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University-Elementary School Partnerships: Analyzing the Impact of a Service-Learning Freshman Engineering Course on Students' Engineering Values and Competence Beliefs*

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There is a growing demand in the US for more engineers, yet attrition rates from university engineering programs are high and diversity in engineering is low. Few resources have been dedicated to the improvement of freshman engineering courses even though freshman students have the highest rates of attrition. Through a synthesis of the literature on inclusive instructional strategies and participant structures in educational settings, we developed, implemented, and researched a freshman mechanical engineering design course that incorporated elements of project-based learning, collaboration, service-learning, and customer-oriented design through a partnership with a local elementary school. Our research was grounded in the value and competence belief constructs defined by expectancy-value theory. Engineering values include enjoying engineering tasks, viewing engineering as useful, and identifying as an engineer and engineering competence beliefs encompass beliefs in one's engineering abilities in the present, as well expectancies for success in the future. Rich qualitative data collected from 72 undergraduate participants suggested that this course was both highly valued and helpful for increasing engineering competence beliefs. Further, these positive impacts were consistent across gender. From our results, we provide recommendations for strategies to help grow and diversify engineering.

Keywords: expectancy-value theory; freshman engineering education; project-based learning; collaboration; service-learning, customer-oriented design

1. Introduction

There have been persistent calls to redesign engineering education at the university level to improve the retention and diversity of its students [1–3]. One challenge that must be addressed is low retention: attrition for undergraduate engineering programs throughout the US is on the order of 40 to 70%, with the highest dropout rates occurring between freshman and sophomore year [2, 4–6]. Poorly integrated curricula, impersonal pedagogy, and a lack of student support have been identified as leading causes of student attrition [7]. Considering the growing demand in the US for engineers, something must be done to retain more students in engineering programs [8]. A second challenge that also must be addressed is a lack of diversity. Engineering represents one of the most male-dominated STEM (Science, Technology, Engineering, and Mathematics) disciplines: approximately 80% of engineering undergraduate degrees in the US are awarded to men [9]. This lack of diversity is both an economic and social justice issue, as supporting a diverse workforce is essential to increasing the knowledge base and advancing society.

This paper examines the development and implementation of a novel freshman mechanical engineering design course that sought to reduce attrition and address diversity. To do so, the undergraduate course was developed around four primary parameters: project-based learning (PBL), collaboration, service-learning, and customer-oriented design; these parameters are discussed in detail below. The course was run as a partnership with an elementary afterschool program, whereby our undergraduates designed, built, and tested dancing robots that met the specifications set forth by their fifth- and sixth-grade student clients. Through a series of design team meetings, the undergraduates also collaborated with and served as role models to the elementary students.

The development of our engineering course was informed not only by a synthesis of the literature on inclusive instructional strategies and participant structures in educational settings (i.e., PBL, collaboration, service-learning, and customer-oriented design) but also by the value and competence belief constructs defined in expectancy-value theory (EVT). Research in EVT suggests that to increase student engagement, persistence, and performance in engineering, a program should develop students' engineering values and competence beliefs [10]. Using EVT as a framework, we defined engineering values to include enjoying engineering tasks, view-

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ing engineering as useful, and identifying as an engineer. We defined competence beliefs as the belief in one's ability to complete engineering tasks in the present as well as one's expectancy for success in future engineering endeavors. EVT is particularly relevant for studies focused on diversity issues as values and competence beliefs are influenced by surrounding cultural norms. For example, longstanding stereotypes related to male superiority in quantitative fields have been found to negatively impact women's interest and performance in engineering disciplines [11, 12].

We invoked the EVT framework as a tool to understand how to design effective engineering education curricula that encouraged more undergraduates, including more women, to engage, persist, and perform well in the domain of engineering. In doing so, we attempted to fill two important gaps in the literature. The first research gap pertains to engineering undergraduate curricula. While there exist progressive engineering courses which incorporate some combination of PBL, collaboration, service-learning, and customer-oriented design, the impact of these courses on undergraduates' values and competence beliefs (or other related measures) is not adequately researched. Further, we are not aware of any courses designed around all four of these inclusive instructional practices. The second research gap relates to EVT. EVT, which was developed to study gender differences in the domains of elementary and secondary mathematics and English [10], has not been applied in the context of undergraduate engineering education and has not been previously used to inform undergraduate engineering curricular change.

