Long-term Impact of a Semester-long Multidisciplinary Service-Learning Assignment in a Fluid Mechanics Course

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In addition, Dr. Ayala has had the opportunity to work for a number of engineering consulting companies, which have given him an important perspective and exposure to the industry. He has been directly involved in at least 20 different engineering projects related to a wide range of industries from the petroleum and natural gas industry to brewing and newspaper industries. Dr. Ayala has provided service to professional organizations such as ASME. Since 2008 he has been a member of the Committee of Spanish Translation of ASME Codes and the ASME Subcommittee on Piping and Pipelines in Spanish. Under both memberships, the following Codes have been translated: ASME B31.3, ASME B31.8S, ASME B31Q, and ASME BPV Sections I.

While maintaining his industrial work active, his research activities have also been very active; Dr. Ayala has published 90 journal and peer-reviewed conference papers. His work has been presented in several international forums in Austria, the USA, Venezuela, Japan, France, Mexico, and Argentina. Dr. Ayala has an average citation per year of all his published work of 44.78.

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Long-term impact of a semester-long multidisciplinary service-learning assignment in a fluid mechanics course

Abstract

Seventy-three students who enrolled in a senior-year level fluid mechanics course during spring semesters from 2019-2022 were asked about their perceptions on the impact in their professional preparation of a semester-long multidisciplinary service-learning assignment. This paper evaluates their current perceived impact of the assignment (long-term impact) and whether it might have changed from when they took the course (short-term impact). A survey was sent to all former students who went through the course and participated in the assignment, with a 61.64% return rate. The survey included questions about how well they remembered the assignment (some of the students were involved in it 4 years prior to completing this survey), the relevance of the project in terms of their professional preparation, how it impacted their collaboration skills, and whether their involvement affected their interest in participating in engineering outreach activities. To determine how their perceived impact of the project on their professional preparation has changed from when they took the class to now when they are working professionals, we compare their recent responses to the responses in reflections they completed while taking the course. The information gathered in the survey also provides a means to evaluate the effectiveness of the project and identify areas for improvement, which has implications for how similar projects might be designed and enacted in the future.

Introduction

The Accrediting Board for Engineering and Technology, commonly known as ABET, is dedicated to promoting the systematic enhancement of the quality of engineering education. ABET strongly emphasizes fostering the comprehensive development of students, encompassing both their disciplinary proficiency and non-technical aptitudes. Within the realm of non-technical skills, ABET explicitly states student outcomes that include collaborative group work and effective communication, both within their specific discipline and in broader contexts [1,2]. These identified student outcomes serve as explicit guidelines, outlining the anticipated knowledge and competencies that students should attain upon completion of their academic program.

Numerous initiatives from various programs have been undertaken to align with the ABET requirements. Some of these initiatives have employed Project-Based Learning (PBL) as a pedagogical approach. Hamoush *et al*. [3] exemplified this by integrating PBL into a junior-level Transportation Engineering course. They utilized a survey instrument incorporating five constructs to gauge distinct facets of student learning: higher-order cognitive skills, self-efficacy, ease of comprehending subject matter, teamwork, and communication skills. Another endeavor was undertaken by Ulseth *et al*. [4], who developed and implemented a novel model of engineering education grounded in team-oriented PBL featuring authentic and intricate industry projects. This model incorporated elements such as students taking ownership and managing technical competencies aligned with the ABET student outcomes.

Several others have applied team-oriented PBL methodologies within the context of fluid mechanics courses. Meikleham *et al*. [5] documented their utilization in a flipped-delivery fluid mechanics course, where they heightened active student involvement through inquiry-based learning involving five experiments employing custom-designed kits. Pérez-Sánchez and López-Jiménez [6] adopted a PBL approach centered on learning, research, and reflection across various courses, spanning different academic levels, including Bachelor's and Master's programs, within a hydraulic and environmental engineering department. They directed student teams towards achieving accurate problem solutions, fostering autonomous and continuous learning. Wie *et al*. [7] directed their attention towards the team-building dimension of PBL implementation. Recognizing common team challenges, such as interpersonal dynamics, schedule discrepancies, labor distribution, and leadership responsibilities, they demonstrated the substantial benefits of incorporating a team-training website into the overall PBL experience.

