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Advancing Equity: Exploring the Experiences of Transgender and Gender Non-Conforming Students in a Pre-College Engineering Course (Work in progress)

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Advancing Equity: Exploring the Experiences of Transgender and Gender Non-Conforming Students in a Pre-College Engineering Course (WIP)

Abstract

Background: Science, Technology, Engineering, and Mathematics (STEM) fields have increasingly highlighted the need to support minority groups to foster a more diverse and equitable environment. While previous research has concentrated on female students in engineering, studies focusing on TGNC students are limited. Evidence indicates that TGNC students leave STEM disciplines at rates higher than or comparable to those of other marginalized groups.

Purpose: This work-in-progress paper aims to investigate the impact of pre-college engineering courses on the self-efficacy of high school students, with a focus on Transgender and Gender Non-Conforming (TGNC) students, to advance a more equitable engineering education environment.

Methods: The study analyzed survey data collected from 788 students across 33 schools in 20 U.S. states and regions who took an introductory high school engineering course in the 2022-23 academic year. Statistical analyses, including t-tests and ANOVA, were conducted to compare pre- and post- survey data, assess changes in self-efficacy and identify differences among male, female, and TGNC students.

Results: Preliminary results reveal that while male and female students exhibited significant increases in self-efficacy after the course, TGNC students did not show similar gains. Additionally, TGNC students reported challenges in perceived support and barriers to pursue an engineering degree compared to male students.

Conclusions: Engineering courses effectively enhance self-efficacy for male and female students but provide less pronounced benefits for TGNC students. These findings underscore the need for targeted interventions and inclusive course designs to better support TGNC students. Future research will aggregate multi-year data to provide a more comprehensive understanding of these dynamics and inform strategies for fostering inclusivity in engineering education.

Introduction

Science, Technology, Engineering, and Mathematics (STEM) fields continue to emphasize the importance of creating equitable and inclusive environments. Transgender and Gender Nonconforming (TGNC) students still face systemic barriers, marginalization, and limited representation in these fields, which continue to be dominated by the traditional gender binary. A national longitudinal study revealed that TGNC students persist in STEM majors at a rate approximately 10% lower than their cisgender peers, despite similar academic ability and self-confidence [1]. Transgender students also reported lower expectations when presenting as female, while queer students experienced STEM as objective yet exclusionary of their identities [2]. In the engineering field, TGNC undergraduate students reported strong skills and community support outside STEM, while emphasizing the need for cultural change and social justice education in their disciplinary programs [3].

Previous content analysis of gender-related articles published in the Journal of Engineering Education (JEE) from 1998 to 2012 indicated that gender research in engineering education primarily focuses on binary gender categories, with most studies examining undergraduate students [4]. Research on diverse gender identities and pre-college populations remains limited. The U.S. Transgender Survey [5] found that most transgender students faced mistreatment in K-12, with 60% of teens reporting harassment, bullying, or being denied gender-affirming clothing, names, pronouns, or facility access. These findings emphasize the need for more inclusive research approaches that better represent diverse experiences of all students across educational levels.

This research is grounded in a pre-college engineering education initiative designed to enhance engineering education across the United States. The program's primary objectives include delivering a comprehensive high school engineering curriculum, providing professional development for teachers, and conducting research to advance engineering education, promoting equitable learning environments for students from diverse backgrounds [6].

The project's prior research has examined students' interest and intentions to pursue engineering. This work-in-progress expands previous findings through an analysis of survey data gathered before and after course participation from high school students enrolled in a high school engineering curriculum during the 2022-2023 academic year to examine whether previous findings persist. The focus of the investigation is on the experiences of TGNC students within the course. We aim to address this focus through the following research question: *How do transgender and gender non-conforming (TGNC) students' self-efficacy in engineering compare to those of male and female students before and after participating in a pre-college engineering course?*

Methods

The survey included high school students from 33 schools located in 20 states and regions, including Arizona, California, the District of Columbia, Florida, Hawaii, Illinois, Indiana, Kentucky, Maryland, Massachusetts, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, the U.S. Virgin Islands, and Virginia.

A total of 788 students enrolled in a high school engineering program and were asked to complete the survey during the 2022-2023 academic year. The pre-survey was distributed within the first month of the course, while the post-survey was administered during the final month; a total of 658 students completed the pre-survey and 338 completed the post-survey. Since the survey was conducted anonymously, individual responses from the pre- and post-surveys could not be directly matched. Table 1 presents the students' gender demographics.

Table 1. Students' Gender Demographics.

