2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53299

[Traditional Research Paper] Enhancing Undergraduate Engineering Teaching Self-Efficacy and Conceptual Understanding of the Engineering Design Process through an Interdisciplinary Community Engagement Project

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ENHANCED TEACHING SELF-EFFICACY AND CONCEPTUAL UNDERSTANDING IN ENGINEERING DESIGN PROCESS THROUGH COMMUNITY ENGAGED LEARNING

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ABSTRACT

In response to Rhode Island's 2013 adoption of the Next Generation Science Standards (NGSS), a local school district partnered with a liberal arts university to address a key implementation challenge: elementary teachers' limited familiarity with engineering concepts and practices. An interdisciplinary community-engaged project connected two courses—Sustainable Energy Systems and Teaching Inquiry Science in the Elementary School—so undergraduate engineering and education students could co-design and deliver a five-lesson wind energy unit to eleven fourth-grade classrooms, reaching over 230 students and their teachers.

This study examined changes in undergraduates' engineering-teaching self-efficacy and their conceptual understanding of the engineering design process. Grounded in experiential and collaborative learning, the project immersed students in authentic classroom practice to build pedagogical confidence and content knowledge.

A one-group pre–post design assessed change using the Wilcoxon signed-rank test, a nonparametric method appropriate for ordinal data and small to moderate samples. Pre- and post-assessments adapted from the Teaching Engineering Self-Efficacy Scale were completed by 43 education and 28 engineering students. Results showed statistically significant gains ($p < .05$) across three self-efficacy dimensions: engineering pedagogical content knowledge, motivational self-efficacy, and outcome expectancy. Education majors exhibited the largest improvements, especially in confidence teaching the engineering design process. Conceptual understanding also increased: correct sequencing of design steps rose from 79.1% to 90.7% for education students and from 92.9% to 100% for engineering students.

Implications include effective design principles for interdisciplinary, community-engaged models that prepare undergraduates to teach engineering and expand K–12 STEM capacity.

Keywords: Engineering design process, engineering teaching self-efficacy, community engaged learning, interdisciplinary collaboration

GOALS AND OBJECTIVES

In 2013, Rhode Island adopted the Next Generation Science Standards (NGSS) prompting an effort to align curriculum and instruction with the new vision reflected in the NGSS (Rhode Island Department of Elementary and Secondary Education [RIDE], 2025). One of the challenges our local school district faced while implementing the NGSS-aligned curriculum was the elementary school teachers' lack of familiarity with the engineering practices and core ideas that are explicitly included in the NGSS. Thus, the district had the pressing need to provide the elementary school teachers with the support for integrating science and engineering in their classrooms.

The needs of the local school district prompted the creation of an interdisciplinary community engagement project, linking engineering and education courses at our liberal arts university. This work included joint efforts from an upper-level engineering elective course, Sustainable Energy Systems, and a sophomore-level education course, Teaching Inquiry Science in the Elementary School. The engineering students provided technical expertise about energy, the wind resource, and wind turbines. Meanwhile, education students complemented engineering students' content proficiency with their emerging expertise in planning grade-specific and NGSS-aligned science lessons.

The district selected fourth-grade teachers and students to participate in the collaborative project due to the strong alignment between the instructional topic of wind energy and the NGSS performance expectations. The success of the project was evaluated across four distinct participant groups: fourth-grade students and teachers in the district, as well as education and engineering students at our university. However, this paper specifically examines the impact of the project on undergraduate participants. The central research question guiding this study is how the community-engaged learning project influences undergraduate students' engineering teaching self-efficacy and their conceptual understanding of the engineering design process.

THEORETICAL FRAMEWORK

Engineering Teaching Self-Efficacy

Self-efficacy plays a critical role in shaping students' mastery goals, influencing their learning approaches, and ultimately affecting academic achievement. Studies conducted on secondary students in Singapore and tertiary students in Spain find that higher self-efficacy is closely linked to mastery goals, fostering a deep learning approach that positively impacts academic success (Fenollar et al., 2007; Liem et al., 2008). Similarly, research involving tertiary students in the South Pacific confirms that self-esteem and self-efficacy together drive mastery goals, leading to improved academic outcomes (Phan, 2011).