In brief, using the lens of EVT, we studied 72 engineering undergraduates enrolled in a freshman mechanical engineering design course. We qualitatively analyzed open-ended survey data to examine how each of four parameters of our course (i.e., PBL, collaboration, service-learning, and customer-oriented design) connected to undergraduates' engineering values and impacted their engineering competence beliefs. Our purpose was to inform curricular change in freshman engineering courses toward the goal of retaining a more diverse undergraduate engineering population.

2. Background

2.1 Inclusive strategies for teaching engineering

We begin by synthesizing the literature on inclusive strategies for undergraduate engineering education. We discuss the potential benefits of incorporating the following strategies into our program development: project-based learning (PBL), collaboration, service-learning, and customer-oriented design.

Available research suggests that PBL courses, i.e., courses designed around the completion of projects, increases student retention and diversity in comparison to more traditional lecture-based courses [2, 7], [13–17]. PBL creates more individualized learning opportunities, allows for hands-on experiences, and helps students bridge the gap between the theoretical and the real world. While relatively common in upper-level engineering capstone courses, PBL is not as prevalent during freshman year when students are most vulnerable to attrition [7, 13].

Equally important, when engineering courses do include projects, these projects frequently center around competitions rather than collaborations. The perception of engineering as a competitive and unsupportive environment can discourage participation by students, in particular, women, who are underrepresented in the field and are subsequently primed to be impacted by stereotype threat [2, 18, 19]. In contrast, collaboration can help to decrease feelings of isolation and to create a more welcoming and supportive environment. Teamwork also provides students with opportunities to contribute in a variety of ways, thereby placing value on diversity rather than creating hierarchies through competition [20]. Further, collaboration can be achieved on multiple levels, for example, the project described in this paper requires undergraduates to work in peer groups, participate in undergraduate-elementary partnerships, and design and build a robot that will dance (rather than compete) with other robots.

Service-learning is a third defining feature of the course under investigation. Because first-year engineering design courses are usually one quarter long and composed of students without substantial engineering experience, many focus on solving artificial or already solved problems. Socially relevant engineering design challenges, such as alternative energy vehicles, assistive devices, or water purification systems, are typically reserved for more advanced students when enrolled in multi-quarter capstone courses. We argue that, in place of artificial problems, service-learning projects can be implemented to engage students in introductory-level engineering design that helps to meet the needs of their communities [21]. Such service-learning projects can be leveraged to benefit both undergraduates and community members. For the undergraduates, a focus on how engineers contribute to society has been shown as a powerful tool for engaging a more diverse group of students in engineering and for elementary students, engineering role models can inspire them to further explore this field [2, 7, 14, 18, 22, 23].

Projects that pair undergraduates with elementary students, as described in this paper, give engineering students the opportunity to inspire and teach children about engineering, thereby giving back to their communities with their engineering work. When the elementary school students play the role of the customer and have a say in the final design that the undergraduates complete, this type of partnership can also be leveraged to expose the undergraduates to engineer-customer interactions as a crucial component of the design process, a fourth component of the course studied here. Most professional engineers "generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" [13, p. 104]. Thus, customer-led design provides first-year engineering students a more authentic engineering experience. Furthermore, designing for a customer, especially in the context of service-learning, highlights user needs as an integral part of the engineering design process, which helps counter the existing culture of disengagement with social issues that has been identified in US engineering programs [24].

