Examining the Engineering Self-Efficacy, Design Self-Efficacy, Intentions to Persist, and Sense of Belonging of First-Year Engineering Students through Community-Partnered Projects

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Examining the Engineering Self-Efficacy, Design Self-Efficacy, Intentions to Persist, and Sense of Belonging of First-Year Engineering Students through Community-Partnered Projects

Abstract

Community-partnered projects (CPP) have been used in education from the 1990's and have been shown to demonstrate effective learning by working on real-time problems which are diverse and cultural, social, and environmental. Additionally, CPPs offer several student benefits including acquiring and applying new knowledge, improving skills in problem-solving, building a connection with the community partner, etc. CPPs are found in many engineering capstone courses taught at senior year; however, little research lies in CPPs when implemented within first-year engineering courses. In this research study, we are interested in assessing students' perceptions of working on a community-partnered project in their first year of engineering. At a large public university in the United States, we have designed a first-year engineering course that provides opportunities for students to work with CPP. In this course, students are tasked with solving a problem that arises somewhere in the local community. These students can then ask questions to the community partner to understand the problem at hand and develop initial prototypes. The prototypes are then shown to the community partner for feedback and later presented a final design to the community partner. This research study aims at answering following research question, 'What factors influence first-year engineering students' perceptions of their motivations, sense of belonging, and engineering self-efficacy through the application of community-partnered projects?'

To examine the engineering, design, and tinkering self-efficacy, intentions to persist, and sense of belonging of first-year engineering students involved in community-partnered projects, a quantitative research design was used. A survey instrument was designed and developed with three parts: Likert scale questions, open-ended questions, and demographic questions. The Likert scale questions included questions on engineering, design, and tinkering self-efficacy, intentions to persist, and sense of belonging scale. Additionally, demographic questions including gender identity, race/ethnicity, engineering major, etc. were also on the survey. After the data cleaning and data pre-processing, exploratory factor analysis (EFA) was performed on the data to find the factor structure. The EFA revealed four factors: engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging. The factor loadings for the final factors ranged from 0.56 to 0.87, and the internal consistency reliability (Cronbach's α) for the four factors ranged from 0.82 to 0.91, indicating high reliability. We used t-test and one-way ANOVA analyses to investigate the factors influencing first-year engineering students' perceptions on the four scales. None of the factors: gender identity, race/ethnicity, and engineering majors, influenced students' perceptions on engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging after their experiences of working on a community partnered project.

Keywords: community-partnered projects, engineering self-efficacy, first-year engineering, intentions to persist, sense of belonging

Introduction

The context within which this study was conducted was a large public university in the South-Central region of the United States of America which had more than 800 students admitted into its varied engineering programs in the Fall 2023 semester. A first-year engineering experience course was designed to introduce these students to the fundamental principles of engineering design and problem-solving. First-year engineering students were enrolled in sixteen (16) different sections of the course, each comprising about 50 students and taught by a professor. Each professor was paired with 6 mentors, who had taken the course in the past and could provide adequate mentorship to the students in each section.

The design of the course followed the e4usa curriculum. The main objectives of the course were to increase student confidence to use engineering tools and engage in engineering thinking (empowerment), to engage students in multidisciplinary teams to explore the interplay among society's need for engineering (engagement), and to excite students about engineering design as a process of developing personal problem-solving agency (excitement). The higher order learning outcomes of the course included designing a prototype under specified requirements and constraints, communicating engineering design process, and considering the ethical impacts of proposed engineering solutions on society.

To achieve these learning objectives, the teaching team convened prior to the start of the semester to redesign the first-year engineering experience course. In its past layout, students' final course project was to determine their own personal problem and design a solution. The team determined that the best way to help students engage in the course was to align this final course project with a community partner where they would solve a real problem. The teaching team, led by the second author reached out to several stakeholders in the region, asking for descriptions of the problems that they were facing. Priority was given to problems that required an engineering solution. These problems were scaled adequately to fit within the scope of a semester course and served as the community-partnered projects introduced to the students in Fall 2023.