Successful endeavors have been made to offer engineering students multidisciplinary teamwork-based learning experiences. McNair *et al*. [8] exemplified this in a cross-course assignment requiring students to form self-managed teams comprising computer engineering, marketing, and industrial design students tasked with constructing dorm rooms for individuals with special needs. Additionally, integrating service-learning projects (SLP) has been explored to enhance community engagement in engineering education. Carrico *et al*. [9] studied the impact of a multidisciplinary project-based service-learning experience, fostering collaboration, deep learning, teamwork, and communication between Mechanical Engineering and Speech-Language Pathology students. The collaboration involved developing manufacturing processes for the in-house fabrication of cost-effective therapeutic materials. Keshwani and Adams [10] observed positive effects on engineering students' communication and leadership skills through a cross-disciplinary project-based service-learning model, aligning engineering and education students. Noteworthy service-learning programs in the U.S. include SLICE (Service-Learning Integrated throughout a College of Engineering) at the University of Massachusetts Lowell, integrating service-learning into core courses without adding extra class or homework time [11,12]. Another prominent initiative is EPICS (Engineering Projects in Community Service), initiated at Purdue University and expanded to over a dozen universities, offering interdisciplinary service-learning courses from first year to senior levels [13,14].

ABET emphasizes the immediate expectations regarding "what students are expected to know and be able to do by the time of graduation," (student outcomes) and also places significance on the long-term influence of students' education as future professionals [1, p. 4],[2, p. 3]. ABET mandates engineering programs to articulate their individual “program educational objectives,” which essentially serve as "comprehensive statements outlining the achievements graduates are anticipated to reach within a few years post-graduation" [1, p. 4],[2, p. 3]. Numerous U.S. programs incorporate teamwork effectiveness and clear communication leading to successful team outcomes in their “program educational objectives.” While ABET necessitates a thorough evaluation and assessment process for attaining student outcomes (short-term), it does not impose a similar process for assessing the long-term impact on program graduates as they transition to professionals (program educational objectives). Meanwhile, in educational research, the importance of extended follow-ups has been consistently underscored as a pivotal focus. However, most recent learning studies only scrutinize student outcomes within single courses at specific institutions [15]. Limited research has explored the long-term effects of formal project work on engineering alumni, with Worcester Polytechnic Institute's PBL interventions being

among the few instances [16,17]. Consequently, there exists a scarcity of research examining the sustained impact of educational interventions.

This paper outlines the outcomes of a survey distributed to past students who participated in a senior-year fluid mechanics course during spring semesters spanning 2019-2022 and were engaged in a semester-long multidisciplinary service-learning project. The objective was to assess their current perception of the impact of the assignment, after several years have passed and they have moved into their professional careers (long-term impact). We also examined how the opinions of all participants as a group may have evolved from when they were students to now as working professionals. We compared their recent group responses with reflections they completed during the course (short-term impact).

Class Setting

The Fluid Mechanics course, part of a midsize university's Mechanical Engineering Technology program, is a 3-credit 300-level class. Conducted face-to-face, the course convenes twice a week for 75 minutes during the spring semesters. Notably, over 80% of the students enrolling in this class are in their senior year. The undergraduate engineering student body is remarkably diverse, encompassing traditional students, individuals from various age groups (including many returning to education after an extended hiatus), full-time employees, active military personnel, veterans, students from underrepresented groups, and transfers from community colleges. This diversity contributes to a heterogeneous student cohort characterized by distinct study habits, varied academic backgrounds, and unique needs. These factors pose challenges to the learning process, making the teaching of the course a particularly demanding task.

Semester-Long Project Implementation

This semester-long multidisciplinary service-learning assignment has been implemented for 5 consecutive years since Spring of 2019 and has been described in detail in Ayala *et al*. [18]. Therefore, we shall only provide essential information relevant to this paper. The project tested the students' creativity, knowledge of fluid mechanics concepts, and skills to work with people from other disciplines. They were told that they were working for a hypothetical company, "Engineering is for all," and were assigned to design and develop learning products for children in elementary schools in the local area. The students were required to pick a fluid mechanics topic, develop a relevant hands-on activity, and create a lesson plan that could be used by an elementary school teacher on his/her own. There were four main events for this project: 1) a classroom visit to the assigned elementary school where the teams introduced engineering and surveyed the interests of the children they would be teaching, 2) a multidisciplinary teaching/learning session where engineers taught science/engineering to educators and educators taught pedagogy to engineers, 3) a dress rehearsal where the teams practiced their elementary school lesson in front of peers and experts, and 4) the actual final elementary school lesson in which the teams taught elementary school students. For each of those four main activities, the teams turned in preliminary assignments to instructors for feedback. Those four activities took place during class time, and student attendance was mandatory.