Beyond student learning, the influence of self-efficacy extends to educators, particularly in the domain of engineering education. Crawford et al. (2021) examined the effects of a professional development (PD) course designed to enhance in-service science teachers' self-efficacy in teaching engineering. Their study demonstrates statistically significant improvements in self-efficacy following PD completion in both 2018 and 2019. Qualitative data further reinforce these findings, illustrating increased student engagement, collaboration, and motivation, along with more effective implementation of project-based learning. Teachers' reflections on their classroom experiences affirm the success of the PD, with statements such as: "My students are more involved and interested in science due to my deeper understanding of the engineering design process and nanotechnology" (Crawford, 2021, p. 5).

Expanding on these findings, Rich et al. (2017) explored the long-term effects of a yearlong training program aimed at improving K-6 in-service teachers' self-efficacy and beliefs surrounding computing and engineering instruction. Their mixed-methods study utilized both a survey and qualitative interviews, revealing statistically significant enhancements in Computing Self-Efficacy, Engineering Teaching Beliefs, Engineering Self-Efficacy, and increased instructional time dedicated to engineering and computing concepts. The findings from this study reveal the importance of early intervention and structured support in helping educators integrate computing and engineering into their curriculum, thereby strengthening their confidence and instructional effectiveness.

Yesilyurt et al. (2021) investigated the effects of an engineering unit within an elementary science methods course for pre-service teachers. Their findings indicate that participation in engineering-focused activities significantly increased pre-service teachers' personal teaching efficacy beliefs, suggesting that direct exposure to engineering pedagogies can enhance instructional confidence and preparedness.

The body of research highlights the integral role of self-efficacy in both student learning and teacher effectiveness in engineering education. Studies consistently show that self-efficacy influences mastery goals and deep learning approaches, leading to improved academic achievement. Likewise, professional development initiatives and structured training programs have demonstrated their ability to bolster self-efficacy among educators, strengthening instructional confidence and effectiveness in engineering and computing education. Collectively, these findings suggest that fostering self-efficacy—through targeted interventions for both students and teachers—can yield significant educational benefits and drive improved learning outcomes.

Community Engaged Learning

Community engagement in higher education is broadly defined as *"*collaboration between institutions of higher education and their larger communities (local, regional/state, national, global) for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity" (American Council on Education, 2026). The role of community engagement in higher education has grown increasingly important as institutions seek to fulfill their civic responsibilities. By actively involving faculty, students, and communities, universities address social, economic, and environmental challenges while providing students with meaningful learning opportunities that bridge theory and practice.

Community engagement strengthens relationships between academic institutions and communities by fostering trust and reciprocal partnerships. Universities, through outreach initiatives and service-learning programs, contribute to addressing societal challenges such as housing needs, poverty, education, sustainability, social justice, and health disparities (Coelho & Menezes, 2021; Holland & Ramaley, 2008; Salam et al., 2019). In addition to benefiting local communities, this engagement enriches student learning by offering experiential opportunities that cultivate problem-solving, leadership, and civic responsibility. Research suggests that students who participate in community-engaged learning demonstrate improved career readiness, interpersonal skills, and critical thinking capabilities (Eyler & Giles, 1999).

Interdisciplinary collaboration is another key advantage of community engagement. Universities unite faculty and students from diverse disciplines, integrating knowledge to solve complex societal challenges. The interdisciplinary nature of community engagement promotes innovative approaches to problem-solving, creating opportunities for engineering, social sciences, environmental studies, and public health to work together toward shared goals (Salam et al., 2019). By developing sustainable solutions, academic institutions can effectively address pressing societal concerns while advancing research and innovation.

In addition to academic and societal benefits, community engagement contributes to economic development and environmental sustainability. Universities that collaborate with local organizations stimulate economic activity by fostering entrepreneurship, workforce development, and job creation (Hassan et al., 2024). Partnerships between institutions and communities lead to the implementation of sustainable initiatives that promote environmental responsibility and long-term growth (Holland & Ramaley, 2008; Álvarez-Vanegas, Ramani, & Volante, 2024). These initiatives illustrate how community engagement serves as a fundamental tool for social change, reinforcing higher education's commitment to serving the broader community.

Recent research continues to highlight the transformative impact of community engagement in higher education. Muwanguzi et al. (2023) provide a comprehensive conceptual exploration of community engagement, emphasizing its role in strengthening democratic values, civic responsibility, and interdisciplinary collaboration. Their study underscores the importance of integrating teaching, research, and community partnerships to address societal challenges while enhancing student learning. Similarly, Chowdhury and Alzarrad (2025) examine strategies for scaling community-based education, identifying institutional resistance and alignment with technical standards as key challenges. Their findings emphasize the need for strong community partnerships, faculty development, and curricular flexibility to maximize the benefits of experiential learning.

