

Engineering Design for Community Impact: Investigating Constructive Alignment in an Innovative Service-Learning Course

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Abstract- In this innovative practice, work in progress paper, we examined the degree of constructive alignment in a pilot course informed by service-learning. Constructive Alignment refers to the degree of alignment between an instructor's intentions and students' experiences of a course. Data for the study were derived from a narrative constructed from the instructor's reflections, describing intentions and experiences, coupled with thematic analysis of a transcript of a class discussion in which students were prompted to express their expectations for the course and their experiences of it. The instructor's intentions were to take students through the experience of doing a real-world engineering project with community impact. Students had signed up for this course with expectations reasonably aligned with this plan. What they did not expect was how open-ended the engineering process would be, how it would demand intrinsic motivation for them rather than focusing on grades, and the degree to which the process would rest on communication skills, with substantial in-class discussion.

I. INTRODUCTION

This study focused on an innovative disciplinary course, utilizing a project-based learning approach for engineering students to explore how they can apply their disciplinary knowledge in the context of a team design project for an external partner. This course takes place in an institution with a large and increasingly diverse student intake.

Recently, one of the faculty members (second author) launched a new course, informed by existing work on service-learning courses. Service-learning courses are an educational experience in which students participate in an organized service activity that meets identified community needs and reflects on the service activity in such a way as to gain further understanding of course content and an enhanced sense of civic responsibility. [1]. Literature has shown there to be many benefits for implementing service-learning courses in the curriculum. For students, service-learning can increase school engagement, reduce risk of high school drop-out, and improve civic and social competencies [2].

The instructor's planning of the course drew upon several existing programs with a service design approach during the planning process, including the EPICS program [3], an engineering-focused service-learning program at Purdue University. Structural elements for the course were also developed based on *La Ruta de Innovación Social* [4], a program developed at *Parque Científico de Innovación Social* in Colombia to help students develop a social innovation throughout a series of explicit steps in the design process.

Additionally, several classroom activities and course design elements drew upon information developed as part of the Crash Course in Anthro-design [5], developed at the Pontifical Catholic University in Chile.

The course was eventually organized and piloted in Spring 2022 with the following student learning outcomes:

1. Prepare to take part in an experiential/service-learning engineering design project by
 - a. identifying cultural norms or expectations for the community served and explain how their role as engineers can best meet the project needs in a service context,
 - b. identifying the engineering disciplinary knowledge that needs to be developed to provide a meaningful contribution to the project, and
 - c. completing necessary logistical preparations for the implementation stage of the project
2. Implement an engineering design by
 - a. Applying disciplinary knowledge identified during the project preparation stage through development of a design plan, prototype, or construction project,
 - b. utilizing project management strategies such as scheduling, documentation, and communication within a team setting and with external project stakeholders,
3. Reflect throughout the process by
 - a. acknowledging how one's personal background and biases can influence their approach to solving engineering problems
 - b. Critical exploration of the design process and its implementation

These outcomes were intended to reflect the wide variety of skills necessary to implement an effective engineering design, ranging from technical knowledge and project management strategies to analysis of the context of a project and stakeholder needs.

Four students across several different majors in the College of Engineering enrolled in the pilot course and engaged as a design team working with a community partner to scope project needs, develop goals for the semester, and implement an appropriate level of engineering design based on the project's needs and the constraints identified. The final deliverable of the

semester depends upon specific project requirements agreed upon between the student team and project partner, and included deliverables such as feasibility studies, preliminary design plans, app development, or physical prototype construction.

In this study, we aimed to investigate the constructive alignment in this course. Constructive alignment is the extent to which the instructor's emphasize alignment between the objectives of a course or unit and the targets for assessing student performance [6]. The data for this study came from firstly a narrative reflection by the instructor as well as an analysis of a class-discussion from the students.