Seventeen (17) projects satisfied the criteria. The project partners ranged from the local city waste treatment center to environmental agencies, the local ministry of transportation, local Zoos, departments within the college of engineering such as Civil Engineering, Biomedical Engineering, Women in Engineering, K-12 Engineering Outreach, and the Dean's office. Other partners within the University were the Food pantry, and the Community Garden. Of these seventeen potential CPPs, teaching faculty identified 12 projects that best aligned with the objectives of the course, had the highest potential for student engagement, and most closely resonated with the teaching faculty's specific interests and prior experiences. The twelve (12) CPPs were introduced to the 16 sections of the first-year engineering course. In each section of the course, students were allowed to choose between two community partnered projects or two variations of the same community-partnered project. This way, we allowed students to practice some self-determination.

For the sixteen-week period of the Fall 2023 semester, students spent 8 weeks working in teams of 4 to address the concerns of the community partners, research the problems posed by the community partners, propose an engineering solution to the problem, and build a prototype of their designed solution. At the thirteenth week, students presented their designs and solutions to the community partners and received feedback for improvement, based on how well they addressed the criteria that the community partners specified. Throughout the process, students iterated their designs and improved their solutions until the final day of presentation to the community partners.

In this paper, we were curious about the experiences of the students. Of particular interest was their perception of engineering self-efficacy, design self-efficacy, belonging, and persistence.

Literature Review

The notion that engineering is a purely technical field has been nuanced extensively in the literature (Forbes & Hoople, 2023; Trevelyan, 2010; Winberg & Winberg, 2017). The sociotechnical nature of the discipline has benefited from decades of research that demonstrate the intrinsic connection between engineers and clients, between engineers and communities, and even among engineers working on the same project (*Engineering as a Social Enterprise*, 1991). The ABET criteria for undergraduate engineering clearly recognizes these desirable outcomes as well ("Criteria for Accrediting Engineering Programs, 2022 - 2023," 2023). Thus, various engineering programs around the world have increased the incorporation of practical capstone projects in their undergraduate programs (Hauhart & Grahe, 2015). These projects typically emerge in the form of community partnered projects (CPPs).

CPPs have their roots in the theory of experiential learning (Kolb, 2015) and have benefited from the works of developmental psychologists that studied the concepts and practices of service learning in higher education (Jacoby & Others, 1996). Service learning combines learning in the classroom with practical applications in and reflections on action in the real world (Jacoby & Others, 1996). This suggests that students gain real-world experience and leverage their motivational indices when the engineering concepts and skills that are learning in the classroom relate to a real-world problem they can relate to.

Service learning in engineering has many benefits, both for students, engineering instructors, university colleges, and the local communities in which these institutions reside ("Service-Learning and Civic Engagement as the Basis for Engineering Design," 2020). The three most common forms of service learning are community partnered projects, industry-focused projects, and competitions.

Our review of the literature surrounding service learning and community partnered projects in engineering revealed several studies previously conducted to understand how they affect students' learning outcomes. While most studies focus on the technical and professional skills that engineering students gain because of participating in community-partnered projects (Siniawski et al., 2015; Zarske et al., 2012), a few highlight the challenges as well (Forbes & Hoople, 2023; Lucena, 2020). CPPs have been shown to improve students' attitudes toward community service (Zarske et al., 2012) and impact identity formation within engineering (Won et al., 2017). Furthermore, students report having improvements in their curiosity, commitment to hard work, and core understanding of the subject matter (Duffy et al., 2008).

Conversely, challenges associated with executing CPPs include reifying dominant structures and savior mentalities (George, 2012; Sohail & Baldwin, 2004). This is a potential issue when the goals of, and communications between students and host communities are not consciously mediated. Another challenge is the fact that real world projects rarely follow a streamlined linear trajectory between problem conceptualization and solving (Lucena, 2020). In reality, progress to completion can be more complex depending on the nature of the project, and the clarity of the instructions from the community partners or even the supervising instructor. Motivation is another key factor. In some cases, students have also been found to be more motivated toward doing industry-sponsored projects or participating in competitions compared to community projects (Forbes & Hoople, 2023). Some suggested reasons include the potential of industry-sponsored projects to signal students to potential employers as work-ready or the potential for some monetary reward (Goldberg et al., n.d.; Steinlicht & Garry, 2014). Notwithstanding, there is ample evidence to suggest that students are drawn to the real-world impacts of community partnered projects (Duffy et al., 2008).

