Work in Progress: Examining Student Critical Consciousness and Engineering Identity in an Engineering Design Class. Insights from Survey Data

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Abstract

In this study, we analyze data from surveys completed by students enrolled in a mid-year engineering design course aimed at cultivating critical consciousness in engineering design. Our investigation focuses on the critical consciousness gained during the course, the significance of engineering identity aspects, and potential divergences between minoritized and non-minoritized students in engineering.

Using R Studio, we conduct quantitative analysis on pre- and post-course surveys (administered in the first and final weeks of the course, respectively) featuring Likert-scale items adapted from validated surveys on engineering design and critical consciousness in education. The survey questions are categorized into critical consciousness and engineering identity. The former encompasses topics such as perceived inequality, egalitarianism, and others, while the latter explores four dimensions of engineering identity: motivation, community, role models in engineering, and engineering family. Demographic data was also collected. We used statistical methods like the Wilcoxon signed-rank test to compare mean scores in pre- and post-course surveys and across student groups despite limited statistical power due to sample size. While critical consciousness and engineering identity gains remain null, some within-group differences are observed.

Introduction

This work was motivated by two gaps in the research and practice of engineering education, namely, the minimal presence of mid-year design courses in the curriculum and the negligible incorporation of considerations and perspectives in design that go beyond technical requirements or specifications. To address these gaps, a course in the Electrical and Computer Engineering department at the University of Illinois Chicago (UIC) was introduced at the mid-year level – that is, the course was offered to second-year and third-year undergraduate students. The objectives of this course were to a) provide an early introduction to the engineering design process and b) contextualize design within a framework of critical consciousness. In doing so, the learning outcomes are expected to be about engineering design and critical consciousness. Moreover, situated within an institution that serves a diverse set of students, another goal of this work is to help affirm students' engineering identity, especially as it may be connected to a minoritized status in engineering.

The conceptual use of critical consciousness [1] is done purposefully to interweave social, political, economic, and cultural considerations into the design process. Such an approach is differentiated from human-centered or user-centered design in that critical consciousness allows for a systems-wide view of design. By looking not just at the user or the designer as humans in

the process but also at the systems at play within the design process, we posit that students will be able to gain a more nuanced understanding of engineering design. Critical consciousness gained traction in education in the 1980s, but this concept has been used in other fields such as medicine and law extensively. We operationalize critical consciousness in engineering education as a student's way to critically understand the world [2] around them, especially as it relates to processes and systems that lead to oppressive designs, to reflect and dialogue with others about this understanding, and to take action subsequently. The reflection, dialogue, and action aspects of this concept are widely used in applications of Freire's critical consciousness. In this work, critical consciousness is incorporated pedagogically and via course content. Implemented in Spring 2023, the course engaged students in collaborative projects with community organizations. It emphasized facilitated discussion and reflection on militarism, globalization, technocracy, color evasiveness, representation, and decolonization, shedding light on the societal implications of engineering decisions. This approach is discussed further in a previous publication [3].

To connect critical consciousness with the affirmation of students as engineers, an engineering identity model is used. This model is a combination of the recognition, performance, and competence dimensions of the science identity model [4] as well as community dimension [5]. While in this report, the constructs of critical consciousness and engineering identity aspects are separate, in subsequent reporting of this study the connections between these two constructs will be expanded upon through the use of qualitative data also collected for this project.

Methodology

The survey used in this work consists of three parts and was distributed to participants using Qualtrics as the surveying tool. The first part of the survey asks participants to answer questions adapted from a critical consciousness scale [6]. The survey sub-constructs include egalitarianism, perceived inequality, and social action. Because the goal of this project was not to develop a survey, the option of using a validated survey was favorable. The survey items used from Diemer were validated with students, albeit younger than the population for our study. The second part of the survey asks participants to answer questions adapted from an engineering identity survey [5]. This engineering identity survey was validated with undergraduate students identifying as Latinx/a/o and part of a national student organization. As a result, the survey items were adapted to this study's population.

For quantitative data analysis, we employ R Studio to analyze information gathered from two surveys: a pre-survey (administered in the first week of the course) and a post-survey (conducted in the final week of the course). Both surveys feature identical Likert-scale items that were recoded into numbers.

We compute cumulative scores for each student within each category (critical consciousness or engineering identity) and subcategory. In our analysis, we utilize the Wilcoxon signed-rank test to assess the significance of observed changes in critical consciousness and engineering identity

scores between pre- and post-course survey data. We also compare the distributions of scores between two independent groups (minoritized and non-minoritized students) to determine if there are significant differences in critical consciousness gains between the groups. The Wilcoxon signed-rank test was chosen for data analysis due to its suitability for smaller sample sizes. This non-parametric test is robust and does not require the assumption of normality, making it particularly well-suited for analyzing data sets with limited observations. Given the modest sample size in our study, employing the Wilcoxon signed-rank test ensures reliable statistical analysis.