The research questions guiding this study are therefore:

1. Instructor:
 - a. What were the instructor's intentions in starting up the course?
 - b. What were the instructor's experiences in delivering the course?
2. Students:
 - a. What were the students' expectations of this course?
 - b. What were the students' experiences of the course?
3. To what extent do we see alignment between:
 - a. Instructor intentions and experiences?
 - b. Student expectations and experiences?
 - c. Instructor intentions and student experiences?
4. What are the specific characteristics of a service-learning course that might make it challenging to achieve constructive alignment?

II. THEORETICAL FRAMEWORK - CONSTRUCTIVE ALIGNMENT

The theoretical framework guiding this study is the theory of constructive alignment that was proposed by John Biggs. Constructive alignment dictates that if students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning activities that are likely to result in their achieving of those outcomes [7]. This directly points to how the learning activities students will be taking a part in must support or contribute to the learning objectives of the course. Furthermore, students' learning has seen to increase to the extent that they engage with and thus study the material [8]. The theory of constructive alignment is embedded in the constructivist theory of learning, and it emphasizes the alignment between the intended learning outcomes and the assessment tasks [9]. By aligning the teaching, learning, and assessment activities in this way the educator is more certain that the intended learning will be achieved [10].

While constructive alignment allows for students to understand not only what they are supposed to learn, but also how and to what standard, there are a few difficulties associated in achieving constructive alignment. It is resource intensive and learning activities need to match with the intended learning outcomes [11]. Another difficulty is that assessment tasks also need to be redefined. While constructive alignment is effective to implement, it does require experience and it is usually difficult to implement initially.

III. METHODS

For this case study of student learning in one innovative course [12], we had to develop a novel research design that would allow for an in-depth exploration of instructor and student intentions and experiences, given this new course which still had a low enrollment. Qualitative analysis was chosen over quantitative because of the small class size for this pilot, and also because we needed to explore in detail the question of "why" our students have engaged in particular actions or behaviors [13].

To address the first research question, we constructed a narrative using reflections given by the instructor (second author). Narrative inquiries gather events and happenings as its data and uses narrative analytic procedures to produce explanatory stories [14]. This does not involve the identification of themes but rather shows the interplay of key aspects of the instructor's intentions in starting up the course, and what their experiences of the course were.

To address the second research question, we used the data from a 30-minute in-class discussion with the students that had been conducted in Week 12. The following four prompts were used to guide the discussion:

1. *What did you think the course was about when you first signed up for it?*
2. *What are some of the ways that the class is different or the same as what you expected?*
3. *How would you describe what we've covered and what you've learned in the class so far to someone who might be interested in taking it another semester?*
4. *How does this project feel the same or different than projects you've worked on in other classes?*

To analyze this data, we had asked the students in advance for permission to be able to record our interaction with them for research purposes and all of them except one, had each consented to this and so the comments of that one student have been left out. We then transcribed the data from this recording and a thematic analysis [15] was conducted to yield themes to capture the students' expectations of the course and their experiences from it.

When analyzing the data, the first author carried out the analysis and this was closely checked by the second author who was also present in the classroom at the time. After this analysis was carried out, the themes were finalized after a discussion with the third author, who was not present for the classroom discussion but was able to scrutinize the categories for clarity and coherence.

IV. RESULTS

This section presents the findings for the first two research questions, centered firstly on the instructor and then on the students.

A.1 Instructor's Intentions

I am an Associate Professor of Practice, currently teaching at Virginia Tech and the second author of this paper. This course is a new engineering-focused service-learning course called "Engineering Design for Community Impact" which was developed during Fall 2021 and piloted during Spring 2022. The course began out of a desire to fill a gap in design-focused courses for students in their second and third years of an engineering program—the current curriculum is set up such that many students are introduced to engineering design in their first year, but then only see highly theoretical courses before again being exposed to design in their senior year. The course was also designed to help provide a service/experiential learning approach to engineering design for students at this level of study.

A.2 Instructor's Experiences

I had noted several themes related to delivering the course that were unique compared to past courses taught. The course was not designed with a specific body of knowledge required to be covered, and so most class sessions were loosely organized around themes related to engineering design and followed a more conversational format. Hence, each class session took a path that was tailored to the students in the design team's needs. The discussion controlled the content that was delivered rather than following a more structured approach and this was a bit of an instructional challenge to manage since each of the students in the course were pursuing a different major.