The communication, synchronization, and motivation challenges described are not helped by the fact that grading students' performances in the execution of community partnered projects is a tedious process. Since students work in teams, the extant challenges of working with peers abound. Some students fail to pull their weight, others pull a little too hard by setting unattainable goals. Similarly, uncontrollable circumstances could deny hitherto diligent students the opportunity to complete their tasks within their teams. In some cases, grading rubrics are also unfair because they fail to capture the essence of the engineering design process and its iterative nature. These challenges, it can be argued, are responsible for some of the poor experiences that students report when working on community projects.

In this paper, we are curious if the elements of the engineering course we designed helped to address some of these challenges. In terms of the three course objectives (empower, engage, and excite), we focus on the potential of leveraging the CPPs as a way to increase students' self-efficacy, persistence within engineering, and sense of belonging. This study addresses the following research question, "What factors influence first-year engineering students' perceptions of their engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging through the application of community-partnered projects?"

Methods

1. Development of the Survey Instrument

The survey instrument was developed during the fall of 2023 by an undergraduate student and three faculty members. The instrument included a total of six scales (please refer Table 1). The survey instrument measures the perceptions of first-year engineering students' perceptions on their experience of working on a community partnered project. A total of 37 items were designed across the six scales in this survey instrument. The participants were required to rate their perceptions on a 5-point Likert-type scale. The Likert scale was anchored with different levels (5) strongly agree (4) agree (3) neither agree nor disagree (2) disagree (1) strongly disagree. The survey instrument also included a few demographic questions.

Table 1. Overview of Scales within the Instrument

Scale (# of items)	Definition	Example Items
Engineering self-efficacy (6)	Students' perceptions regarding their confidence in abilities to work on engineering problems	- I can identify problems requiring engineering solutions - I can communicate the solution to the engineering problems in written form
Tinkering self-efficacy (7)	Students' perceptions regarding their experience, competence, and comfort with manual and software related project activities	- I can utilize tools to fix solutions to engineering problems - I can utilize technology to build solutions to engineering problems
Design self-efficacy (5)	Students' perceptions regarding their confidence in abilities to work design related things on their project	- I can identify a design need - I can recognize changes needed for a design solution to work
Intentions to persist (6)	Students' perceptions regarding their intentions to successfully complete the course and degree and persist in the program	- I am fully committed to completing my engineering degree - I do not see any reasons to withdraw from pursuing an engineering degree
Expectancies of success (5)	Students' perceptions regarding their expectations on their course and program success	- I can meet the goals set for me in the engineering program - I can successfully earn credits for the engineering courses
Sense of belonging (8)	Students' perceptions regarding their feelings of belongingness to the engineering community	- I feel that I belong in the engineering community - I felt like an engineer when working on a community partnered project

The six scales of the survey instrument drew inspiration from several existing research studies (Morrow & Ackermann, 2012; Mamaril et al., 2016; Lee et al., 2020). The items in the scales engineering self-efficacy, tinkering self-efficacy, and design self-efficacy were derived from Mamaril et al., (2016). The items in the scales intentions to persist and expectancies of success were derived from Lee et al., (2020). Some of the items of the scale intentions to persist and sense of belonging were derived from Morrow & Ackermann (2012).

2. Evidence of Content Validity and Face Validity

Three faculty members who are not part of the research team but have substantial experience designing survey instruments reviewed the items to gather evidence of the instrument's content validity. Furthermore, three possible participants were given the survey items, and their comments on the items' clarity and phrasing were solicited to gather evidence of the instrument's face validity. These sources were used to inform changes that were made to the questions, such as making them more specific and rewording some of them to reduce repetition.

3. Exploratory Factor Analysis

Procedure

The survey instrument's factor structure was ascertained through the use of exploratory factor analysis (EFA). Three weeks in the fall of 2023, a major public university in the United States provided the data for EFA. To increase the response rate, two reminders were sent out: one in the second week and one in the third. The participants were reached in the classroom through the course instructors. To prevent bias in the responses from the participants, Qualtrics' feature of randomizing survey questions was used. There were no incentives given to the participants.