Gender	**Pre-test**	**Post-test**
Male	338	204
Female	253	120
TGNC	22	5
Not mentioned	45	9
Sum	*658*	*338*

Limitation

We recognize the small sample size as a key limitation of this study. While the sample size is limited, it reflects the underrepresentation of TGNC individuals in engineering. Moreover, LGBT+ students in STEM face risks and unfair burdens when navigating visibility without meaningful institutional inclusion efforts [7]. We hope that the preliminary findings of this work-in-progress study will draw attention to the underrepresentation of TGNC students and the inequities they face in engineering. Our goal is to expand the sample size in future research to achieve more comprehensive and generalizable results.

Survey and Data Analysis

The pre- and post-surveys were designed based on Social Cognitive Career Theory (SCCT), which explains how environmental factors and learning experiences could influence students' confidence and expectations for success, ultimately affecting their interests and decisions about commitment [8]. Seven constructs and 54 survey items were investigated, which were adapted from Lent et al. [9], who explored the links between students' interest, satisfaction, and their intentions to pursue engineering majors based on SCCT. The seven constructs and the number of corresponding items are as follows:

- Engineering-related self-efficacy (11)
- Engineering curiosity (14)
- Engineering identity (5)
- Interest in engineering (5)
- Intentions and commitment (3)
- Outcome expectations (9)
- Support and barriers to pursue an engineering degree (7)

All survey items were evaluated using a Likert scale ranging from 0 (no confidence) to 4 (complete confidence). The survey also included four demographic questions capturing age, gender, race, and grade level. Appendix A provides some example survey items used for the study.

In this work-in-progress paper, we calculated construct scores by identifying related survey items, summing all participant's responses, and dividing by both the number of items and the number of participants to obtain an average. This process was applied separately to pre- and post-survey responses, creating composite scores for each time point to measure changes over time. Preliminary quantitative analysis included the use of two-tailed t-tests to compare pre- and post-survey construct scores. ANOVA was conducted to explore differences among students of different genders within pre- or post-survey data.

Results

The t-test results showed that there was a statistically significant increase ($p = 0.0002 < 0.01$) in terms of self-efficacy between pre- and post-survey data, underscoring a marked increase in students' self-efficacy in the engineering field after taking the course. Further analysis for each gender group showed a statistically significant increase in self-efficacy for both male ($p = 0.0196 < 0.05$) and female ($p = 0.0067 < 0.01$) students, while no change was observed for TGNC students. Other construct scores did not show a statistically significant difference. Table 2 shows the p-value results comparing pre- and post-survey construct scores.

Table 2. T-test Results Comparing Pre- and Post-Survey Construct Scores.

Construct	**All**	**Male**	**Female**	**TGNC**
Self-efficacy	0.0002**	0.0196*	0.0067**	0.3097
Engineering Curiosity	0.8817	0.5449	0.5779	0.8834
Engineering Identity	0.0776	0.2273	0.3777	0.2617
Engineering Interest	0.8922	0.6365	0.9404	0.6801
Intentions & Future Plans	0.9635	0.7280	0.9727	0.9316
Outcome Expectations	0.5980	0.5902	0.9934	0.8975
Support & Barriers	0.0805	0.4568	0.1836	0.5968

Note:A P-value less than 0.05 is flagged with 1 stars (*); A P-value less than 0.01 is flagged with 2 stars (**).

The ANOVA results showed that in the pre-survey data, male and female students had statistically significant differences across most constructs, including engineering curiosity, engineering identity, engineering interest, intentions & future plans, outcome expectations, and support & barriers, with p values near or smaller than 0.001 (<0.01). In the post-survey data, the differences in engineering curiosity and support & barriers disappeared, while significant differences remained for the other constructs. These statistical results suggest a potential possibility that the high school engineering course could be more effective in helping female students, compared to male students, by improving their engineering curiosity and feeling supported to pursue an engineering degree.

The pre-survey data also revealed a statistically significant difference between male and TGNC students in support & barriers ($p = 0.006 < 0.01$), which disappeared in the post-survey data. This suggests that the high school engineering course could have the potential to encourage TGNC students to pursue an engineering degree. Although no statistically significant differences were found between TGNC students and other student groups in other constructs, this does not imply the absence of actual differences, as the results could be influenced by the small TGNC student sample size. Table 3 presents the ANOVA results comparing gender groups in the pre- and post-survey data.

Table 3. ANOVA Results Comparing Gender Groups within Pre- and Post-Survey.