2.2 EVT as the theoretical framework

The theoretical framework underlying the development of our engineering design course is expectancy-value theory [25, 26]. EVT posits that the values one holds for a task (i.e., engineering in this study) together with one's competence beliefs for that task predict engagement, persistence, and performance in that task [10]. EVT was initially developed to study gender differences in fifth- through twelfth-grade students' values and beliefs about mathematics and English [10]. Through longitudinal empirical studies, the EVT model includes three types of subjective task values: intrinsic value, utility value, and attainment value [25, 27, 28]. In the context of engineering, intrinsic value accounts for how much interest one has in engineering. Utility value measures the degree to which one finds the act of learning engineering to be useful in some way, especially for one's future. And attainment value captures how much one considers engineering important to one's identity. Cost is often discussed as a fourth value, referring to the stresses associated with and sacrifices made for engineering. However, most of Eccles and colleagues' research does not explore the cost construct in depth and, as such, it is not as robustly supported in the literature as the other three values. Thus, we decided not to include cost in our analyses. The EVT model also includes two types of competence beliefs: ability beliefs and expectancies for success [25, 28]. In the context of engineering, ability beliefs address beliefs in one's present-day engineering abilities, whereas expectancies for success measure how well one expects to do on engineering tasks in the future. However, while theoretically distinct, Eccles and colleagues have found that the ability beliefs and expectancy constructs are highly related empirically [10, 29]. Therefore, we employed the general competence belief construct to encompass both present-day ability beliefs and future expectancies for success.

The items traditionally used in EVT research to measure values and beliefs are targeted at the domain-specific level, e.g., how much students like doing mathematics, and are closed-ended in format [10]. Subsequently, conclusions are limited to the quantification of students' existing values and competence beliefs; the data offer no information as to *how* to develop more effective curricula. Given that our purpose was to invoke EVT as a tool to learn *how* to more effectively design engineering curricula, we determined that the standard EVT questions used with 'engineering' in place of 'mathematics' would not be sufficient to answer our research questions. Data pertaining to the specific aspects of engineering that students value and derive competence beliefs from is required to inform curricular change. For example, if students place high value on the social application of engineering and/or derive competence beliefs from their ability to contribute to society with their work, then it is important that engineering courses address the many ways that engineering is socially relevant. The same could be said for design or problem-solving skills, etc. Thus, for our research design, it was important that we collected data on the reasons behind students' values and competence beliefs. We accomplished this through a qualitative analysis of open-ended survey data.

3. Research methods

3.1 Study context

Introduction to Engineering Graphics, CAD and Conceptual Design was a ten-week design course required for first-year mechanical engineering undergraduates at the University of California, Santa Barbara and taught by one of the authors. Students were expected to learn several foundational skills—free hand sketching, mechanical drawings, computer aided design, laser cutting, soldering, basic microprocessor programming, and the design of basic circuits, motors, and gear trains—to ensure all could successfully complete the final project: to design and build a custom robot that would dance as part of a robot flash mob (project-based learning and collaborative goal). The undergraduates were divided into 17 groups of four to five students (collaboration) and each group was paired with two to three elementary students at a local public elementary afterschool program. The ele-