METHODOLOGY

Community Engaged Learning Project Implementation

The pilot year of the community engagement project was launched in Spring 2019 and featured three key components: a professional development workshop, a sequence of classroom lessons on wind energy and engineering design, and a culminating celebration event. The initiative began with a daylong workshop for fourth-grade teachers and the Assistant Superintendent, hosted at our university and facilitated by faculty from engineering and education. This session introduced participants to core engineering design concepts and wind energy through hands-on activities, while also creating space for teachers to exchange best practices with university faculty.

Building on the workshop, interdisciplinary teams of undergraduate engineering students enrolled in *Sustainable Energy Systems* and education students in *Teaching Inquiry Science in the Elementary School* (the second course in a two-semester elementary science methods sequence) collaboratively planned and delivered five lessons across eleven fourth-grade classrooms, reaching more than 230 students. The first two lessons introduced foundational concepts of energy and wind, followed by a third lesson on the engineering design process using model turbine kits (Vernier, 2025). In the final two lessons, the college students guided fourth graders through designing, building, and testing wind turbine blades using an iterative engineering design approach.

The project concluded with a celebration event at the university, where students tested their model-scale turbines in a wind tunnel and participated in additional engineering design activities, reinforcing both the technical concepts and the collaborative spirit of the project.

Research Procedures and Methodology

The project assessment measured self-efficacy and content knowledge through pre- and post-tests across four participant groups: fourth-grade students, fourth-grade teachers, and undergraduate education and engineering students. Each assessment was designed to take no longer than 20 minutes. Pre-tests were conducted in late January and early February 2019, before the project began, and post-tests were completed in late April and early May 2019, following the final celebratory event. Outcomes were evaluated by comparing baseline data to post-project results.

This paper specifically examines how the project impacted undergraduate participants' engineering teaching self-efficacy and their conceptual understanding of the engineering design process. Other assessment outcomes will be presented in future research. The undergraduate students completed pre- and post-tests evaluating their confidence in teaching engineering and their understanding of concepts in energy, energy conversion, wind energy, and the engineering design process. These assessments were administered in their classrooms without the presence of course instructors.

The engineering teaching self-efficacy survey was adapted from the Teaching Engineering Self-Efficacy Scale (TESS), originally designed for K-12 teachers in the United States (Yoon, Evans, & Strobel, 2012). To suit the study's undergraduate participants, the scale was shortened to 18 six-point Likert-scale items measuring three dimensions of engineering teaching efficacy: engineering pedagogical content knowledge self-efficacy (9 items), motivational/engagement self-efficacy (4 items), and outcome expectancy (5 items). Response categories ranged from "strongly disagree" (1) to "strongly agree" (6).

A Wilcoxon signed-rank test was conducted to analyze median differences in undergraduate students' engineering teaching self-efficacy before and after the community-engaged learning project. Item analysis was also performed on multiple-choice questions assessing students' understanding of engineering design concepts, evaluating the percentage of correct responses and response distribution.

RESULTS AND DISCUSSION

Forty-three education and twenty-eight engineering students completed both pre- and post-tests. This section presents the findings regarding their engineering teaching self-efficacy and conceptual understanding of engineering design process in the pre- and the post-test.

Education and Engineering Students' Engineering Teaching Self-Efficacy

It is only appropriate to use a Wilcoxon signed-rank test if our research design and data meet the test's three assumptions. The three assumptions are that: (a) the dependent variable is continuous or ordinal; (b) the independent variable is categorical with two related groups; and (c) the distribution of the differences between the two related groups are symmetrical in shape (Laerd Statistics, 2025). Our research design meets the first two assumptions. The difference scores between each participant's pre- and post-test for each of the 18 six-point Likert-scale items were approximately symmetrically distributed, as assessed by a histogram with superimposed normal curve. This shows our data has passed the third critical assumption of the Wilcoxon signed-rank test, too. The histogram that shows the approximately symmetrical distribution of the differences between each education student's pre- and post-test scores for Item 9 is provided here as an example (Figure 1).

