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The impact of implementing community engagement projects in a first-year engineering course

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The impact of implementing community engagement projects in a first-year engineering course

Introduction

This study sets out to investigate the impact of community engagement projects on student perceptions of a first-year engineering course at Virginia Tech. This general engineering course is the first of a two-course sequence required of incoming students, and focuses on learning outcomes such as major exploration, engineering problem-solving strategies, introductory programming skills, technical communication, project management skills, and effective teamwork strategies. The course does not typically include a physical/hands-on build component, which has caused students to express some degree of dissatisfaction in the value of many of the learning activities, especially those related to non-technical learning outcomes. In Spring 2024, we adjusted the semester-long project scope to include input from and engagement with community project partners; implementation of similar projects has been shown to increase students' perceived value of introductory level courses [1], [2], [3], [4]. This paper describes the impact of those projects on students' perceptions of the course, building upon the planning and implementation process described in a prior work-in-progress paper [5].

The six project partners who took part in this initiative work for the Facilities Department at the university on various engineering-related projects in their day-to-day roles and volunteered their time to engage with student teams and provide materials for the course. Given the size of the institution, students taking the course are rarely exposed to or have knowledge of the type of work done by facilities and operations staff; therefore, these project partners were seen by student teams as being external to the course and their on-campus experiences and thus fulfilled the role of community partners in these kinds of projects. This pairing provided an opportunity for reciprocal community engagement, an important aspect if these types of partnership, in allowing students to learn about university operations, and the project partners to better understand their student stakeholders and potentially benefit from the solutions [6]. Each project partner proposed a theme for students to explore related to their daily work, provided data for analysis as part of the course's programming module, and periodically answered questions throughout the semester via email. Two out of the six project partners attended an in-person project kickoff, and all attended at least one section of the final poster sessions to provide feedback at the end of the semester. Please refer to the preceding work-in-progress paper for more details related to the planning and implementation process [5].

These projects were piloted in three sections of the course in Spring 2024 with 185 students enrolled and grouped into 34 teams ranging from 4-6 students each. While most students in this course are admitted to a General Engineering program and take the course in the Fall semester, it is notable that these three sections were considered "off-cycle" in that the students enrolled were out of sequence with traditional plans of study. Most students in the course had been admitted to a non-engineering major and enrolled in an effort to transfer into the College of Engineering, while others took the course as a free elective or were retaking the course having not succeeded academically in prior semesters or withdrawing due to extenuating circumstances. The course also contained a small contingent of transfer students from other institutions who did not

previously have credit for the class; these students were admitted directly into their disciplinary majors and were further ahead in their academic curriculum than a traditional first-year student. While not the focus of this study, it is noteworthy that the range of student backgrounds in the off-cycle class can pose a challenge to faculty teaching the course, given the variety of expectations, prior knowledge, and skills present among the student population.

Both quantitative and qualitative data were collected at the end of the semester to gauge students' views about the course and their project work. This data was analyzed through the lens of the Course Acceptance Model framework [1]; the quantitative data was collected using questions that had been administered in past surveys and was compared to prior course offerings to see if the project partners influenced students' perception of the coursework, with special attention paid to whether it affected the perceived value of non-technical course learning outcomes such as teamwork and communication skills.

Our primary research question being investigated is: *does the implementation of community engagement projects positively impact students' views of a general first-year engineering course that focuses on technical and non-technical skills necessary for success in future engineering careers?*

Methods

We collected feedback about the course and the project through a series of in-class assignments near the end of the semester to understand what, if any, impact these projects had on students' perceptions of the course. Both quantitative and qualitative data were collected; the quantitative questions posed to students had been used as part of prior end-of-course surveys and therefore could be compared to previous semesters' responses. Responses to these questions were followed by an open-ended question to better understand the results of the quantitative responses. This qualitative question was unique to the Spring 2024 semester, and therefore, not able to be compared to prior course offerings.

Fourteen quantitative questions were presented to students as they finished their semester projects as part of a regular weekly reflective check-in assignment. These questions were selected from a larger suite of questions that had previously been administered as a program-wide end of semester survey based on the MUSIC model of academic motivation [7]. Students were prompted to respond to each question on a Likert scale of 1 (Strongly Disagree) to 6 (Strongly Agree). Each of the selected questions has been mapped to the course acceptance model (CAM) framework [1]. The following questions were included in this assignment; more detail regarding the planning process can be found in the associated work-in-progress paper [5]:

Ease

- I was confident that I could succeed in the coursework.
- I felt that I could be successful in meeting the academic challenges in this semester.
- I was capable of getting a high grade in the course.
- Throughout the course, I felt that I could be successful in the coursework.