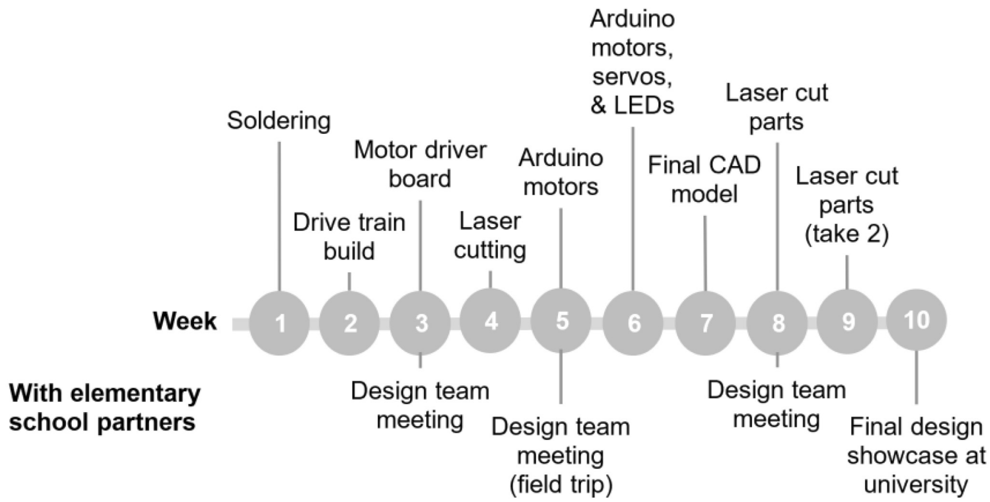
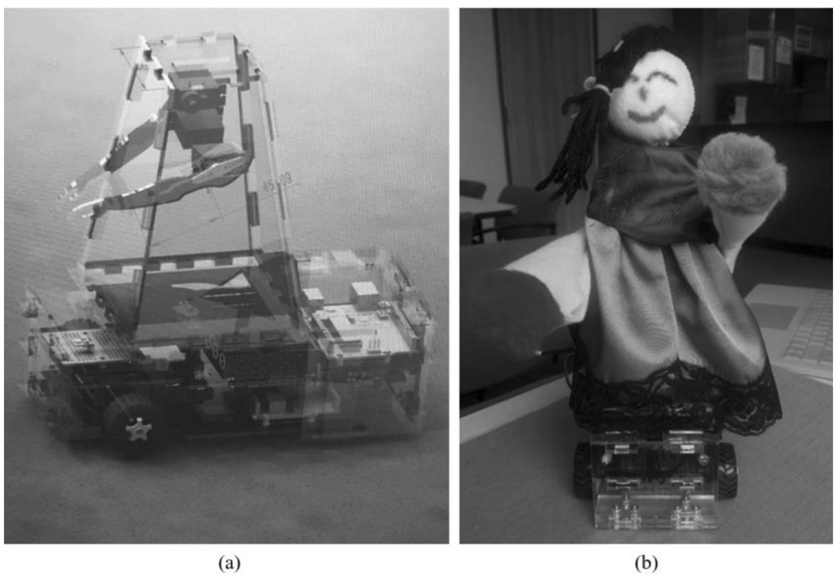


Fig. 1. Timeline of the ten-week undergraduate engineering course described by lab topic.

mentary afterschool program was held on Friday afternoons for a period of eight weeks and was led by the lead author of this paper. The elementary students served as the customers for the undergraduates (customer-oriented design): They defined the specifications of the robot, including what it would look like and how it would dance. The elementary students were also partners (service-learning and collaboration): they participated in three design team meetings with undergraduate representatives to help create the robot designs and worked independently to build a light-up component that would attach to the robot (e.g., a collar with blinking LEDs for a dog robot). The program concluded with a robot dance performance at the university engineering design showcase; all elementary student partners were invited to attend with their families. See Fig. 1 for a timeline of the undergraduate course and Fig. 2 for an example of a completed robot.

3.2 Participants

This study tracked undergraduate engineering students enrolled in a freshman mechanical engineering design course at the University of California, Santa Barbara during the spring quarter of 2017. Of the 84 undergraduates enrolled, 72 agreed to participate in our study, including 11 women and 61 men. Undergraduates were offered one point on an assignment to complete the survey, with an option to not have their responses used for research purposes. Undergraduates were also guaranteed that their responses would not be released to their professor with any identifying information, so they could answer hon-



(a) (b)

Fig. 2. An example of a final robot render (a) and final robot (b).

estly without concern for their grades or future interactions. Further, this study was approved by the Institutional Review Board (IRB). Finally, all names used were changed to pseudonyms.

As stated above, 11 of the 72, or 15%, of our undergraduate participants were women. The gender breakdown in this freshman mechanical engineering design course was reflective of the college of engineering at this university (see Table 1). Because we are interested in promoting diversity in engineering, we included examination of participants' gender in our study. However, we recognize that many students belong to more than one diverse student group and that they are thus forced to grapple with multiple barriers to persist in engineering [30]. Further, we acknowledge that there is much heterogeneity within each gender. For the purposes of this research, then, we rely on the gender binary as an analytic tool but recognize its limitations and commit to valuing the complexity of all students. In addition, one to two self-selected undergraduates from each of the 17 groups (composed of four to five undergraduates per group)—31 of the 72 undergraduate participants—met with their elementary partners for three design team meetings: these undergraduates were deemed as having *facetime* with students. The undergraduate-elementary student teams were established by the researchers and lasted for the entire duration of the program, meaning the same undergraduate team met with the same elementary students for all three design team meetings; however, the undergraduate team representatives that met with the elementary school students were free to switch from one meeting to the next. More specifically, 39% of undergraduates with facetime attended all three design team meetings, 26% attended two of the three meetings, and 35% attended only one meeting. Although not all undergraduate team representatives were present for all design team meetings, the established team pairings provided the students with the opportunity to build sustained relationships as they worked collaboratively on the robots towards a collective goal.