Analytical Approach

The kurtosis and skew of each of the 37 items were examined prior to conducting the factor analysis in order to verify the assumption of univariate normality (Seltman, 2013). To assess the appropriateness of the survey instrument, the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) test were used. The KMO scores greater than 0.8 suggest the possibility of factor structure and thereby suggesting share variance among items. By calculating the item correlation matrix, Bartlett's test of sphericity is used to determine whether factor analysis is feasible. A significant test result of $p<0.05$ suggests that the data is factorable. By calculating the item correlation matrix, Bartlett's test of sphericity is used to determine whether factor analysis is feasible. A significant test result of $p<0.05$ suggests that the data is factorable. The factors were extracted using principal axis factoring (PAF), which takes measurement error into consideration when doing self-report research (McCoach, Gable, & Madura, 2013). The promax with Kaiser normalization rotation method was used with standard kappa (kappa=4) because it allows for factor correlation, which was thought to be likely in this analysis.

Parallel analysis, scree plots, and Kaiser's criterion method were used to investigate the number of factors post the confirmation of factorability of the data (McCoach, Gable, & Madura, 2013). According to McCoach, Gable, and Madura (2013), items with factor loadings less than 0.4 (<0.4) or cross loadings greater than 0.3 (>0.3) on at least two factors were eliminated. After the survey instrument's factor structure was finalized, Cronbach's alpha (α) was used to assess each scale's internal consistency reliability. A α greater than 0.6 ($\alpha>0.6$) is considered good, and an $\alpha>0.8$ is preferred (McCoach, Gable, & Madura, 2013). The statistical software program SPSS was used to conduct the entire EFA.

To understand the different factors that influence undergraduate engineering students' perceptions on engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging, independent samples *t*-test and one-way ANOVA analyses were conducted (McCoach, Gable, & Madura, 2013; Kittur, 2023). Independent samples *t*-test was conducted to understand the influence of gender identity on the four different scales of the survey instrument. Additionally, one-way ANOVA analyses were conducted to examine the impact of race/ethnicity and engineering majors on the four scales of the survey instrument.

Results

Participants

The survey received responses from 255 people in total, 226 of whom gave their complete answers, which were kept for the EFA. There were no missing values for any of the 37 survey item responses (226). Table 2 displays the demographic data for the participants. The final sample included 74 percent male. Approximately half of the sample self-reported their race/ethnicity as White (48.2 percent), Hispanic or Latin X (12.8 percent), Asian (19 percent), American Indian or Alaska Native (8 percent), Black or African American (10/6 percent), and Native Hawaiian or other Pacific Islander (1.3 percent).

Table 2. Demographic information of the participants

Category	***N***	**%**
Total	226	100
Gender		
Male	168	74.3
Female	58	25.7
Race/Ethnicity		
White	109	48.2
Asian	43	19.0
Hispanic or LatinX	29	12.8
Black or African American	24	10.6
American Indian or Alaska Native	18	8.0
Native Hawaiian or Other Pacific Islander	3	1.3
Academic Department		
Computer Science	48	21.2
Mechanical Engineering	40	17.7
Electrical and Computer Engineering	37	16.4
Biomedical Engineering	23	10.2
Aeronautical Engineering	21	9.3
Civil Engineering	13	5.8
Chemical Engineering	10	4.4
Industrial and Systems Engineering	8	3.5
Aerospace Engineering	5	2.2
Environmental Engineering	5	2.2
Architectural Engineering	4	1.8
Engineering Physics	4	1.8
Engineering Undecided	8	3.5

Exploratory Factor Analysis

Seltman (2013) states that when the absolute values of skewness and kurtosis for each of the 46 survey items were less than 3.0, an acceptable limit was reached (see Table 3). The items were found to be suitable for factor analysis by Bartlett's test for sphericity ($p<0.001$). If factor analysis was carried out, the extraction of factors for accounting meaningful variance was approved by the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) (KMO=0.95) (McCoach, Gable, & Madura, 2013). The data could be used to infer five, four, and four factors, according to Kaiser's criterion, scree plot, and parallel analysis. Four factors were chosen moving forward. Promax rotation was employed because the factor correlations were highly correlated (>0.33) (McCoach, Gable, & Madura, 2013).