Usefulness

- In general, the coursework was useful to me.

- The coursework was beneficial to me.

Attitude

- The coursework held my attention.
- The instructional methods used in this course held my attention.
- The instructional methods engaged me in the course.
- I enjoyed completing the coursework.
- The coursework was interesting to me.

Future Use

- I found the coursework to be relevant to my future.
- I will be able to use the knowledge I gained in this course.
- The knowledge I gained in this course is important for my future.

Responses from two prior semesters were compared to Spring 2024 data to control for differences in the on- versus off-cycle student population as well as differences in instructional style. These semesters were selected due to their similarities and differences from the study semester as described in Table 1 below, being the most recent offerings of the course with available data to compare.

Table 1: Comparison Semesters

Semester	Similarities	Differences
Fall 2021	• Same instructor as study semester • Same overall course schedule and structure as study semester (i.e. similar deliverable styles, grading scheme, expectations, etc.)	• This was an "on-cycle" semester made up by predominantly first time in college general engineering students • The semester project did not have external partners, although it was themed around improving campus problems identified by students
Spring 2022	• Similar student population due to being an off-cycle course offering	• Different instructor from study semester • Different project theme than study semester, without external project partners.

The data from these surveys were analyzed using a two-sample two-tailed t-test assuming unequal variances; while the Likert-scale data does not meet some commonly held assumptions of t-tests, studies have shown this to be a useful statistical test for larger samples sizes such as those found in this paper, even when they contain ordinal data [8]. The comparison between Fall 2021 and Spring 2024 (study semester) was completed to demonstrate differences in student responses due to the implementation of the new project but could be confounded by the differences in student population. Therefore, a comparison was also conducted between the

Spring 2022 and Spring 2024 semesters to identify differences in the project implementation comparing a similar student population; this semester, however, could be influenced by the presence of a different course instructor. To further control for other variables, the two control semesters were compared against each other. Course grade averages were also retrieved to investigate whether they influenced students' perceptions of the course.

A correction factor was added to the family-wise error rates using the Bonferroni correction method. Given three comparisons presented (F21-S24, S22-S24, and F21-S22), the p-values resulting from each t-test were compared to the following adjusted alpha values to test for significance:

$\alpha = 0.05/3 \rightarrow \alpha_{adj} = .017$

$\alpha = 0.01/3 \rightarrow \alpha_{adj} = .003$

To supplement the quantitative data collected and provide deeper insights into students' perceptions of their project, an open-ended question was included near the end of the semester as part of a weekly reflective assignment as follows:

In 2-4 sentences, reflect on your experience working on a semester-long project that was coordinated with an external project partner. How was the experience for you? What did you learn (and how do you know)?

This question was unique to the study semester and therefore could not be compared to student work from prior semesters. The following section summarizes the results of the quantitative analysis, supplemented by qualitative data gathered from responses to this prompt.

Results and Discussion

Quantitative Results

Quantitative data was compiled and summarized according to the four constructs of the Course Acceptance Model (Table 2, Figure 1). Survey responses were compared between the study semester (S24) and two control semesters (F21, S22), with statistically significant results across all four constructs of the Course Acceptance Model for both adjusted alpha values used in the comparison. Between the control semesters (F21-S22), there was a statistically significant difference for $\alpha_{adj} = .017$ for Ease, but no significant difference found across Usefulness, Attitude, or Future Use.