Given that the project centered around instructing elementary school children, engineering students collaborated with elementary preservice teachers from the College of Education, who played a crucial role in ensuring the success of elementary school lessons. Consequently, cross-disciplinary teams of students were formed, each comprising five members – three from the engineering domain and two from education. Team assignments were determined early in the semester using CATME. Following the team formation, teams collaborated to create a team charter, outlining rules of engagement and designating project and communications managers for both the engineering and education facets. Additionally, students were required to contribute to a shared Google Site, serving as a communication platform for the team throughout the semester.

It is important to point out that during spring semesters from 2019-2022, COVID impacted the course delivery, and the project implementation moved online. This created challenges that were overcome by providing students with even more detailed instructions and templates to follow. Table 1 summarizes the mode of delivery of the project activities across the spring semesters from 2019-2022.

Table 1. Summary of mode of delivery of project activities from Spring 2019 to Spring 2022 due to adjustments to COVID

Pre-Covid	Transition	COVID/Online	Post COVID
Spring 2019	Spring 2020	Spring 2021	Spring 2022
On campus face-to-face implementation	Asynchronous implementation	Zoom implementation	Off-campus face-to-face implementation

Survey

A survey was sent to all 73 former students who went through the course and participated in the project, resulting in a 61.64% return rate. The survey had 4 main sections. The first section asked students demographic questions, such as age, gender, semester of participation, current job, and how long they have been in that job. The second section asked questions related to the actual project implementation, such as how well they remember the project, project difficulty, how well the project was aligned to the course, whether the guidelines and expectations were clear, whether they received adequate support, and their perceived relevance of the project in their professional preparation. The third section assessed the perceived impact of the project on their collaboration skills, asking student to indicate their level of agreement (Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree) with the following statements:

1. The semester-long project offered an opportunity to develop effective communication skills within a team.

2. The semester-long project helped me understand the importance of teamwork in a professional setting.
3. The semester-long project enhanced my ability to resolve conflicts and disagreements within a team.
4. The semester-long project was effective in enhancing my collaboration skills.
5. The semester-long project helped me become a better listener and consider diverse perspectives.
6. The semester-long project provided chances to demonstrate leadership skills.
7. The semester-long project allowed me to adapt my approach when collaborating with individuals from different disciplines.
8. The semester-long project helped me to learn how to communicate with a nontechnical audience.

Two open-ended questions asked students to consider how the project influenced their collaboration skills:

9. In your opinion, in what ways has the semester-long project positively impacted your collaboration skills as an engineer? (Please provide specific experiences as needed)

10. Did you face any challenges during the collaboration process? If so, what were those challenges and how did you overcome them?

Lastly, the fourth section assessed the overall impact of the project and recommendations. Students were asked for their level of agreement with these statements:

1. The semester-long project contributed to my overall learning experience in the fluid mechanics course.
2. The semester-long project improved my problem-solving skills.
3. The semester-long project helped me to be a better prepared engineer for the workforce.
4. I would recommend this project be included in future iterations of the fluid mechanics course.
5. My involvement in the semester-long project affected my interest in participating in engineering outreach activities.

Four open-ended questions were included to capture students' reflections in their own words:

6. Please explain your response regarding your recommendation to include or not this project in future iterations of the fluid mechanics course.
7. Do you believe that the skills developed during the semester-long project are transferable to your professional life? Please explain your answer.
8. What do you think are the strengths and weaknesses of the semester-long project to enhance its impact on understanding fluid mechanics concepts?
9. What changes or improvements would you suggest for the semester-long project?

Reflective Assignment

When these former students took the course, they were asked to complete an assignment reflecting on the project they just completed. The students were asked to answer, among other questions, the following [18]:

1. What did you learn? What did you learn about engineering? What did you learn about teaching?
2. How did faculty support students to make these adjustments? How helpful/necessary did students find this support?
3. How valuable was this Engineering Lessons Project? What was valuable about this experience? What was challenging? Do you have any suggestions for improving the project in the future? If so, please share your thoughts.
4. What factors affected your motivation for this project over the course of the semester? For example, did your instructor impact your motivation, the topic itself, your relationship with your teammates, your interactions with the kids, feedback you received etc. Please consider factors that positively affected your motivation as well as factors that negatively affected it and consider how your motivation may have changed over time.
5. How did teaching an online lesson rather than an in-person lesson change the way this project affected you? For example, do you think you learned more or less as a result? Did you learn different knowledge or skills than you would have learned by preparing for and teaching a face-to-face lesson? Please explain your response.
6. What did you learn from working with the education students? Please explain.
7. How did this project affect your vision of teaching careers?
8. How has your understanding of fluid mechanics changed as a result of this project?