Table 1 contains the medians of education and engineering students' scores for each of the 18 six-point Likert-scale items assessing their engineering teaching self-efficacy, as well as the medians of the differences, before and after their participation in this project. Education students median scores are higher in each statement in the post-test than in the pre-test. Engineering students' median scores improved across 15 questions while the median scores for the other 3 questions remained the same from the pre- to the post-test.

The dimension of engineering teaching efficacy that education students show the greatest improvement is "engineering pedagogical content knowledge self-efficacy," for which the median of the differences for each of the 9 statements assessing that dimension is 2 or 3. The median of the differences for each statement assessing the other two dimensions, motivational self-efficacy and outcome expectancy, is 1. Engineering students' median difference is 1 for each statement in all three dimensions except for three items in the dimension of outcome expectancy being less than 1. Both education and engineering students improved their engineering teaching self-efficacy in all three dimensions after their participation in the project; however, education students increased their efficacy in engineering pedagogical content knowledge and outcome expectancy more than engineering students.

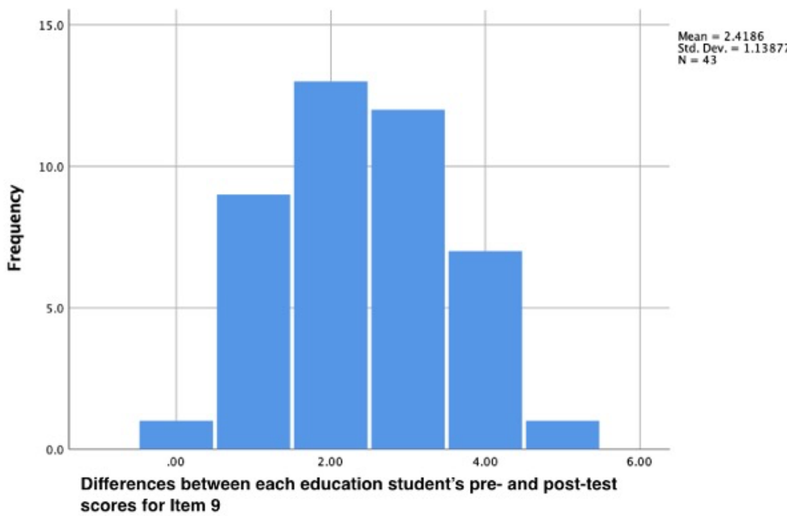

Figure 1. The distribution of the differences between each education student's pre- and post-test scores for Item 9

Table 1. Education and engineering students' median scores of their perceived self-efficacy in engineering teaching and the median differences between their pre- and post-test scores.

	Education Students			Engineering Students		
Engineering Pedagogical Content Knowledge Self-efficacy	Pre-test	Post-test	Diff	Pre-test	Post-test	Diff

1	I can explain the different aspects of the engineering design process.	2	5	3	5	6	1
2	I can assess my students' engineering design products.	3	5	3	5	6	1
3	I know how to teach the engineering design process effectively.	2	6	3	4	6	1
4	I can teach engineering as well as I do most subjects.	2	5	2	5	6	1
5	I can employ engineering activities in my classroom effectively.	3	5	2	5	6	1
6	I can discuss how engineering is connected to our daily life.	4	6	2	5	6	1
7	I can create engineering activities at the appropriate level for my students.	4	6	2	4	5	1
8	I can recognize and appreciate the connections between engineering and other STEM fields.	4	5	2	5	6	1
9	I can guide my students' solution development with the engineering design process.	3	5	2	4	6	1
Motivational Self-efficacy							
10	I can motivate students who show low interest in learning engineering.	4	5	1	4	5	1
11	I can increase students' interest in learning engineering.	4	6	1	4	5	1
12	Through engineering activities, I can make students enjoy the class more.	4	6	1	4.5	6	1
13	I can encourage my students to interact with each other when participating in engineering activities.	5	6	1	4	5	1
Outcome Expectancy							
14	I am generally responsible for my students' achievements in engineering.	4	5	1	5	5	0.5
15	When my students do better than usual in engineering, it is often because I exerted a little extra effort.	4	5	1	4.5	5	1
16	My effectiveness in engineering teaching can influence the achievement of students with low motivation.	4	5	1	5	5	0.5
17	If I increase my effort in engineering teaching, I see significant change in students' engineering achievement.	4	5	1	5	5.5	1
18	I am responsible for my students' competence in engineering.	4	5	1	5	5	0