Students generally seemed motivated and interested in their project during class discussions. However, there were some challenges in encouraging the students to meet and work regularly on their project outside of class. Because of the open-ended nature of the project, many of the interim deadlines were self-selected by the student team with support from the instructing team. However, this flexibility also tended to lead to self-selected goals that were too ambitious and weren't prioritized by the students over exams and assignments in their other courses. Each student was required to complete a weekly timesheet documenting time outside of class, but no weekly time commitment was required. It was my recommendation that a weekly target for time spent out of class be clearly communicated from the outset to prevent work being pushed towards the end of the semester.

Although students in the course had completed a general engineering program within the prior year covering key design concepts, a large portion of the class ended up being devoted to reviewing these in the context of the semester design project. For example, the students initially struggled with identifying the project scope and identifying an achievable goal. The team also required quite a bit of coaching to break down their longer-term goals into smaller tasks. Finally, engineering communication was covered several times throughout the semester to give the team enough feedback so that they could improve their written work. The team appeared to improve in their confidence throughout the semester; initially they were

hesitant to reach out to external stakeholders about their project but appeared more comfortable in professional communications as the course progressed.

B. Students' Expectations

B.1 Application of Engineering Knowledge

It was clear when students had initially signed up for the course, that they believed it was required to use the knowledge they had already picked up from the previous year and apply that in some form. This is seen through Student 2 when they mentioned how they *"thought it would be more out in the field doing hands-on work"*.

This idea of "application" being a necessary part of the course was further supported by Student 1's comments who stated, *"I did also think that the course was going to be very hands-on and interactive."* Student 1 mentions their interest in seeing what type of students would be taking the class in terms of the different majors they would be working with. In the discussion, they mention how *"I felt like there were going to be plenty of different disciplines that we would have to work with"*. This backs up the theme of how the students did perceive that different engineering disciplines and prior knowledge of engineering skills would be an important aspect of this course and how this course would also require them to use this knowledge and work on a very hands-on project.

B.2 Going through a process to work on an engineering project

From the in-class discussion, the second main theme as to what they believed the course was going to be about, was some sort of design process to work on an engineering project and produce some deliverable. Student 1 had expressed this by mentioning how they believed that *"I thought this course would have a class project, and we would have to work through some sort of engineering process"*. It can be clearly seen that an *"engineering project"* in the class was expected, along with *"working through some sort of engineering process."* Student's 2 and 3 mentioned how they felt the same way however, they had expected this project to have already been determined. They stated in their discussion how *"Yeah, I thought the same, but I thought the project was already determined and we wouldn't have to end up choosing it."*

C. Students' Experiences

C.1 Course open-endedness

One of the things the students experienced from the course which they didn't expect, was the level of open-endedness. There were many different mentions of how students felt they had more control of the project. Student 1 echoes this by mentioning *"There is a lot more freedom in what we were allowed to do than I had originally thought."*

Since these students were only in their second year of engineering, they are perhaps not very used to taking full control of a project. Student 2 emphasizes this idea with regards to the open-endedness of the project when they stated that *"while it felt good, there were times where it did feel a lot more stressful because we had to take more control of our own project and so we had to keep ourselves on track."* From this student's comments, it can be seen through phrases such as *"take more control of our own project"* and *"keep ourselves on*

track", that there really were no fixed constraints or boundaries in this course; it was very much up to the students to take control of it.

C.2 Intrinsic Motivation

One of the mentions which was unexpected from the students' discussion, was how intrinsically motivated they were to complete the project. Intrinsic motivation is when there is the basic human need for being competent and self-determining [16]. This is essentially when people are carrying out a task for no external reward and purely for their own internal competency. The students had mentioned how since the course had no pressure in terms of grades, they were able to just focus on providing a deliverable that is of high quality to the stakeholder. Student 1 mentioned how within this course, *"it felt less like turning in this assignment and getting a bad grade, but rather, I need to turn this in because I need to make sure the project is good."* It is interesting to see the connection between how the lack of worry about getting a bad grade, lead to the students wanting to work on the project properly.