Table 3. Descriptive Statistics of Survey Items

#	Measure	Mean	*SD*	Skew	Kurtosis
	Engineering self-efficacy	4.09			
1	I can identify problems requiring engineering solutions	4.19	0.68	-0.69	1.49
2	I can solve real-time engineering problems	3.91	0.84	-0.81	1.02
3	I can interpret the data when solving engineering problems	4.14	0.73	-0.64	0.80
4	I can articulate the solutions to the engineering problems	4.09	0.72	-0.65	1.13
5	I can communicate the solution to the engineering problems in written form	4.13	0.76	-0.76	0.89
6	I can independently propose solutions to engineering problems	4.07	0.77	-0.82	1.10
	Tinkering self-efficacy	4.09			
7	I can utilize hand/power tools to build solutions to engineering problems	3.96	0.97	-1.02	1.08
8	I can utilize tools to fix solutions to engineering problems	4.12	0.74	-0.92	2.04
9	I can assemble things	4.16	0.75	-1.04	2.25
10	I can disassemble things	4.16	0.76	-1.09	2.67
11	I can apply engineering concepts in solutions to engineering problems	4.16	0.65	-0.57	0.96
12	I can utilize machines to build solutions to engineering problems	3.98	0.84	-0.56	0.06
13	I can utilize technology to build solutions to engineering problems	4.08	0.80	-1.04	1.99
	Design self-efficacy	4.15			
14	I can identify a design need	4.15	0.66	-0.65	1.77
15	I can design new things	4.12	0.75	-0.71	0.93
16	I can develop design solutions	4.13	0.65	-0.82	2.59
17	I can evaluate a design	4.12	0.70	-0.79	1.67
18	I can recognize changes needed for a design solution to work	4.21	0.64	-0.52	0.69
	Intentions to persist	4.16			
19	I can complete a major in engineering	4.25	0.82	-1.18	1.98
20	I am fully committed to completing my engineering degree	4.12	0.99	-1.19	1.16
21	I intend to graduate with an engineering degree	4.21	0.99	-1.48	2.10
22	I do not intend to drop out from my engineering degree	4.14	0.99	-1.43	2.05
23	I do not see any reasons to withdraw from pursuing an engineering degree	3.95	1.04	-0.93	0.33
24	I plan to be still enrolled in the engineering college	4.30	0.90	-1.56	2.77
	Expectancies of success	4.16			
25	I can meet the goals set for me in the engineering program	4.19	0.66	-0.51	0.51
26	I can satisfy the objectives of the engineering program	4.20	0.68	-0.79	1.83
27	I can successfully earn credits for the engineering courses	4.24	0.73	-1.29	3.34
28	I can pass all the engineering courses	4.01	0.77	-0.72	1.16
29	I can master the knowledge and skills taught in this course	4.14	0.68	-0.70	1.72
	Sense of belonging	4.10			
30	I feel that I belong in the engineering community	3.97	0.85	-0.82	1.15
31	I feel I am a part of my class	4.08	0.72	-0.77	1.52
32	I feel I am included in my class	4.15	0.72	-0.96	2.37
33	I felt comfortable interacting the client	4.04	0.83	-0.77	0.74
34	I felt comfortable interacting with the professor in class	4.30	0.84	-1.44	2.60
35	I felt comfortable interacting with the peers in class	4.21	0.75	-0.94	1.37
36	I felt comfortable interacting with the mentors in class	4.14	0.81	-0.92	1.21
37	I felt like an engineer when working on a community partnered project	3.87	1.02	-0.98	0.62

Note. N=226, all items were rated on five-point scales

A number of the survey items had factor loadings of more than 0.4, and the one item with factor loadings of less than 0.4 in the survey instrument was eliminated from the analysis (Pett, Lackey & Sullivan, 2003). Examples of items that had cross-loadings include ‘I can utilize tools to fix solutions to engineering problems’, ‘I can complete a major in engineering’, ‘I can meet the goals set for me in the engineering program’, ‘I felt like an engineer when working on a community partnered project’, etc. The one item that had less than 0.4 factor loadings is ‘I felt comfortable interacting with client’. The EFA yielded four factors in total, but the scales measuring "Tinkering self-efficacy" and "Expectancies of success" were excluded. Table 4 displays the factor loadings of the final factor structure. Factor loadings for the first factor (F1), second factor (F2), third factor (F3), and fourth factor (F4) ranged from 0.59 to 0.75, 0.65 to 0.71, 0.75 to 0.87, and 0.56 to 0.73. The four factors had high reliability, as indicated by their internal consistency reliability (Cronbach's α) ranging from 0.82 to 0.91.