Table 2 and Table 3 show the ranks test outcome, which compares education or engineering students' pre- and post-test median scores for each of the 18 six-point Likert-scale items assessing their engineering teaching self-efficacy. It is a positive rank when a participant's post-test score is higher than the pre-test score, a negative rank when the post-test score is lower than the pre-test one, and a tie when the pre- and the post-test scores are the same. All education students increased their scores (37- 43 positive ranks; 88.1%- 100%) or kept the same scores (0-5 ties; 0%- 11.9%) from the pre- to the post-test in seven questionnaire items, Item 1, 2, 3, 4, 6, 7, and 9. All engineering students' scores increased (18-23 positive ranks, 64.3%- 82.1%) or remained the same (5- 10 ties, 17.9%- 35.7%) from the pre- to the post-test in three questionnaire items, Item 1, 3, and 6. The items that every education or engineering student scored higher or the same from the pre- to the post-test are in the "engineering pedagogical content knowledge self-efficacy" dimension.

The number of education students' positive ranks for each questionnaire item ranges from 25 (58.1%) to 43 (100%), while the number of engineering students' positive ranks are between 11 (39.3%) and 23 (82.1%). This indicates that at least about 60% of education students and 40% of engineering students improved their scores on each engineering teaching self-efficacy item. For both groups of students, the item with the highest number of positive ranks is Item 3, "I know how to teach the engineering design process effectively" (43, 100% of education students; 23, 82.1% of engineering students), and the lowest number of positive ranks is Item 18, "I am responsible for my students' competence in engineering" (25, 58.1% of education students; 11, 39.3% of engineering students). For engineering students, Item 5, "I can employ engineering activities in my classroom effectively" shares the highest number of positive ranks with Item 3.

Eleven items have negative ranks among education students, though none receives more than 4 negative ranks (9.3%). The two items receive 4 negative ranks are Item 10 ("I can motivate students who show low interest in learning engineering") and Item 14 ("I am generally responsible for my students' achievements in engineering"). Engineering students decreased their scores on 15 items with the number of negative ranks ranging from 1 (3.6%) to 9 (32.1%). The item received the highest number of negative ranks (9, 32.1%) is Item 16 ("My effectiveness in engineering teaching can influence the achievement of students with low motivation"). More than 20% of engineering students also decreased their self-efficacy scores on two other items, Item 18 (7, 25.0%) and Item 14 (6, 21.4%). Overall, a higher percentage of engineering students scored lower in the post- than the pre-test on more items than education students (15 vs. 11 items). Item 14 receives a greater number of negative ranks from both groups.

The number of ties ranges between 0 (0%) and 15 (34.9%) across the 18 items for education students and from 3 (10.7%) to 10 (35.7%) for engineering students. Education students have the highest number of ties on Item 18 (15, 34.9%), 13 and 17 (14, 32.6%), while engineering students have most ties on Item 1, 6, and 18 (10, 35.7%). Both groups have about 35% of students scored the same on Item 18 in the pre- and the post-test. Table 4 summarizes the findings about the questionnaire items with most/least positive or negative ranks and items with most ties among education and engineering students, respectively.

Table 2. Ranks outcome on education students' perceived self-efficacy in engineering teaching.

Survey Question Number	Number of Negative Ranks (percentage)	Number of Positive Ranks (percentage)	Number of Ties (percentage)	Total
1	0 (0%)	41 (95.3%)	2 (4.7%)	43
2	0 (0%)	41 (95.3%)	2 (4.7%)	43
3	0 (0%)	43 (100%)	0 (0%)	43
4	0 (0%)	37 (88.1%)	5 (11.9%)	42
5	1 (2.3%)	38 (88.4%)	4 (9.3%)	43

6	0 (0%)	39 (90.7%)	4 (9.3%)	43
7	0 (0%)	37 (88.1%)	5 (11.9%)	42
8	1 (2.3%)	35 (81.4%)	7 (16.3%)	43
9	0 (0%)	42 (97.7%)	1 (2.3%)	43
10	4 (9.3%)	30 (69.8%)	9 (20.9%)	43
11	2 (4.7%)	32 (74.4%)	9 (20.9%)	43
12	1 (2.3%)	33 (76.7%)	9 (20.9%)	43
13	1 (2.3%)	28 (65.1%)	14 (32.6%)	43
14	4 (9.3%)	29 (67.4%)	10 (23.3%)	43
15	3 (7.0%)	31 (72.1%)	9 (20.9%)	43
16	1 (2.3%)	30 (71.4%)	11 (26.2%)	42
17	1 (2.3%)	28 (65.1%)	14 (32.6%)	43
18	3 (7.0%)	25 (58.1%)	15 (34.9%)	43

Table 3. Ranks outcome on engineering students' perceived self-efficacy in engineering teaching.