Construct	**Pre or Post Data**	**Male vs Female**	**Male vs TGNC**	**Female vs TGNC**
Self-efficacy	Pre	0.160	0.932	1.000
	Post	1.000	1.000	1.000
Engineering Curiosity	Pre	0.000**	0.443	1.000
	Post	0.091	1.000	1.000
Engineering Identity	Pre	0.000**	0.382	1.000
	Post	0.000**	1.000	0.622
Engineering Interest	Pre	0.000**	0.364	1.000
	Post	0.001**	1.000	1.000
Intentions & Future Plans	Pre	0.000**	0.075	1.000
	Post	0.000**	0.876	1.000
Outcome Expectations	Pre	0.000**	0.340	1.000
	Post	0.001**	0.972	1.000
Support & Barriers	Pre	0.000**	0.006**	0.556
	Post	0.054	1.000	1.000

Note: A P-value less than 0.01 is flagged with 2 stars (**).

Overall, the preliminary quantitative analysis indicates that high school engineering courses have the potential to improve self-efficacy for male and female students, though this effect was not observed in TGNC students. Compared to male students, the courses appear to have a greater impact on enhancing engineering curiosity among female students. Additionally, the courses contributed to increased feelings of support for pursuing an engineering degree among both female and TGNC students.

Discussion and Implementation

Our research findings indicated that existing pre-college engineering courses provide some support for TGNC students, but this support remains limited. The curriculum design strategies for other minority groups (e.g., female students) cannot be directly replicated for TGNC students.

Previous studies suggest it could be related to the cultural norms of the engineering discipline, which tend to be less supportive of TGNC students compared to other minority groups. Students with minoritized identities of sexuality and/or gender (MIoSG) in STEM reported navigating a “dude” or “bro” culture characterized by hypermasculinity, assumed heterosexuality, anti-LGBTQIA+ discourses, and the marginalization of MIoSG students and cisgender women [10]. Queer college students often perceive STEM fields as less accepting and social sciences as more queer-friendly [11].

Within the broader educational context, TGNC youth exhibit significantly higher engagement in all categories of high-risk health behaviors and experiences compared to their cisgender peers, while reporting substantially lower levels of protective factors [12]. Similarly, TGNC college students experience significantly higher rates of all seven types of interpersonal victimization including violent victimization, sexual victimization, intimate partner violence, stalking, bullying, microaggressions, and discrimination compared to cisgender students [13]. This calls for action not only within the field of engineering but also across broader educational sectors. When schools implemented strategies to reduce harassment, TGNC youth reported stronger connections with school personnel, which were in turn associated with increased feelings of safety [14].

Future Plan

Our subsequent work involves integrating data from the project spanning 2020 to 2023. This approach aims to expand the sample size of minority student groups, facilitating more robust quantitative statistical analyses. Additionally, examining student performance across multiple years will allow for a more comprehensive investigation of factors influencing learning outcomes. TGNC students also face intersectional oppression. For example, sexual and/or gender minority (SGM) STEM undergraduates experience varying degrees of fit in their environments, with gender minority students facing more frequent and severe microaggressions than sexual minority students, while racial minority SGM students report compounding identity challenges [15]. Future research could further explore how the multiple identities of TGNC students intersect in STEM environments and how these identities influence their learning experiences and academic achievements to reveal which structural factors may exacerbate these inequalities and investigate potential interventions to improve inclusivity in STEM education environments.

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Appendix A: Example Survey Items

Scale: 0 = no confidence; 1 = low confidence; 2 = moderate confidence, 3 = high confidence; 4 = complete confidence

Engineering-related self-efficacy
Q1 Understand engineering in class
Q2 Understand engineering outside of class
Q3 Apply engineering to solve a problem

Engineering Curiosity
Q1 Take things apart to see how they work
Q2 Identify new problems that could be solved
Q3 Ask information-seeking questions

Engineering Identity
Q1 My parents or guardians see me as an engineer
Q2 My teacher(s) see me as an engineer
Q3 My peers see me as an engineer

Engineering Interest
Q1 Reading articles or books about engineering
Q2 Working on engineering projects
Q3 Solving complicated engineering problems

Intention/Commitment – Future Plans
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

Outcome Expectations
Q1 I would earn an attractive salary if I became an engineer
Q2 I would be respected by other people if I became an engineer
Q3 Becoming an engineer would allow me to do work that I find satisfying

Supports/Barriers to Pursue an Engineering Degree
Q1 I have access to an engineering role model(s) if I decide to pursue an engineering degree
Q2 I feel supported by my friends and family if I decide to pursue an engineering degree
Q3 I feel there are others like me who are engineers or pursuing an engineering degree