Table 4. Factor loadings of the survey item structure

#	Items	F1	F2	F3	F4
	Engineering self-efficacy (*Cronbach's α = 0.86*)				
1	I can identify problems requiring engineering solutions	0.59			
2	I can solve real-time engineering problems	0.66			
3	I can interpret the data when solving engineering problems	0.63			
4	I can articulate the solutions to the engineering problems	0.75			
5	I can communicate the solution to the engineering problems in written form	0.63			
6	I can independently propose solutions to engineering problems	0.59			
	Design self-efficacy (*Cronbach's α = 0.87*)				
14	I can identify a design need		0.71		
15	I can design new things		0.69		
16	I can develop design solutions		0.69		
17	I can evaluate a design		0.69		
18	I can recognize changes needed for a design solution to work		0.65		
	Intentions to persist (*Cronbach's α = 0.91*)				
20	I am fully committed to completing my engineering degree			0.81	
21	I intend to graduate with an engineering degree			0.87	
22	I do not intend to drop out from my engineering degree			0.75	
23	I do not see any reasons to withdraw from pursuing an engineering degree			0.75	
24	I plan to be still enrolled in the engineering college			0.83	
	Sense of belonging (*Cronbach's α = 0.82*)				
31	I feel I am a part of my class				0.73
32	I feel I am included in my class				0.73
34	I felt comfortable interacting with the professor in class				0.62
35	I felt comfortable interacting with the peers in class				0.62
36	I felt comfortable interacting with the mentors in class				0.56

Note. F1 = Engineering self-efficacy, F2 = Design self-efficacy, F3 = Intentions to persist, F4 = Sense of belonging

t-test and One-way ANOVA analyses

In this study, the *t*-test and one-way ANOVA analyses were conducted. The scores on each factor were calculated by averaging the response scores of all the items that were categorized under the factor. For example, the first factor's (engineering self-efficacy) score was calculated by averaging the response scores of items 1, 2, 3, 4, 5, and 6 (refer Table 4).

t-test – gender identity

Gender identity of freshmen engineering students did not significantly influence any of the four factors (engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging). Males on average reported higher confidence in all the scales in comparison with females.

> There were no statistically significant differences in the freshmen engineering students' ratings on the engineering self-efficacy scale (p=0.756) based on their gender identity. Also, the self-reported self-efficacy of male participants (*M*=4.09, *SD*=0.59) and female participants (*M*=4.07, *SD*=0.55) was similar.
>
> There were no statistically significant differences in the freshmen engineering students' ratings on the design self-efficacy scale (p=0.941) based on their gender identity. Also, the self-reported self-efficacy of male participants (*M*=4.15, *SD*=0.58) and female participants (*M*=4.14, *SD*=0.48) was similar.
>
> There were no statistically significant differences in the freshmen engineering students' ratings on the intentions to persist scale (p=0.134) based on their gender identity. Despite the minor difference in the self-reported self-efficacy of male participants (*M*=4.19, *SD*=0.79) and female participants (*M*=4.0, *SD*=0.97).
>
> There were no statistically significant differences in the freshmen engineering students' ratings on the sense of belonging scale (p=0.556) based on their gender identity. Also, the self-reported self-efficacy of male participants (*M*=4.19, *SD*=0.60) and female participants (*M*=4.14, *SD*=0.55) was similar.

One-way ANOVA analyses - Race/Ethnicity

Race/ethnicity of freshmen engineering students did not significantly influence any of the four factors (engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging).

