify as sexual and gender minorities (SGM) found that anti-SGM bullying was correlated with "discomfort in STEM classrooms as well as perceptions of acceptance of SGM people in STEM climates in general." Their findings suggest a connection between school experiences and students' perceptions of STEM fields. The findings presented in this paper may have been the result of a similar connection, where negative school environments contributed to TGNC students' attitudes toward engineering.

Our emergent findings highlight the unique experiences of TGNC students in a pre-college engineering course. TGNC students reported significantly lower intentions to pursue engineering and interest in engineering relative to their cisgender male and female peers. This finding adds to previous research, which found TGNC undergraduate students were ~10% less likely to remain in STEM majors compared to their cisgender peers [17]. Few studies, particularly quantitative studies, have focused on TGNC undergraduates because this population is small. Those who have presented findings share a common theme of students reporting a heteronormative, exclusionary environment in engineering [17 – 20]. Haverkamp et al. [19] utilized collaborative autoethnographic methods to explore the experiences of two TGNC undergraduate engineering students who expressed an engineering environment with exclusionary social dynamics. Group projects and interactions, which are common to engineering, were identified as "a particular hurdle towards engineering peers being part of their social support network" [16]. The ability to function effectively on a team is listed as a student outcome for ABET-accredited engineering programs [21]. Incorporating teamwork into engineering curricula has been suggested as a method to combine diversity, equity, and inclusivity (DEI) principles with engineering content [22]. TGNC students identifying team experiences as a hurdle in engineering suggests a larger, systemic issue where the very practice that aims to support students instead leads to marginalization. Similar to undergraduate engineering classes, e4usa includes ample opportunities for high school students to work in groups as they complete daily classroom work and larger engineering design challenges. The group work may have contributed to TGNC students' lower intent to pursue engineering and interest in engineering. Such experiences may have dissuaded these students from engineering at

a critical time since pre-college engineering exposure has a significant impact on one's intent to pursue engineering as a degree [23].

Implications for Practice

Promoting authentic change for TGNC students cannot be done without critical reflection on the system of engineering education. This begins with reflecting on how transphobic ideals and practices may appear in classroom settings. Examples include the use of binary gendered terms, deadnaming and/or misgendering students, and promoting heteronormativity in classrooms. Pre-college stakeholders (e.g., teachers, administration) are encouraged to constantly examine their own privilege along with their preconceived and espoused notions about TGNC students. We urge those in advocacy and research roles to center the voices of TGNC students during solution building. In scholarly and written forms of activism, we ask researchers to avoid theories, frameworks, and references to other research that exclude the voices of TGNC people.

Conclusion & Future Work

Fostering inclusive pre-college experiences is an essential first step to broadening participation in engineering. Few works exist that examine TGNC student experiences after taking an engineering course, much less in pre-college settings. A more comprehensive understanding of TGNC student experiences is needed in order to promote movement towards equitable educational experiences for all learners. This work found that TGNC students reported lower intentions to pursue engineering and interests in engineering relative to their cisgender peers. Engagement through team-based experiences, often suggested as an avenue to promote equitable and inclusive learning, may be oppositely affecting TGNC students within an engineering course.

Future work is needed to further explore the experiences of TGNC students, from both quantitative and qualitative perspectives. More quantitative work is needed to further explore our findings with a larger sample of TGNC pre-college students, while qualitative research would provide greater depth to articulate our understanding of TGNC students' experiences. The intent of this work and of future work to come is to center and amplify TGNC voices during the creation of engineering experiences to radically improve engineering education and educational justice overall.

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Appendix: Example Survey Items

Engineering-related self-efficacy

Instructions: *Please use this section to rate your confidence toward the following actions using the scale provided.*	
Scale: 0 = no confidence; 1 = low confidence; 2 = moderate confidence, 3 = high confidence; 4 = complete confidence	
Q1	Understand engineering in class
Q2	Understand engineering outside of class
Q3	Identify a design need

Interest in engineering

Instructions: *Please use this section to indicate your degree of interest in doing each activity using the the provided scale.*	
Scale: 0 = no interest; 1 = low interest; 2 = moderate interest, 3 = high interest; 4 = very high interest	
Q1	Working on a project involving engineering concepts
Q2	Identifying alternate solutions to engineering problems

Intentions and commitment

Instructions: *Please use this section to indicate the extent to which you agree or disagree with each statement using the provided scale.*	
Scale: 0 = strongly disagree; 1 = disagree; 2 = unsure, 3 = agree; 4 = strongly agree	
Q1	I intend to take an additional engineering course or courses in high school
Q2	I intend to take an additional engineering course or courses in college
Q3	I intend to pursue a college degree in an engineering discipline

Support and barriers

Instructions: *Please use this section to indicate the extent to which you agree or disagree with each statement using the provided scale.*	
Scale: 0 = strongly disagree; 1 = disagree; 2 = unsure, 3 = agree; 4 = strongly agree	
Q1	I have access to an engineering role model(s) if I decide to pursue an engineering degree
Q2	I feel there are others like me who are engineers or pursuing an engineering degree