As explained in detail in a previous publication [18], when analyzing students' reflections, thematic analysis was used to understand students' experience of PBL. We analyzed students' reflections using priori codes. Additional codes were added through rounds of coding and discussion. A final codebook was established and used by each researcher to code an assigned data set. Codes were compared between the researchers to check the inter-coder reliability, which resulted in all codes having over 80% agreement [18]. The same coding process and final codebook was used to analyze the graduates' responses to the open-ended questions in the survey.

Results and Discussion

Many of the former students (75.46%) who responded to the survey completed the project more than 2 years ago, and the average time in their current employment position is 1.72 years. Most of the respondents are male (94%), and most are younger than 30 years old (91.48%). Respondents currently work in a variety of different companies, such as: Abbott Nutrition, AdvanceTEC, Alliance MEP, Asplundh Engineering, Baltimore Aircoil Co., Bamforth Engineers + Surveyors, Bridgestone, BWXT, Caterpillar, Dominion Energy, Georg North America, George Nice and Sons, Howmet Aerospace, Huntington Ingalls Industries, Imagine One, Jacobs, Lockheed Martin, Michael Baker International, Mikro Systems, National TAB,

Newport News Shipbuilding, Norfolk Naval Shipyard, Northrop Grumman, Omron Automation, PACE Collaborative, Plasser American Corp, Rockingham Steel, Shuttlewagon, Southern Industrial Constructors, Sumitomo Drive Technologies, The Boeing Company, U.S. Army, Virginia Beach Schools, VectorNet, and Wabtec. This suggests that their evaluation of the project's impact is likely to have been significantly shaped by their diverse ongoing professional experience.

The former students responded to a variety of questions about the project implementation, including how well they remembered the semester-long group project. The majority of respondents (82%) ranged from remembering it moderately well to remembering it very well (see figure 1). They were also asked to briefly describe the project, describe the lesson taught to elementary students, and to describe the role(s) they played in the project as an engineering student. Overall, their answers (figure 1) aligned well with their claim in their written responses on how they remembered the project. Table 2 summarizes the results of the other questions on the actual project implementation. All their responses collectively suggest that their evaluation of the project's impact is founded on a solid recollection of their experiences during the project.

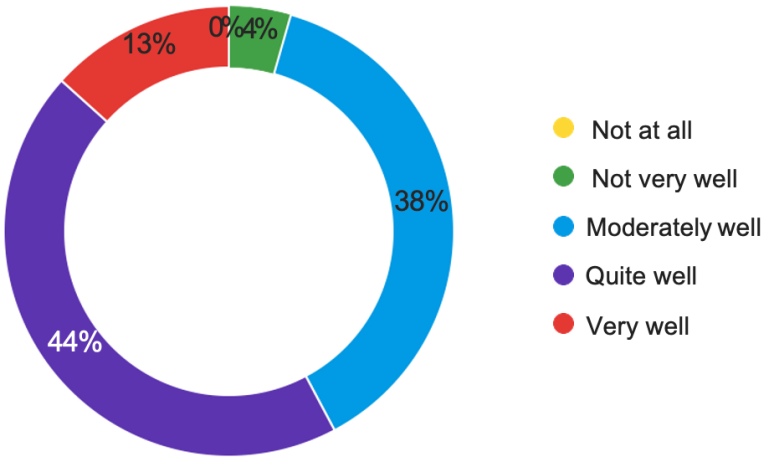

Figure 1. Results of the question: how well do you remember about this semester-long group project from our MET 330 Fluid Mechanics class?

Table 3 shows the results of the questions on the perceived project's impact on collaboration skills. The former students were asked about their level of agreement with several statements. To analyze the results, we calculated an average by assigning the following weights to their responses:

Strongly Disagree	-2
Disagree	-1
Neutral	0
Agree	+1
Strongly Agree	+2

Table 2. Summary of results of the other questions on the actual project implementation.