> There were no statistically significant differences in engineering students' ratings on the engineering self-efficacy scale (*p*=0.409) based on their race/ethnicity. However, students identifying as American Indian or Alaska Native reported higher self-efficacy (*M*=4.38, *SD*=0.46) in the engineering self-efficacy scale and students identifying as Black or African American reported the lowest self-efficacy (*M*=3.94, *SD*=0.60).
>
> There were no statistically significant differences in engineering students' ratings on the design self-efficacy scale (*p*=0.207) based on their race/ethnicity. However, students with

race/ethnicity as American Indian or Alaska Native reported higher self-efficacy (*M*=4.3, *SD*=0.51) in the design self-efficacy scale and students identifying as Hispanic or LatinX reported the lowest self-efficacy (*M*=3.99, *SD*=0.53).

There were no statistically significant differences in engineering students' ratings on the intentions to persist scale (*p*=0.724) based on their race/ethnicity. However, students identifying as Asians reported higher self-efficacy (*M*=4.26, *SD*=0.76) in the intentions to persist scale and students identifying as Hispanic or LatinX reported the lowest self-efficacy (*M*=3.93, *SD*=0.93).

There were no statistically significant differences in engineering students' ratings on the sense of belonging scale (*p*=0.751) based on their race/ethnicity. Also, students identifying as Black or African American reported higher self-efficacy (*M*=4.24, *SD*=0.60) in the sense of belonging scale and students identifying as Hispanic or LatinX reported the lowest self-efficacy (*M*=4.13, *SD*=0.44).

One-way ANOVA analyses - Engineering Major

Engineering majors of freshmen engineering students did not significantly influence any of the four factors (engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging).

There were no statistically significant differences in engineering students' ratings on the engineering self-efficacy scale (*p*=0.685) based on their engineering majors. Also, electrical and computer engineering (ECE) students reported higher self-efficacy (*M*=4.2, *SD*=0.66) in the engineering self-efficacy scale and computer science and biomedical engineering students reported the lowest self-efficacy ((*M*=4.09, *SD*=0.58), (*M*=4.09, *SD*=0.70)).

There were no statistically significant differences in engineering students' ratings on the design self-efficacy scale (*p*=0.191) based on their engineering majors. Also, ECE students reported higher self-efficacy (*M*=4.3, *SD*=0.54) in the design self-efficacy scale and computer science students reported the lowest self-efficacy (*M*=4.11, *SD*=0.46).

There were no statistically significant differences in engineering students' ratings on the intentions to persist scale (*p*=0.379) based on their engineering majors. However, ECE students reported higher self-efficacy (*M*=4.43, *SD*=0.51) in the intentions to persist scale and computer science students reported the lowest self-efficacy (*M*=4.03, *SD*=0.74).

There were no statistically significant differences in engineering students' ratings on the sense of belonging scale (*p*=0.673) based on their engineering majors. Also, mechanical engineering students reported higher self-efficacy (*M*=4.3, *SD*=0.54) in the sense of belonging scale and aeronautical engineering students reported the lowest self-efficacy (*M*=4.06, *SD*=0.63).

Conclusions

In this paper, a survey instrument was designed to measure the perceptions of first-year engineering students' perceptions on their experience of working on a community partnered project. The final four factors are engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging. In the process of survey design and development, the research team followed the required steps including collecting evidence for content and face validity, factor analysis, and internal consistency reliability for all four factors. The results from EFA supported the four hypothesized factors. The factor loadings for the final factors ranged from 0.56 to 0.87, and the internal consistency reliability (Cronbach's α) for the four factors ranged from 0.82 to 0.91, indicating high reliability. None of the factors: gender identity, race/ethnicity, and engineering majors, influenced students' perceptions on engineering self-efficacy, design self-efficacy, intentions to persist, and sense of belonging after their experiences of working on a community partnered project.

Like all studies, this study also comes with several limitations. The data collected is not representative of a larger sample of freshmen engineering students across the United States as the respondents in this study were from a single university. The data collected has limitations in explaining the reasons for why the factor 'tinkering self-efficacy' was suggested by EFA to be deleted from the study. Also, we do not know the reasons for different factors not influencing students' perceptions on the four scales. More research is required to further investigate the reasons for the findings that emerged from this study. Additionally, investigating a qualitative study to gain critical insights on freshmen students' experiences of working on a community partnered project and its influence on their engineering self-efficacy, motivations, and sense of belonging, is a potential direction for future research.

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