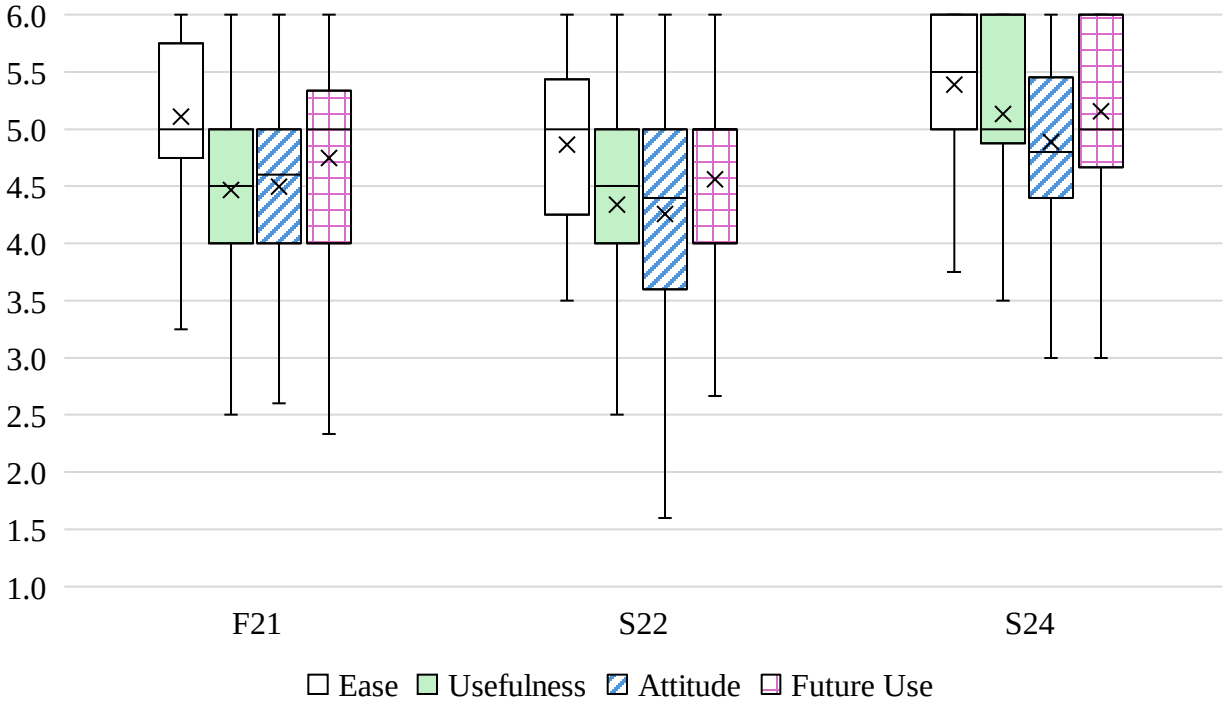
The largest increase in responses was found in the Usefulness construct; this was the lowest-scoring metric in control semesters, and a promising outcome given past anecdotal student feedback that viewed the course as unrelated to their disciplinary work. The results also appear to be largely independent of the course instructor and the differences in on-cycle and off-cycle student populations. It should be noted that the number of responses varies somewhat from the total number of students enrolled in each semester due to not all students completing the associated survey assignments.

Table 2: Quantitative analysis results

	Ease	Usefulness	Attitude	Future Use	N
F21 Avg.	5.11	4.47	4.50	4.75	246
S22 Avg.	4.86	4.34	4.26	4.56	108
S24 Avg.	5.39	5.13	4.89	5.16	154
F21 Std. Dev.	0.70	1.09	0.96	0.96	--
S22 Std. Dev	0.83	1.17	1.10	1.07	--
S24 Std. Dev	0.59	0.79	0.76	0.71	--
P-value F22-S24	6.01E-08**	4.99E-09**	6.93E-07**	1.03E-06**	--
P-value F21-S24	2.86E-05**	7.94E-12**	8.59E-06**	1.27E-06**	--
P-value F21-S22	0.007*	0.328	0.051	0.124	--

*p<0.017 **p<0.003

Figure 1: Student Response Summary



Student responses were also summarized by the project topics explored throughout the semester, which were randomly assigned to teams to balance the workload of project partners. This data is presented below for reference; no statistical analysis has been provided due to the many team

dynamic factors that could come into play at this level of granularity (Table 3). Broadly speaking, each of the projects scored highly across the CAM constructs, suggesting that no single project theme was substantially more effective in stimulating student interest in course content.