Survey Question Number	Number of Negative Ranks (percentage)	Number of Positive Ranks (percentage)	Number of Ties (percentage)	Total
1	0 (0%)	18 (64.3%)	10 (35.7%)	28
2	3 (10.7%)	16 (57.1%)	9 (32.1%)	28
3	0 (0%)	23 (82.1%)	5 (17.9%)	28
4	1 (3.6%)	22 (78.6%)	5 (17.9%)	28
5	1 (3.6%)	23 (82.1%)	4 (14.3%)	28
6	0 (0%)	18 (64.3%)	10 (35.7%)	28
7	1 (3.6%)	20 (71.4%)	7 (25.0%)	28
8	2 (7.1%)	19 (67.9%)	7 (25.0%)	28
9	4 (14.3%)	21 (75.0%)	3 (10.7%)	28
10	4 (14.3%)	17 (60.7%)	7 (25.0%)	28
11	3 (10.7%)	17 (60.7%)	8 (28.6%)	28
12	2 (7.1%)	20 (71.4%)	6 (21.4%)	28
13	3 (10.7%)	17 (60.7%)	8 (28.6%)	28

14	6 (21.4%)	14 (50.0%)	8 (28.6%)	28
15	5 (17.9%)	16 (57.1%)	7 (25.0%)	28
16	9 (32.1%)	14 (50.0%)	5 (17.9%)	28
17	4 (14.3%)	15 (53.6%)	9 (32.1%)	28
18	7 (25.0%)	11 (39.3%)	10 (35.7%)	28

Table 4. Questionnaire items with most/least positive ranks and negative ranks and items with most ties

	Items with most positive ranks	Items with least positive ranks	Items with most negative ranks	Items without negative ranks	Items with most ties
Education Students	3	18	10, 14	1, 2, 3, 4, 6, 7, 9	18, 13, 17
Engineering Students	3, 5	18	16, 18, 14	1, 3, 6	1, 6, 18

Our research's null hypothesis for a Wilcoxon signed-rank test is:

H0: the median difference between the paired values (pre- and post-test of engineering teaching self-efficacy) is equal to zero.

And the alternative hypothesis is:

HA: the median difference between the paired values (pre- and post-test of engineering teaching self-efficacy) is not equal to zero.

Table 5 shows the Wilcoxon signed-rank test statistics for education and engineering students. The statistical significance of the Wilcoxon signed-rank test for each questionnaire item's median difference between education students' pre- and post-test shows that the null hypothesis is rejected. In other words, education students who participated in a community engaged learning project significantly improve their engineering teaching self-efficacy at the end of the project. For engineering students, there was a statistically significant median difference in 16 of the 18 questionnaire items. The two items that engineering students didn't make significant improvement after their participation in the project are Item 16 ("My effectiveness in engineering teaching can influence the achievement of students with low motivation") and Item 18 ("I am responsible for my students' competence in engineering"). Both items are from the "outcome expectancy" dimension of the engineering teaching self-efficacy questionnaire.

Table 5. Wilcoxon signed-rank test statistics

	Education Students			Engineering Students		
Survey Item	Difference in medians	z^a	Asymp. Sig. (2-tailed)^b	Difference in medians	z^a	Asymp. Sig. (2-tailed)^b
1	3	-5.623	$p < .001$	1	-4.146	$p < .001$
2	3	-5.618	$p < .001$	1	-3.182	$p = .001$
3	3	-5.755	$p < .001$	1	-4.298	$p < .001$