Question	% of respondents who agreed or strongly agreed
The difficulty level of the project was easy to moderate	74%
The project aligned with the fluid mechanics concepts covered in the course	78%
The project guidelines and expectations clearly communicated at the beginning of the course	93%
We received adequate support and feedback	89%

Table 3. Summary of results of the questions on the impact of the project on collaboration skills.

The semester-long project helped me to learn how to communicate with a nontechnical audience	**1.33**
The semester-long project helped me understand the importance of teamwork in a professional setting	**1.31**
The semester-long project offered an opportunity to develop effective communication skills within a team	**1.29**
The semester-long project provided chances to demonstrate leadership skills	**1.27**
The semester-long project was effective in enhancing my collaboration skills	**1.24**
The semester-long project helped me become a better listener and consider diverse perspectives	**1.22**
The semester-long project allowed me to adapt my approach when collaborating with individuals from different disciplines	**1.22**
The semester-long project enhanced my ability to resolve conflicts and disagreements within a team	**1.02**

All responses were positive with an average always above 1.0, which means the former students mostly agree that the project had a positive impact on their collaboration skills. The item with the lowest average (but still above 1.0) asked whether the project enhanced their ability to resolve conflicts and disagreements within a team. Although the mean of 1.02 is still a positive outcome suggesting respondents tended to agree that the project helped them learn how to negotiate team conflicts, it aligns well with their responses to the open-ended question related to team challenges: “Did you face any challenges during the collaboration process? If so, what were those challenges and how did you overcome them?” The former students recalled experiencing

challenges within their teams. Several common themes emerged in their responses. Nine respondents mentioned conflicts related to meeting times and schedules.

> *…due to the size of the group and numerous schedules, it was hard to get together. Sometimes it would only be a few people per meeting, or someone had a schedule conflict, but it was hard to get the whole group together unless it was scheduled way in advance. (Current opinion of a former student)*

Twelve respondents mentioned team dynamic issues due to a lack of collaboration and/or cooperation from one or a few team members.

> *I did not work well with one partner, however being able to overcome this and create a good project is an important skill. I work with some people now who I may not agree with all the time, but since I know the objective, I can focus on that and get it done. (Current opinion of a former student)*

> *There were a few times that some teammates were performing below expectations. We resolved this by having tough conversations but also asking what we can do to help them out. (Current opinion of a former student)*

> *Another problem we faced was our own team members being no shows and not pulling their weight in the project. (Current opinion of a former student)*

During the spring 2020 and spring 2021 semesters, the project was carried out following all COVID restrictions, including requiring all interaction to occur online. The challenges of interacting during the pandemic were also mentioned as part of the respondents' discussion of team dynamic issues.

> *Yes, I experienced lazy group members with lack of interest in the project…. COVID didn't make it better, the work would have been better distributed between the group under normal circumstances. (Current opinion of a former student)*

> *During the semester-long project COVID-19 sent the classes to all online. This made communication much more difficult with the team. (Current opinion of a former student)*

It is interesting that, contrary to what students have expressed in the past, we did not find many complaints about the project workload. In the past (immediately after the project), when students were asked their opinion about the project right after completing it, they strongly felt that the workload in the course was too overwhelming [18].

> *This was not super valuable to our development as it was a lot of work and time for a minimum amount of professional development. The professional development I'm referring to is working among a team of differing individuals,*

helping less experienced people understand difficult engineering topics, and communicating effectively in an online work environment. These skills easily could have been learned in less time and less effort instead of in such a long and complicated project. The challenging part was how much time it took away from my other studies or my studies of content in this class itself as often I found myself spending more time on this project rather than studying the difficult course content of this class. (Previous opinion of a former student).

The items with the three highest averages are related to communication skills within the team and with nontechnical audiences and the importance of teamwork in their profession. These results align well with the responses to the open-ended question: "In your opinion, in what ways has the semester-long project positively impacted your collaboration skills as an engineer?" We found common themes in their responses. Twenty-three former students highlighted that a positive impact was the exercise of explaining technical topics to non-technical people and communicating better as engineers.