Table 3: Project Topic Comparison

Project Theme	N	Ease	Usefulness	Attitude	Future Use
Building Energy Controls and Occupancy Monitoring	26	5.37	5.15	5.00	5.18
Energy Reduction and Smart Controls for Outdoor Lighting	25	5.25	5.10	4.72	5.04
Photovoltaics on Campus	29	5.49	5.45	5.16	5.39
Pickup/drop off improvements	30	5.48	5.03	4.86	5.26
Reducing Campus Landfill Waste	22	5.50	4.95	4.61	4.97
Stormwater infrastructure	22	5.20	5.05	4.89	5.02
Overall	154	5.39	5.13	4.89	5.16

Grade data (Table 4) was also compiled from available university resources [9] to investigate whether student perception could have been affected by how they were evaluated; past studies have shown that course grades may have a small impact on students' views of a course [10]. Although the sample size of three semesters is relatively small, it does not appear that there is a correlation between students' overall GPA per semester (out of 4.0 maximum points) and their perceptions of the course material as viewed through the CAM, further confirming the minimal impact of grades on course evaluations and supporting that the shift of projects to include a community engagement component could have been a factor in more positive opinions of the class.

Table 4: Course grade comparison

Semester	Ind. Section GPAs	Avg. GPA
Fall 2021	3.38, 3.39, 3.58, 3.53	3.47
Spring 2022	3.24, 2.58, 2.95	2.92
Spring 2024	3.38, 3.0, 3.3	3.23

Overview of Short-Answer Responses

A preliminary analysis of the qualitative data supports these findings, with the following recurring sentiments emerging from student short-answer responses to the question prompt about their work with an external project partner:

Project-related knowledge

A number of students expressed an appreciation for what they learned specifically related to the project topic itself. For example, a student on a team tasked with looking into the opportunities for and challenges related to implementation of photovoltaics on campus noted how much they learned about that specific topic:

> I actually learned a lot about solar panels and the necessary requirements for them. I knew it was complicated but now that I know a little about it, I somehow feel like I know less about solar panels then before. This was a good experience for me and I'm glad it happened.

Throughout the semester, the course emphasized taking a systems approach to deconstructing engineering problems and looking at the importance of processes and organizational structures when posing solutions. Several students, as exemplified below, noted a much greater understanding of how the university operates as a result of working on their project:

> Initially, I thought that the topic given to our group wasn't as broad and there wasn't enough information and data for the same. But, on the contrary, I ended by learning some really important things about [the university] and its working. It allowed me to gain some valuable lessons on teamwork. Although we never met our project partner, he always made sure to give us all the data we asked for. Overall, I enjoyed working with my team on the project and ended up realizing how much potential and scope our topic actually had.

Project partner interaction

Several students indicated that they did not interact very frequently with their project partners, with some noting that they desired an opportunity for more interaction. However, all student responses that noted an interaction positively reflected on the insights they gained through these experiences. One student noted that although they did not directly interact with their partner, they still saw value in their involvement:

> I don't think I ever saw our external project partner this semester, but that is partly our fault because we never reached out to them. I did appreciate the data that was provided by our external project partner. It was less stressful not having to go out and collect our own data. All we had to do was analyze it, and draw useful conclusions from it. I learned that Solar panels can be a great alternative energy source to non-renewable energy sources. I learned that communication is very important as well, both with team members and the external project partner. If we had met up with our external project partner, we could have inquired more about what they were expecting from us.

Student attitude was also positively influenced by the presence of an authentic project in the local campus community:

> I think working on a semester-long project that was with an external project partner made the project more interesting. Since we were working on something that directly involved our campus I think it made me more interested in doing it. I enjoyed our project partner too and he

> made things really clear for us and answered a lot of our questions which made researching easier since we had a better idea of what was going on.

A common sentiment expressing a desire for more opportunities to interact with the project partners is exemplified below:

> In fact, our group didn't have as much experience coordinating with external project partner as I thought it would. However, we did have a chance to speak directly with our external project partner while we were presenting our project. Generally speaking, I think it would be great if we could have more time to speak with our external project partner if possible.

"Real-world" project topics

Responses show that students liked the "real world" aspect of the project topics, with several expressing a newfound appreciation for the importance of research and scoping in engineering, which is closely related to course learning outcomes. One student succinctly summarized their feelings related to this while referencing the importance of working on a project that could, at least in theory, have some impact:

> It was really cool to work on something that could actually make a difference. I'm used to most projects being something that has already been solved and they just want to see how we would solve it so it is cool so see how it works when you are coming up with an entirely new solution.

The authentic nature of the project also transferred to non-technical skills for some students, such as the following example referencing the importance of teamwork:

> The experience was invaluable. It placed me in a real-life situation where I had to learn to collaborate with peers and project partners to brainstorm possible solutions to a problem.