Finally, the rate of attrition in engineering at this university is slightly lower than the national average discussed in the Introduction: of the 2010 freshman engineering cohort at the target university, 31% of students did not complete their engineering degree. Attrition rates were highest immediately after the freshman year—14% of students left before their sophomore year. An additional 10% of students left before their junior year and the remaining 7% left before their senior year. The statistics are similar across gender (see again Table 1).

3.3 Research questions

Using data collected from our study, we explored the following research question: How did each parameter of our engineering design course (i.e., PBL, collaboration, service-learning, and customer-oriented design) connect to students' engineering values (i.e., intrinsic, utility, and attainment values) and impact students' engineering competence beliefs? We explored this question by examining undergraduate participants' responses as a collective, by gender, and by facetime status.

3.4 Data

We administered exploratory open-ended surveys to undergraduate students enrolled in our freshman engineering design course during the last week of the quarter. The survey consisted of 11 items organized into three sections: general engineering questions, course experience questions, and demographics. Most undergraduates completed the survey in 15 to 20 minutes. Given that the goal of this paper was to learn about undergraduates' experiences with the course, in addition to demographics (i.e., age, gender, and facetime), we focused on their responses to the following three questions: (1) Did you enjoy the project for this course? Why or why not? (2) What did you like and/or not like about working with the elementary students as part of this project? (3) Are you (more, less, or equally) confident in your decision to be an engineer after taking this course? Why?

Table 1. Graduation and retention rates for freshman engineering cohorts at the target university from 2006–2015 compared across gender

			% all (% female) retained to . . .			**% all (% female) completing degree by end of . . .**		
Year	**Count**	**% Female**	**2nd Year**	**3rd Year**	**4th Year**	**4th Year**	**5th Year**	**6th Year**
2006	299	15	77 (64)	58 (44)	51 (38)	36 (29)	47 (33)	48 (33)
2007	295	15	70 (71)	54 (51)	47 (42)	36 (33)	43 (38)	44 (38)
2008	431	15	73 (62)	60 (49)	55 (41)	42 (35)	51 (41)	52 (41)
2009	368	17	81 (81)	67 (61)	62 (53)	46 (45)	58 (48)	59 (50)
2010	291	13	86 (84)	76 (68)	69 (65)	56 (59)	68 (65)	69 (65)
2011	339	17	88 (86)	76 (70)	71 (64)	59 (61)	66 (63)	
2012	338	15	90 (90)	75 (71)	71 (67)	60 (62)		
2013	325	18	83 (78)	71 (56)	66 (51)			
2014	335	20	91 (89)	81 (79)				
2015	270	20	91 (91)					

3.5 Analysis

Responses were coded in NVivo, a computer program for coding qualitative data. Previously defined codes aligning with EVT value and competence belief constructs and the course parameters were invoked to deductively code students' responses to the program experience questions [31]. Two sets of codes were used: (1) student values (i.e., intrinsic, utility, and attainment) and competence beliefs based on EVT and (2) course parameters (i.e., PBL, collaboration, service-learning, customer-oriented design). Four researchers met weekly to discuss the data and develop a reliable coding scheme. Two of these researchers then coded all data. For two-thirds of the surveys, these two researchers coded responses individually and then met together to compare codes and reach consensus on any disagreements. They coded the remaining surveys individually; however, any questions that emerged were brought to the group and reviewed among the researchers until consensus was reached. Furthermore, one-eighth of the surveys that were to be coded individually were randomly selected, coded by both researchers, and checked for inter-rater reliability. We consistently found over 90% agreement on each check, implying reliable and trustworthy coding methods.