I believe that having to collaborate with people outside of my field of study gave me good insight on how engineering is in the professional world. I find myself constantly having to change my terminology at work currently depending on who I'm working with in order for goals to be understood. (Current opinion of a former student)

It helped bridge different knowledge bases/levels based on the audience I'm working with. Whether it was with my fellow classmates, where they knew what was going on with the slightest reference to something fluids related or engineering related to an education student who has never heard these terms before. Your audience is always going to change, so it's sometimes best to adapt to their pace so they can properly understand what you are trying to convey. (Current opinion of a former student)

This project taught me how to take a complex engineering principle and break it down into small basic parts that could be taught to young students. On several occasions, the education students told us that what we (my engineering partner) were saying was too complicated and that we needed to go back and break it down more or use less complicated words. (Current opinion of a former student)

Nine respondents described the positive impact of working in teams.

The semester-long project creates a space where you must work with other students that you most likely are not familiar with. This is a good experience to help the transition to the workplace. In my experience engineers are hired to a team and are expected to work with other teammates to solve problems. This is where I found the most impact from the semester-long project. (Current opinion of a former student)

I think it has impacted my skills positively by helping me develop the skills of being able to listen and see how others may approach a situation differently than I might. I used this

when starting in my position at Lockheed and seeing how my coworker may go about doing the same projects or assignments as me and learning how I might be able to streamline my process to be more efficient. (Current opinion of a former student)

The former students' positive comments about the benefits of teamwork experience are consistent with student opinions immediately following the project. When asked their opinion about the project right after completing it, past students reported that the project helped in their development of professional skills, especially their communication skills with those of different backgrounds [18].

The project taught numerous professional development skills including collaborating in both an online environment and working with other fields other than engineering. I would apply what I learned in communicating with all future groups including those in which we primarily were in an online working environment. (Previous opinion of a former student)

Figure 2 shows the results of items related to the overall impact of the project. 75.55% to 82.22% of the respondents agreed or strongly agreed that the project contributed to their overall experience in the course, helped them to be a better-prepared engineer for the workforce, and improved their problem-solving skills. In striking contrast, 64.44 % of the respondents were neutral in their opinion of whether the project affected their interest in participating in engineering outreach activities, which was a surprise given all the other positive comments. In the past, engineering students who just completed the project explained how the project helped solidify their understanding of engineering concepts in order to effectively impart them to both education students and elementary school students. [18].

This project allowed me to reexamine basic concepts of fluid mechanics as I reexplained them to groups who may not have had any previous knowledge of said concepts. By explaining them to someone new I learned some new things about something I already learned while teaching it to someone who never learned it. (Previous opinion of a former student)

My actual understanding of fluid mechanics as a whole was more defined because of the project and while we didn't go over the complicated ones, the concepts we did implement into our project design made my understanding of them much more solid. (Previous opinion of a former student)

The engineering lessons project provided me with valuable experience. This is the first time that I have taught other people anything. I have noticed that to teach something, you have to understand it on a fundamental level. This helped me with my engineering class. (Previous opinion of a former student)