During the in-class discussion, Student 3 had mentioned this class was different to the other classes they were taking in the regard where *"in the projects I have for other classes, we have a lot less freedom"* relating to the open-endedness of the project, but then goes on to mention how *"I am not worried about doing well in this class, but it is more like I am doing something good for the stakeholder."* Through this comment, we see that the priority for the student is not the grade, but rather the quality of the work, and this will also be beneficial for the external stakeholder. This is reiterated through their statement of *"It is very much a lot more about the project than the grade."* This idea of intrinsic motivation was further echoed by Student 2 when they mentioned how *"I felt like all of us were motivated to just do the project and produce something good by the end of it."*

C.3 Communication

The last major theme brought up by the students how important communication was in the course. Students mentioned how they knew basic communication would be important but were not expecting to do so at the extent to which they needed to for the course. Student 2 mentions how *"the course was a lot more discussion-based than what I had initially expected."* and this is echoed by Student 1 who mentioned how they were *"expecting the course to be structured around lectures covering certain material in class, and then we will be working on the project on the side. Whereas here, it was more discussing the project and working on it."* The students in their previous years working in teams were a part of courses where there would be general lectures covering basic content, and then a lot of the teamwork portion was done outside of class. However, for this course, the project was the entire course and so the 'lectures' consisted of more discussions about their project. Hence, phrases like *"a lot more discussion-based"* and *"more discussing the project"* reiterate this idea.

V. DISCUSSION/CONCLUSION

Based on the findings presented above, we can now address the third and fourth research question which really focuses on constructive alignment in the course and its challenges.

In relation to the alignment between the instructor's intentions and experiences, we see that the instructor intended for the students to go through typical project management strategies within a team setting to deliver the final variable. This was echoed in the instructor's expectations when it was mentioned how it was expected that students complete a timesheet documenting the work completed outside class. Even though it was mentioned as a challenge initially, the instructor also mentioned that students had to communicate with each other outside of class and had to regularly update their project schedule. These experiences all align with the instructor's intentions for the students in implementing project management strategies such as scheduling, documentation and communication. These experiences align with learning outcomes 1c, 2b and 3b of the course.

In relation to the alignment between students' expectations of the course and their experiences from it, one similarity was this idea of the process of working in an engineering project. From the course description, students expected to go through some sort of process in delivering an engineering project. This was echoed in their experiences of going through a process of taking more ownership of the project and communicating with each other and the external stakeholder to a greater degree than originally expected. Though they had not expected to be so heavily involved in the communication and hands-on aspects of the project, this was still something they had expected out of the course which aligns with what they had experienced.

The idea of working through an engineering process, implementing different project management strategies and developing a final deliverable, was where we saw alignment with the final part of this research question. This is specifically seen in the theme of utilizing project management strategies to producing a final deliverable. Aspects of the course like using prior disciplinary knowledge were expected by both the student and the instructor and while it did play a part in the completion of the final deliverable, this wasn't emphasized by the students as being something they experienced as much as some of the other themes. Parts of the course where we saw little alignment for the third research question were centered around considering the importance of cultural norms and expectations from the community, as well as acknowledging how one's background and personal biases can influence their approach to solving engineering problems.

In conclusion, this study has delivered some useful insights in relation to the challenges of designing and delivering a service-learning course in engineering. While there was a large degree of constructive alignment between the instructor's intentions and the students' expectations, there were some key areas where students found it challenging to be a course that demanded of them different capacities than in the other engineering courses they had done - specifically, the more open-ended nature of this project-based course required a higher degree of intrinsic motivation and more communication with peers and the instructor. These are very useful attributes to be developing in engineering graduates, but there are challenges when these are first encountered. More explicit curriculum signaling of engineering graduate attributes could potentially address this.

VI. REFERENCES

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