The demographic data reveals a diverse composition of survey participants (a summary is shown in Table 1). The majority of respondents are second-year students, with a smaller representation from third-, fourth-, and fifth-year students. Additionally, non-transfer students outnumber transfer students. Gender distribution is solely male, and the sample exhibits racial diversity, with representation from Asian, White, and Other racial groups. A subset of participants identifies as Latinx. Notably, most participants were first-generation college students (n=9).

Table 1. Demographic characteristics

Demographics	Count	Demographics	Count	Demographics	Count
Year in College		Race		First Gen	
2nd	6	Asian	5	No	2
3rd	3	Other	1	Yes	9
4th	1	White	4		
5th	1	NA	1		
Transfer Student		Latinx		Gender	
No	4	No	5	Male	11
Yes	7	Yes	6		

Within the scope of this study, we were interested in potential disparities in gains in critical consciousness and engineering identity between minoritized and non-minoritized students. To delineate between these groups, we established criteria based on demographic characteristics. In determining whether a student is considered part of a minoritized group within engineering, we examined various demographic factors. For gender, classifications included 'male,' 'female,' or 'other.' Regarding race, options encompassed 'White,' 'Black,' 'Asian,' or 'other.' Additionally, participants indicated 'yes' or 'no' for Latinx ethnicity. A student was categorized as part of a minority group if any of the following conditions were met: 1. Their gender was not classified as 'male.' 2. Their race was not categorized as 'White' or 'Asian'. 3. If they identified as Latinx/o/a. This method enabled us to identify and classify students from minoritized groups (n=6) based on their demographic characteristics within the engineering field.

Limitations

This work is limited by the small sample size, comprising only 11 participants. This constraint reduces the statistical power of our analysis, limiting the generalizability of our findings to broader student populations. However, the statistical test applied is suitable for small samples such as this one.

Another limitation of our study is that the factors we used in our study could not be confirmed through confirmatory factor analysis (CFA) due to the limitations posed by our small sample size. CFA is a statistical technique used to validate and confirm the underlying structure of a measurement instrument or construct by testing a pre-specified factor model against observed data. However, with our limited sample size, conducting CFA would not provide robust or reliable results, as CFA requires a sufficiently large sample size to ensure statistical power and accuracy.

Results and Discussion

When investigating the gains of Critical Consciousness (CC) and Engineering Identity (EngID) over the course, we performed tests for the full sample (see Table 2) as well as for separate groups, such as first-generation students, minoritized students, or non-minoritized students. None of the tests showed significant differences.

Table 2. Comparison of scores between pre- and post-surveys, Wilcoxon Rank Sum Tests

Variable	Descriptive Statistics						Results
CC (all items)	survey	n	mean	median	sd	var	W = 46,
possible lowest = 32,	pre	11	122.	127	12.5	157.	p = 0.23
possible highest = 192	post	12	131.	128.	13.3	177.	
EngID (all items)	survey	count	mean	median	sd	var	W = 71,
possible lowest = 80,	pre	11	333.	360	53.4	71.2	p = 0.78
possible highest = 400	post	12	339.	344.	31.7	97.7	

Aside from investigating the gains of critical consciousness and engineering identity over the course, we were also interested in comparison across different groups (such as minoritized and non-minoritized students) at a fixed moment of time. For that, we ran the Wilcoxon Rank Sum Test on the Perceived Inequality and Egalitarianism sub-categories of critical consciousness and all four sub-categories of engineering identity, which are motivation, community, engineering role models, and engineering family. We did that for pre-survey and post-survey data. While none of the tests showed any significant difference in mean scores in the pre-survey, there were some insights in the post-survey data for the Egalitarianism variable (see Table 3).

Table 3. Difference between Minoritized and Non Minoritized students in post-survey responses, Wilcoxon Rank Sum Test

Variable	Descriptive Statistics						Results
Egalitarianism (CC)	minoritized	count	mean	median	sd	var	W = 30,
	no	7	28.9	30	2.04	4.14	p = 0.037*
	yes	5	23.6	23	4.22	17.8	

*Denotes statistical significance

Table 3 shows that $p<0.1$ was seen from the test on the Egalitarianism subcategory of Critical Consciousness post-survey. This variable was calculated as a sum of five Likert-scale items, each with a value between 1 and 6. Minoritized students have lower scores (mean 23.6, median 23) in this subcategory than non-minoritized students (mean 28.9, median 30). However, there were no such differences in the pre-survey, where scores of minoritized students had a mean of 25.3 and a median of 25, and non-minoritized students had a mean of 25.8 and a median of 28. After taking the course, the Egalitarianism mean score decreased for minoritized students and increased for non-minoritized students (see Fig. 1).