To address our research question—how each parameter of the engineering course (i.e., PBL, collaboration, service-learning, and customer-oriented design) connected to students' engineering values and impacted students' engineering competence beliefs—we looked for intersections between students' descriptions of program parameters and references to their engineering values and competence beliefs, as defined by EVT. We were interested in *how* the students valued and derived competence beliefs from the course. We also wanted to learn whether some parameters of the course were more impactful than others. Data were deductively coded for student values (intrinsic, utility, and attainment) and competence beliefs based on EVT, as well as for the course parameters (PBL, collaboration, service-learning, customer-oriented design). We looked for intersections between the EVT and course parameter codes.

4. Results and discussion

From our qualitative analysis of undergraduates' open-ended survey responses, we found that this course connected to students' engineering values and positively impacted students' engineering competence beliefs. Each of the course parameters (i.e., PBL, collaboration, service-learning, and customer-oriented design) contributed to these outcomes. Further, results were comparable in women and men and, for the most part, in both the undergraduates who worked directly with the elementary students (i.e., had facetime) and those who only maintained indirect contact; there were some discrepancies based on facetime status, which are discussed below.

4.1 Course connections to engineering values

The engineering value constructs were coded when students described some part of the course as enjoyable or interesting (intrinsic value), useful to them in some way (utility value), or important for confirming their engineering identity (attainment value). In their self-reported experiences with our course, nearly all undergraduates described connections between at least one aspect of the course and their engineering values.

4.1.1 Intrinsic value

Undergraduates most commonly described intrinsic value for the project-based nature of the course; that is, approximately 90% of students enjoyed the hands-on process of designing, building, and testing their robots over the 10-week period. Additionally, about one-third of students self-reported intrinsic value for each of the remaining course design parameters: collaboration, service-learning, and customer-oriented design. These trends were consistent across gender. However, the undergraduates who met directly with the elementary students (i.e., undergraduates with facetime) more commonly described value for the service-learning parameters of the course: nearly half of undergraduates with facetime intrinsically valued partnering with the elementary students versus just over one-quarter of undergraduates without facetime. Examples illustrating how undergraduates described their intrinsic value for each of the four course parameters are provided below.

As stated above, most undergraduates described the course project as enjoyable or interesting which, according to many, contrasted with their experiences in other courses. For example, Clive, appreciated the creative freedom this course offered, stating, "I had never worked with something like this before, and learning how to tap into creativity to build something was a new and fun experience for me." And Mike found the hands-on experiences to be novel and satisfying: "The labs and outside of class work were very indicative of what I should expect when working as an engineer after college and is much different from a normal class setting of lectures and sections. And making a final, working product in the end is a very satisfying goal to reach and made the class much more enjoyable."

Several of the undergraduates also discussed their enjoyment in working in peer groups and collaborating with the elementary students; they saw these as ways to make friends and have fun. This was especially important to Vaibhav, an international student, who explained, "The course is cool. Because I am an international student, this is my first time working with US students in my life. The best thing I learnt is being a team." And Dustin explained that collaboration with the elementary students made the project even more enjoyable: "Building the robot in tandem with the [elementary] students was very fun. It was awesome to see their happiness when we showed them the sketches we made, and the overall work was never boring." Inspiring the elementary children to pursue engineering through this partnership was also a notable highlight of the course for many students. Dalia reported, "I liked being able to help make a robot for a kid who may potentially be influenced to follow a career path in the STEM field. Their creative imagination also allowed us to build something fun." Finally, the added challenge of designing the robots to the specifications of a customer deepened the engagement levels for many undergraduates and provided a more authentic engineering experience. For example, according to Arthur, "I liked having to accommodate to a customer's design (not based on my design and ideas). It pushed my limits and stopped me from cutting corners. It expanded my horizon of thinking."

4.1.2 Utility value

Nearly half of the undergraduates explicitly stated that they considered the knowledge and skills they obtained from the engineering course to be useful for their futures. As was the case for the intrinsic value derived from the course, utility value was most commonly mentioned in reference to PBL and was consistent across gender and degree of interaction with the elementary students. In contrast to intrinsic value, however, only a handful of students described utility value for their collaborative experiences and no undergraduate directly described utility in reference to service-learning or customer-oriented design. Given the low numbers of students who described utility for collaboration, it is unreasonable to make inferences about patterns across gender or degree of interaction with the elementary students.