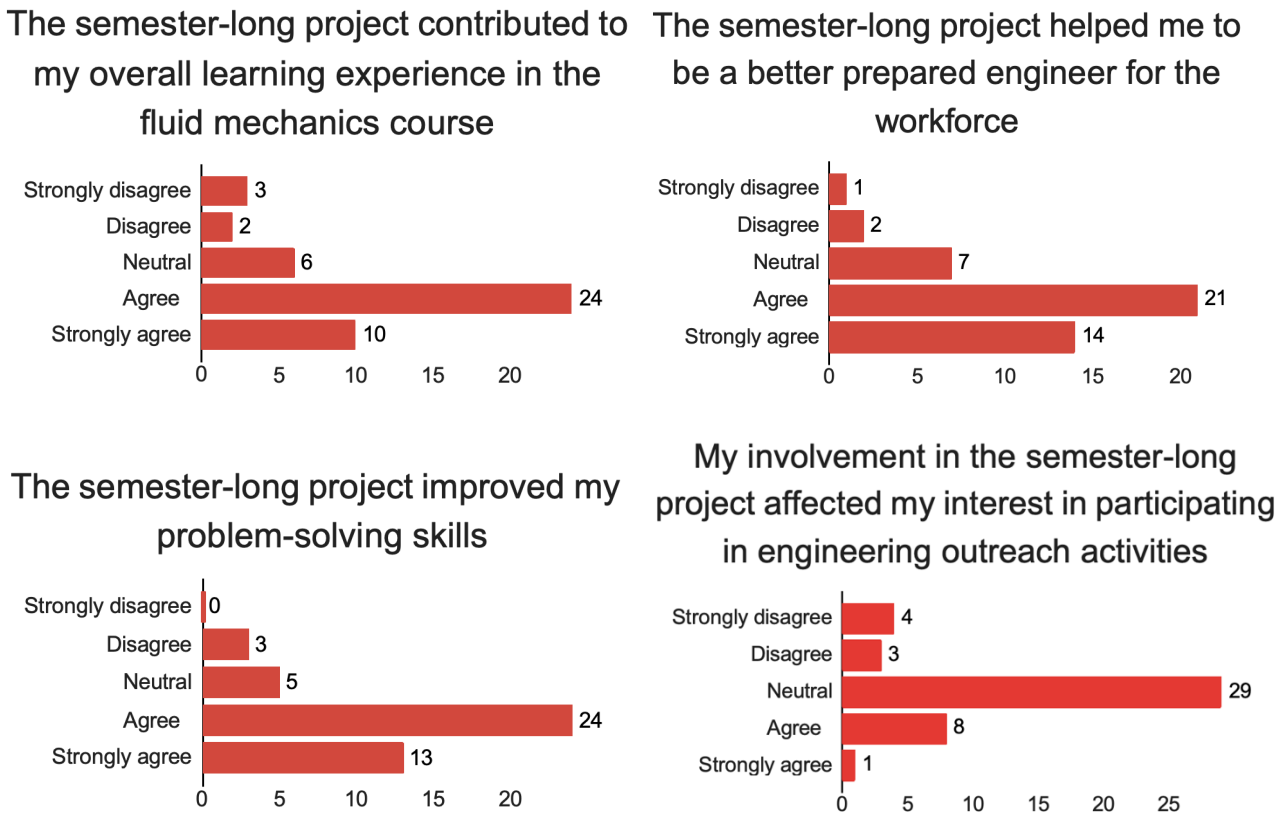

Figure 2. Results on items related to the perceived impact of the project.

When asked if they would recommend this project to be included in future iterations of the fluid mechanics course, 80% of respondents agreed or strongly agreed (and only 6.66% disagreed or strongly disagreed). They were further asked to explain their response. We found common themes in their responses. 11 of the respondents said it provides opportunities to learn and develop life and professional skills.

> *I think having the project is more beneficial because it helps us learn life / professional skills which could not be taught by taking a formal final exam. (Current opinion of a former student)*

> *It's probably the most useful project I had at ODU. It actually had real-world impact and required skills I use today at work and in previous jobs. Presentation skills and talking to people. Engineering doesn't get a good reputation for people persons so a project like this that forces you to present in front of arguably one of the toughest audiences, kids, is worth its weight in gold. Having to prep a project or explanation and give it to people who know nothing about it is an everyday skill students need to hone if they want to be successful. Corporate world is nothing but meetings after meetings and collaboration between departments. You have to learn to work with people of all sorts and backgrounds. I worked at a Fortune 500 medical logistics company for a year and a half*

and it was all people skills, presentations, and building rapport. Being able to stand in front of a group of strangers and sell an idea is a super power. This project was the only one that even scratched at that surface. Giving students an opportunity to collaborate, plan, present, and then fail or succeed in front of a crowd will prep them in life for more things than anything else ever could. You have to learn how to communicate to people who have no clue what you're saying, don't care what you're saying, or already know more than what you're saying. Expand more on these types of projects. (Current opinion of a former student)

As previously highlighted, many (20) respondents reported benefits from the project, including the project's positive impact on their communication with non-technical audiences, teamwork skills, interdisciplinary skills, and understanding of concepts. Similar positive patterns were found in their answers to the question: Do you believe that the skills developed during the semester-long project are transferable to your professional life?

Yes. As mentioned in a previous question / answer, the project helped me learn how to collaborate with people who were outside of my discipline as well as learn how to interact with people of different ages while all discussing the same topic. (Current opinion of a former student)

I would agree. Like before, there are many keys to teaching, understanding, and listening to others. The more exposure that one can get from those aspects, I believe can really help one's professional career. (Current opinion of a former student)

Yes, like I mentioned, it's important to have the skillset to hold an audience's attention, clearly define a subject, provide examples, feedback, and correct them when they aren't interested or are getting lost. (Current opinion of a former student)

Yes, as stated in other areas, it help me think of a more general education that most people have to explain a problem, solution and end goals. It also showed that not everything has to be an extravagant way of thinking or explaining but can be small and simple. (Current opinion of a former student)

The positive opinions about the project are encouraging and reflect the project's contribution to the professional development of engineers, but two respondents offered comments that highlight the project's contribution to another population: the elementary students. They explained that the project serves as motivation for children to become engineers.