4	2	-5.349	$p < .001$	1	-3.774	$p < .001$
5	2	-5.437	$p < .001$	1	-3.740	$p < .001$
6	2	-5.511	$p < .001$	1	-3.906	$p < .001$
7	2	-5.346	$p < .001$	1	-3.891	$p < .001$
8	2	-5.175	$p < .001$	1	-3.630	$p < .001$
9	2	-5.692	$p < .001$	1	-3.709	$p < .001$
10	1	-4.469	$p < .001$	1	-2.714	$p = .007$
11	1	-4.867	$p < .001$	1	-2.813	$p = .005$
12	1	-5.048	$p < .001$	1	-3.406	$p = .001$
13	1	-4.658	$p < .001$	1	-3.035	$p = .002$
14	1	-4.245	$p < .001$	0.5	-2.105	$p = .035$
15	1	-4.651	$p < .001$	1	-2.128	$p = .033$
16	1	-4.833	$p < .001$	0.5	-1.268	$\boldsymbol{p = .205}$
17	1	-4.630	$p < .001$	1	-2.597	$p = .009$
18	1	-3.907	$p < .001$	0	-1.522	$\boldsymbol{p = .128}$

[a] Based on negative ranks.
[b] $p < .05$ was selected as the minimum criterion for significance.

Education and Engineering Students' Understanding of Concepts in Engineering Design Process

Beyond teaching self-efficacy, education and engineering students were also assessed on their understanding of concepts in engineering design process. Education and engineering students were given a scenario describing a challenge of designing and developing a prototype of a small candy dispenser, about which they were asked multiple follow-up questions in the pre- and post-assessments. The scenario and the follow-up questions were modified from the Henry County Schools (n.d.) engineering design process quiz.

Education students were asked to select which of the following statements best describes the problem in the scenario.

A. Your candy dispenser must be made with at least seven different items.
B. Aunt Laura has made several different flavors of candy.
C. Your Aunt Laura needs someone to invent a candy dispenser for her.
D. None of these

Of the 44 education students responded to this question, 30 students (68.2%) selected the correct statement in the pre-test, and 35 students (79.5%) answered correctly in the post-test. Of the incorrect answers for this population, the mode were A and D on the pre-test, and A on the post-test. More education students were able to identify the problem in the scenario correctly after their participation in the project; however, some students were still confusing the candy dispenser design criteria (Statement A) with the problem in the scenario (Statement C) at the end of the project.

In addition, education students were asked to identify which of the following will be a constraint and which will be a criterion for the candy dispenser design challenge: 3 straws, 2 paper clips, 1 bowl, 1 cup, 1 CD, 2 pipe cleaners, glass, dispense free sample, tape, 2 rubber bands, name of dispenser, 1 file folder, must be made with at least seven different items, items which create a safety hazard. Table Six shows that the percentage of correct identification as a constraint or criteria decreases slightly across most items between pre- and post-assessments. The three items where the percentage of correct identification increased were "name of dispenser," "must be made with at least seven different items," and "dispense free sample." The items with the greatest changes in the percentage correct are "must be made with at least seven different items," which has a 12% increase, and "name of dispenser," which has an 8.9% increase from the pre- to post-test. Overall, these results demonstrate that after participating in this project more education students were able to identify the three criteria for the candy dispenser design; however, approximately half of them were not able to identify whether it is a constraint or criterion for most of the items in question.

Table 6. The percent of items correctly identified as a constraint or criteria by education students in the pre- and post-test.

Item	Pre-test % correct	Post-test % correct	Diff
3 straws	55.6	53.3	-2.2
1 bowl	56.8	53.3	-3.4
1 CD	56.8	53.3	-3.4
glass	75.7	75.6	-0.1
tape	54.1	53.3	-0.7
name of dispenser	73.0	81.8	8.9
must be made with at least seven different items	43.6	55.6	12.0
items which create a safety hazard	57.9	53.3	-4.6
2 paper clips	56.8	53.3	-3.4
1 cup	59.5	53.3	-6.1
2 pipe cleaners	55.6	53.3	-2.2
dispense free sample	69.4	71.1	1.7
2 rubber bands	58.3	53.3	-5.0
1 file folder	55.6	53.3	-2.2

Both education and engineering students were asked to order the following steps that best represent what will occur during the Engineering Design Process as they develop the candy dispenser.

A. Draw various sketches of possible solutions of the candy dispenser.
B. Research different candy dispensers using the internet.
C. List the criteria for the candy dispenser.
D. Develop the prototype for the candy dispenser.