Undergraduates commonly described the utility of the course project for their futures. For example, according to Jason, "The course helped develop skills that I think will be very applicable to what I want to do in the future." and Bill, "I have learned so much already from this course by being proactive and learning from my mistakes and that can be related to so many areas of life." Several undergraduates also described the collaborative nature of the course as useful for developing their communication skills. Victoria explained, "It helped my communication skills and as two different teams we had to communicate very clearly what each team would be responsible for and what would be more realistic in terms of the project." Similarly, Alex noted, "I feel I can effectively work with others in a group and that will help me throughout my lifetime."

4.1.3 Attainment value

The comments made by approximately one in five undergraduates implied that this course shaped their identities as engineers. These findings were consistent across gender and facetime status. However, the responses by the undergraduates were, for the most part, directed at their experiences in the course as a whole, so we were unable to break down the findings by course parameter. For example, Mike explained, "I now have more understanding of what an engineer is and does, and it makes it more appealing as a lifelong career choice, as it seems new challenges are at every step of the way." And according to Asher, "This course has really showed me more of what it is like to be an engineer, the struggles and the rewards. And because of this I am happy to have picked this as my career path because I think it is rare to have such a rewarding career in other fields."

4.2 Course impact on engineering competence beliefs

The engineering competence belief construct in this paper measures undergraduates' beliefs in their abilities to perform well on engineering tasks. Nearly two-thirds of undergraduates reported increased levels of confidence in becoming engineers as a direct result of this course—the PBL structure was the only cited reason for these increased competence beliefs. The results were consistent across gender and facetime status.

More specifically, a common theme that emerged from the survey data was that undergraduates surprised themselves by successfully building a robot from scratch and this newfound knowledge increased their beliefs in their own abilities. For example, Alex explained, "I am much more confident to be an engineer, as I've learned things that I thought were beyond my capabilities, and now realize that I will learn the majority of what I need to know in classes." Fred described increased ability beliefs because of this course but expressed an overall decrease in his expectancy for success in engineering because of his other course experiences. According to Fred, "I do feel less confident after this school year, but not because of this course. I feel like I'm doing fine in this course. In all honesty, this class boosted my confidence because I realized that everything I learned from elementary school up until the end of high school actually gave me a lot of the necessary skills I need to be a successful engineer.'' Fred's experience reiterates the need to redesign traditional engineering courses, such as we have done with our engineering design course.

5. Limitations

Our study is limited in two primary ways. One limitation of our analysis is that we had many fewer women participants (11) versus men (61). However, this limitation reflects the larger issue we wish to address with our research: not enough women are electing to major in engineering. Although, in this study, we found no major differences between male and female undergraduate students' experiences with the engineering course, it is possible that differences may have gone unnoticed because of the small sample size of only 11 women. More research with larger sample sizes should be conducted to further investigate the impact of PBL, collaboration, service-learning, and customer-oriented design on the development of engineering values and competence beliefs by gender.

A second limitation relates to the identification of diverse groups: We only compared undergraduate responses by gender in this study. Comparative analyses based on race/ethnicity will be conducted in future iterations of this research to help us further contribute to the diversification of the field of engineering.

6. Conclusions

The US has a demand for more engineers, yet little has been done to reform undergraduate engineering education. The findings from this paper have several practical implications for instructors and institutions. We have demonstrated that developing freshman engineering courses around project-based learning, collaboration, service-learning, and customer-oriented design leverages both male and female students' values for engineering and helps to increase their confidence in their engineering abilities. Further, we have shown that partnering with elementary schools can provide freshmen with the opportunity to be 'real' engineers, while connecting them with their communities and helping them learn to design projects to the specifications of a customer. This is particularly important for freshmen courses because professional engineering companies rarely work with universities to offer novice freshman students authentic engineering experiences. Since these partnerships also benefit the elementary students, they can be typically be established without any additional costs beyond the materials required to build the robots. Additionally, open-source CAD tools, such as FreeCAD, can be implemented to reduce costs as necessary. Based on these findings, we encourage other university engineering programs to incorporate collaborative projects into their courses and to construct partnerships with local elementary schools.

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