It was an incredible concept for a project. I was just unlucky with my team. I would hate to take away the great opportunity not just for the college students but especially don't want to take it away from the children who could see one of the presentations and decide to become an engineer and end up changing the world for the better! (Current opinion of a former student)

I believe it is important that young kids get introduced to avenues of career and employment, so that they can at least be presented with some aspirations of what to be when they grow up. I was even confirmed of this feeling with one of the adults of the children's group, stating how important it is that these kids know there's more to be than an online person or an athlete. (Current opinion of a former student)

The former students were asked to summarize the strengths and weaknesses of the semester-long project and to offer suggestions for improvement. The themes evident in the reported strengths are similar to positive comments discussed earlier. There were no consistent themes in the reported weaknesses, instead respondents shared a variety of comments that were closely related to their own experiences, such as the size of groups, broad concepts, the impact of COVID, short class time, time-consuming, scheduling, lack of help from teachers, online lessons, stress on college students, and negative team dynamics, among few others. Regarding their answers on their recommendations for changes and improvements, once again, they were closely related to their individual experiences, but the one theme that did arise was surprising because it focused on improving the instruction on fluid mechanics for the children, rather than for the college students. These recommendations focused on changing the nature of the project to be more practical, focusing on an older audience of children, and dedicating more time to meeting with the elementary students.

If I could change anything, it could be to have the activity or concepts be even more practical in nature. With kids these young, they need to learn things more hands-on and dynamically. (Current opinion of a former student)

Older students, more meetings with them or longer meetings, do an engineering project to teach the concepts rather than just teaching the topic. Like designing and building a drone over the semester would be much more engaging for everyone or designing a full cooling system. (Current opinion of a former student)

Limitations

While this study suggests the semester-long multidisciplinary service-learning project had positive long-term effects on engineering students' professional development, it is not without limitation. A 61% return rate is quite high for a survey administered several years after a project's termination; however, we do not know the opinions of the former students who did not respond and whether or not their experiences in the project affected the likelihood that they responded. Furthermore, respondents may have been hesitant to report negative experiences related to an instructor they liked or to a program with which they were generally satisfied. Finally, we are relying on the respondents' memory of the project to judge its long-term effects. Although we attempted to account for this by asking respondents to rate how well they recalled the project events and to describe what they did remember, and by asking both quantitative and qualitative items, the former students' ability to accurately recall their experiences influences the accuracy of our findings. As such, the results of the study should be interpreted cautiously.

Conclusions

This paper explored perspectives of participants over two time periods in order to understand the perceived long-term impact of a semester-long multidisciplinary service-learning project in a fluid mechanics course and contrast it with the perceived short-term impact. All the participants were involved in a project in which they developed and helped teach a hands-on fluid mechanics activity to elementary students alongside partnering education students as part of their coursework during a fluid mechanics course taken between spring 2019 and spring 2022. Immediately following the project, the participants completed a written reflection in which they responded to more than a dozen open-ended questions. The participants were surveyed again in Fall 2023 and asked to reflect back on the impact of the project on their professional development. Reflections completed immediately after the project revealed generally positive perceptions, with students expressing appreciation for the project despite some concerns about workload. The results from the recent survey reveal uniformly positive responses, affirming the lasting positive impact of the project on the participants' collaboration and communication skills. These benefits seen retrospectively match positive responses reported immediately following the project with participants explaining how the opportunity to work on a diverse team and the responsibility to explain concepts to non-technical audiences improved their teamwork and communication skills. The multidisciplinary nature of the project and its service-learning focus appeared to have lasting benefits for the participants. Despite these positive influences on the participants' professional skills, the project showed minimal influence on their inclination toward engaging in engineering outreach activities. It is unclear why the project did little to enhance the participants participation in engineering outreach, given that they largely reported enjoying the project and seeing its benefits for children. In the current survey, most participants acknowledged the project's contribution to their overall course experience, enhancing preparedness for engineering roles and refining problem-solving skills. Given the need to address ABET standards and to prepare engineers to work with diverse teams on complex problems, the researchers recommend engineering educators consider engaging students in multidisciplinary service-learning based projects.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grants #1821658 and #1908743. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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