An analysis of the pre- and post-tests revealed that more education students were able to list the steps of the engineering design process after participating in a community engaged learning project. Of the 43 education students who responded to this question in both pre and post-tests, 16 students (37.2%) listed the steps in the correct order on the pre-test. By the post-test, 25 students (58.1%) were able to identify the correct order of steps, a 20.9% increase. Four education students changed their answers from the correct answer in the pre-test to an incorrect answer in the post-test. Of the incorrect answers for this population on both the pre- and post-test, the mode was BCAD: research various candy dispensers, list the criteria, draw sketches for possible candy dispensers, and then build a prototype. There was a 20.8% decrease of incorrect answers from the pre-test to the post-test. Of the students who changed their answers from the pre-test to the post-test, the majority (65%) changed their answer from an incorrect response to the correct response.

An analysis of the pre- and post-tests for engineering students revealed that the percentage of students who listed the steps of the engineering design process in the correct order slightly decreased over the course of this project (71.4% on the pre-test and 67.9% on the post-test). All students who gave an incorrect response indicated BCAD as their response. Six students (21.4%) switched their answer from a correct answer in the pre-test to an incorrect answer in the post-test, while five students (17.9%) switched their answer from an incorrect response in the pre-test to a correct response in the post-test.

The correct order for the engineering design process is as follows: list the criteria, research various candy dispensers, draw sketches for possible candy dispensers, and then build the prototype. However, in practice, the first two steps of this process are interchangeable, to an extent, or happen simultaneously. Using both answers, CBAD and BCAD, as correct, 79.1% of education students answered correctly on the pre-test. By the post-test, 90.7% of education students gave a correct response, a 14.7% increase. The engineering students had more correct responses on both the pre- and post-test, too. For the pre-test, 92.9% of engineering students gave the correct answer. By the time they took the post-test, all 28 engineering students provided one of the two possible correct answers.

CONCLUSIONS AND SIGNIFICANCE OF THE STUDY

A community engagement project involving interdisciplinary collaboration between engineering and education courses, in collaboration with the local school district, educated fourth graders about engineering design and wind energy. The project not only met the needs of the school district, but also enhanced undergraduate learning through hands-on, experiential engagement with the community. Assessment data demonstrates increased engineering teaching self-efficacy in engineering and education undergraduates. Among the three engineering teaching self-efficacy dimensions, both groups of students showed the greatest improvement in engineering pedagogical content knowledge self-efficacy.

Education students also demonstrated a deeper understanding of engineering design concepts, with more participants correctly identifying the problem in the candy dispenser design scenario, its criteria, and the steps of the engineering design process. However, some students continued to conflate design problems, criteria, and constraints.

Yesilyurt et al. (2021) found that while pre-service teachers significantly enhanced their personal engineering teaching efficacy after participating in engineering-focused lectures and activities, their engineering teaching outcome expectancy did not show a parallel increase. The authors suggested that authentic field experiences—such as designing or teaching engineering lessons—may be essential for strengthening outcome expectancies. Similarly, Coppola (2019) reported that pre-service teachers improved their self-efficacy in engineering pedagogical content knowledge, engagement, and disciplinary practices, but not in outcome expectancy, after first experiencing an exemplar engineering mini-unit as learners and then designing and teaching their own mini-unit to K–5 students. Coppola emphasized the importance of providing multiple mastery experiences in engineering instruction to build robust teaching self-efficacy. In line with these findings, Webb and LoFaro (2020) argued that teacher preparation programs can better prepare elementary pre-service teachers to teach engineering by offering dedicated engineering methods courses, rather than limiting exposure to brief coverage within already overloaded science methods courses.

Our results support and extend these recommendations. Pre-service teachers in our study demonstrated significant growth across all three dimensions of engineering teaching self-efficacy—including outcome expectancy—after first engaging with exemplary science and engineering units as learners in the initial course of a two-semester elementary science methods sequence, and then planning and teaching five integrated science and engineering lessons in the subsequent course.

Beyond measurable outcomes, the project fostered meaningful partnerships between the university and the local school district, providing undergraduates with authentic teaching experiences while enhancing NGSS-aligned instruction in elementary classrooms. The findings underscore the value of community-engaged learning as a pedagogical strategy for strengthening both content mastery and teaching confidence in interdisciplinary STEM education. This model illustrates how reciprocal university–school collaborations can simultaneously advance undergraduate learning, teacher preparedness, and K–12 STEM engagement. The project success of our pilot year attests to the effectiveness of using community engaged learning as a pedagogical approach and ensures continued collaboration between our university and the local school district for future years.

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