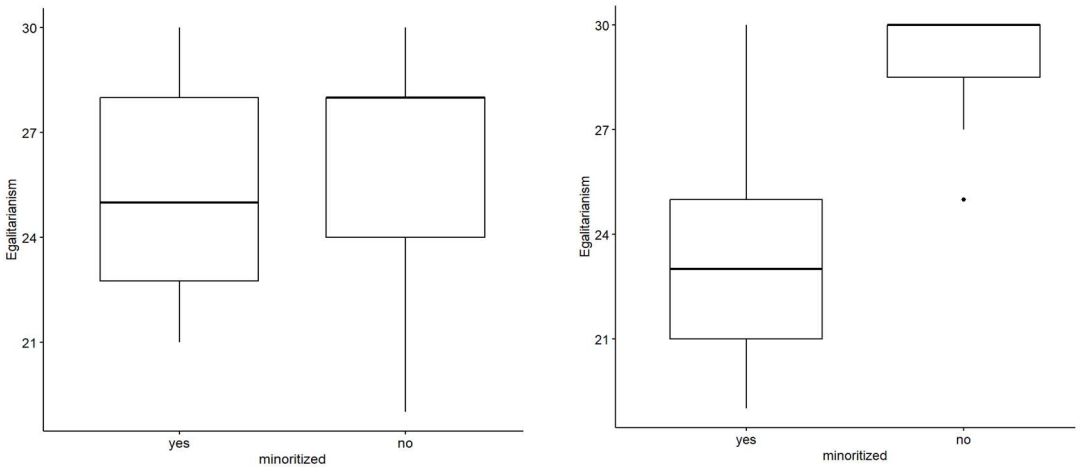

Fig. 1 Egalitarianism scores of minoritized and non-minoritized students. Left: pre-survey; Right: post-survey.

It is important to mention that these were not matched pre- and post-tests. In other words, some students who took the pre-survey did not take the post-survey, and vice versa. We did not exclude students who took only one survey, which could have affected the results, especially the tests where we had a small sample size since even one new participant's response could have severely shifted the mean and median score of the group. To eliminate this effect, we could follow up the analysis with a Wilcoxon ranked-signed test, keeping only the responses of those students who took both surveys.

Conclusion

With such limited data, the quantitative analysis of surveys provides very limited insights, such as different perceptions of the Egalitarianism aspect of Critical Consciousness among minoritized and non-minoritized students in engineering. By applying a suitable statistical test for a sample, we found that any critical consciousness gains over the course of the semester were not statistically significant. Interestingly, the post-survey responses show that there are statistically significant differences between minoritized and non-minoritized students. Although we did not find any statistically significant changes over the course of the semester, we believe that reporting nonsignificant findings in statistical tests offers valuable insights for educators using similar methodologies, helping them understand potential limitations or areas for refinement in their own practices. These results, toggled with preliminary results from another part of this project where we collected qualitative data, point to the need to strengthen a study's methodology by incorporating multiple types of data. Future and additional work entails re-purposing the surveys used to adapt them further to the study population and enriching the analysis through the use of qualitative data, including interviews and course artifact analysis.

References

[1] P. Freire, *Education for critical consciousness*. Bloomsbury Publishing, 2021.

[2] P. Freire and I. Shor, *Pedagogy for liberation: Dialogues on transforming education*. Palgrave Macmillan Limited, 1987.

[3] R. A. Revelo, J. A. Mejia, L. M. Moguel, and A. Stutts, "Critical Consciousness And Engineering Design Teaching Framework," in *Practice Papers*, Jan. 2023. doi: https://doi.org/10.21427/5YAP-JJ20.

[4] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *Journal of research in science teaching*, vol. 44, no. 8, pp. 1187–1218, 2007.

[5] R. A. Revelo, "Culturally situated survey of engineering identity for Latina/o undergraduates," in *2015 IEEE Frontiers in Education Conference (FIE)*, IEEE, 2015, pp. 1–5.

[6] M. A. Diemer, L. J. Rapa, C. J. Park, and J. C. Perry, "Development and validation of the critical consciousness scale," *Youth & Society*, vol. 49, no. 4, pp. 461–483, 2017.