Others noted how their project gave them a chance to interact with something they may have not fully appreciated in the past, broadening their view of how much work is required to go into them beyond the final result:

> My experience working on this semester long project that was coordinated with an external project partner was really cool. It was something that I have never done before so just collaborating with all my teammates and getting info from the project partner was really new to me. I learned that there is so much that goes into these type of projects behind the scenes that we just don't see but only see the final product.

Other themes

Some students did not directly answer the prompt as intended but instead reflected on several notable themes such as mentioning it was their first time working on a semester-long project, pros/cons of team dynamics, and their development of time management skills throughout the course, such as the following example:

> This experience was beneficial for me because it gave me more insight on engineering as a whole. We got to work on real life problems where engineers are needed. I learned how to brainstorm solutions and work cooperatively in a group.

While the overwhelming majority of comments expressed a positive sentiment, a small number of students provided critical feedback showing that there is more work to be done in helping all

students appreciate the connection between their individual technical skills, like MATLAB, and the semester project. For example, one student noted that the experience helped them learn about their project topic and its application to engineering design, but appeared to desire an experience more tailored to their specific discipline:

> Unfortunately, our project partner was not as actively involved with our project as I would have liked, however we still did learn a lot. Not only did I learn about stormwater infrastructure and its implementation at Virginia Tech, I also got to experience a taste of the professional design process through our project partner. I enjoyed the experience, however in comparison to my projects in other courses such as [specific higher-level disciplinary course reference removed] this felt like a complete waste of my time.

Another student had an overall favorable view of the project but specifically noted the more technical aspects of the course as the main learning experience, rather than the many non-technical outcomes covered throughout the course of the semester.

> The experience overall was fairly decent. My team did what we were supposed to do and we got a fairly good result. The main thing I learned was the matlab related stuff, I found that interesting, and will most likely be useful to me in the future.

Limitations and Future Work

While the results of this study are promising for the positive effects that community engagement projects can have on introductory engineering courses, there are several limitations and areas of future research that remain. It is notable that the Fall 2021 semester used as a control was the first in-person semester after more than a year of online coursework due to the COVID-19 pandemic, which had an especially noteworthy effect on students who experienced the pandemic through the transition from high school to college [11]. It is possible that some of the quantitative results could have been negatively impacted by pandemic-related influences due to ongoing masking and social distancing requirements in addition to a potentially more difficult transition from high school to college for first-year students.

Building and maintaining relationships with project partners is also a notable limitation to pursuing these kinds of learning experiences at scale in the classroom. As noted in the prior paper that this study builds upon, a significant amount of planning effort is required by course instructors or coordinators to ensure alignment between project partners' needs and expectations as well as the learning outcomes for students taking the course. While the results of this study indicate that the effort is worthwhile, many instructors may not have the workload capacity to build and maintain these partnerships.

The results of the analysis in this study have been generalized for all projects in the semester in an effort to compare to past semester offerings of the course. There is further work to be done to evaluate whether any specific level of project partner interaction or project topic was more effective in improving students' perceptions of the course. If, for example, a limited amount of partner involvement is shown to provide the same benefits as a high level of project partner interaction with students, that could have implications for the scalability of similar programs.

Conclusions

The addition of a real-world context backed by project partners appears to have had a positive impact on students' perceptions of the first-year engineering course being studied for this paper. In comparing student perspectives to past semesters without these kinds of projects, students in the study semester responded more favorably across all four dimensions of the Course Acceptance Model, with the most remarkable increase in their view of how useful the coursework was. A qualitative analysis supports this, with many students noting that they found the idea of engaging with a real project to be valuable and encouraged them to think deeply about the type of work that goes into campus projects.

The study also finds these results promising given the variable level of engagement that students had with project partners. Several teams met with their project partners up to two times throughout the semester, while others did not directly engage with them and instead worked with provided datasets and questions managed by the course instructional team. While many students did express an interest in a higher level of engagement with their project partners, most noted that even without this aspect they were able to appreciate the projects they were working on.

While not a focus of this study, it is also notable that the project partners appeared to enjoy the process, with all of them expressing interest in continued collaboration moving forward. These results suggest that, despite the additional planning and workload considerations, the implementation of community engagement projects can have a measurable and meaningful impact on how students engage with first-year engineering courses.

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