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Work in Progress: Iterating Eco-Social Justice Learning Experiences Through Community-Partnered Capstone Design Projects

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Abstract

Capstone design is a critical culminating experience in the academic trajectory of all undergraduate engineering students. At the University of San Diego, each year a handful of engineering capstone design teams out of the several dozen across the college work on community-partnered projects. The projects are seeded and nurtured by efforts from a formalized university initiative, the Engineering Exchange for Social Justice. During the 2021-2022 academic year, the authors of this paper were instructors for the year-long, multidisciplinary engineering capstone design course. The course structure and timeline cater to traditional, corporate/industry-sponsored projects. Three out of ten teams across our two course sections worked on community-partnered projects. We sought to learn about the student experience for those working on the community project teams. Each team member completed a reflection assignment with specified prompts at the end of the fall and spring semester. We analyzed the reflections using inductive thematic analysis. We identified 'Justice' and 'Connectivity' as primary themes, which connect to sociotechnical proficiencies we hoped to develop in the students. However, the reflections also highlighted challenges and shortcomings of our current model. For this work-in-progress paper, we share our salient findings from each theme, as well as instructor observations and lessons-learned from this community project capstone model.

Introduction

Capstone design is a critical culminating experience in the academic trajectory of all undergraduate engineering students. At the University of San Diego (USD) senior engineering students across three disciplinary majors (electrical, integrated, and mechanical engineering) collaborate on transdisciplinary teams during their year-long capstone design course experience. Teams work on traditional industry-sponsored projects, entrepreneurship projects of their own ideation, or competition projects (such as the Baja Society of Automobile Engineers competition). Additionally, each year a handful of teams out of the several dozen across the college work on community projects. By 'community projects' we refer to projects that emerged out of a community partnership and need/desire that the team will work to address in partnership with the community, which often entails community partner(s) serving as project mentors.

Capstone design instructors guide the teams working on industry, entrepreneurship, and community projects as a whole cohort, with all teams engaging in roughly the same project management and engineering design course activities, and subject to the same deadlines and analogous deliverables. As instructors, we have often heard community project mentors and student teams vocalize frustrations and challenges they are facing in having to force their project to fit within the well-established capstone design course structure that caters well to industry and entrepreneurship projects. The community projects are often differentially multifaceted, layered, and complex; they deal more firsthand with real people in real situations in a way that the industry projects—which have usually been tidily scoped for students—don't. The community projects can be unwieldly in their 'realness'.

However, learning in this context also stands to also pay multifaceted and layered dividends; if executed well, we submit that the sociotechnical [1,2] learning opportunity provided by community capstone projects can provide an unquantifiable richness, texture, and ethical preparation to uniquely prepare students for responsible and ethical engineering praxis. And yet, we recognize the limitations in our current instructional model that prevent this ideal from fully coming to fruition (yet).

In this work in progress paper, we share preliminary findings from our nascent exploration of the student experience working on community capstone design project teams using student reflections and instructor observations.

Context

The University of San Diego is a private, Catholic university, known for its commitment to the formation of values, community involvement, and preparing leaders dedicated to ethical conduct and compassionate service [3]. In 2019, seven faculty and staff members in the University of San Diego's (USD) Shiley-Marcos School of Engineering (SMSE) initiated the Engineering Exchange for Social Justice (ExSJ). The ExSJ is a framework designed to connect transdisciplinary faculty members, students, and external volunteers, in working collaboratively with community groups to co-create solutions to sociotechnical challenges. The ExSJ is inspired by the European 'science shop' model [4-6], and is similar to the service-learning model [7-8], though it emphasizes bi-directional 'exchange' between the community and university rather than the on-directional flow implied by 'service.' Further, it acknowledges and is inspired by indigenous wisdom and practices [9-12].

We previously reported on 1) the ExSJ framework, 2) the infrastructure, mechanisms, and activities we are using to apply this framework, and 3) the challenges and complexities we are facing as we apply it [13]. At its core, the framework is meant to support the connection between engineering and social justice, and it operationalizes this effort through multiple mechanisms that fit within the university context. For example, the ExSJ, "provides a system whereby communities are encouraged and supported to submit project ideas, which are developed and channeled through a panel of professionals and academics to create suitable projects for students in a wide variety of programs inside engineering disciplines and across campus" [14]. One such mechanism for students to engage in the community-partnered projects is through the capstone design course.

Community-Partnered Capstone Design Projects

During the 2021-2022 academic year, the authors of this paper were instructors for the year-long, multidisciplinary engineering capstone design course. We had ten teams across our two course sections; three of those teams worked on community-partnered projects. The projects included: 1) a food production project, focused on prototyping a small-scale sustainable food production system designed for implementation in a local community experiencing a food desert; 2) a youth outreach project, focused on creating an engineering project to be used in a youth afterschool setting serving a demographic underrepresented in engineering higher education and practice;

and 3) a waste-upcycling project, focused on designing a process and sample products for the production of sellable goods from waste to be used by a youth organization in Mexico.

Methods

At the end of each semester, we prompted students to individually complete a reflection, and respond in ~200 words to given prompts. The fall semester reflection prompts were as follows:

- How have you integrated previous coursework from outside of engineering into your capstone design experience?
- Describe your role in detail on how your contributions have impacted the engineering decisions your group made.
- What constraints did you consider and how has it impacted your design?
- How have you approached learning new things when you did not have the knowledge you needed to solve the problem?

The spring semester reflection prompts were as follows:

- What did you learn about working on a team in capstone design that you think will help make you a successful engineer?
- Describe an example of an engineering analysis in your design project that you were personally involved in conducting.
- What societal, ethical, and professional issues did you consider in your capstone design experience?
- Describe an example of an experiment and/or prototype you were personally involved in testing.

We analyzed each community-partnered project team member's fall and spring reflections using inductive thematic analysis [15]. We let themes emerge authentically rather than forcing relation to the original prompts. We identified preliminary themes, then went through an iterative process of mapping the student reflections to the themes, adjusting, and then finalizing the themes.

Results and Discussion

For this work-in-progress paper, we briefly share and comment upon our salient findings from two primary themes that emerged from the student reflections: 'Justice' and 'Connectivity.'

Justice

As projects originating from the ExSJ, each community-partnered project was connected to social and environmental justice in some way. It was clear from the student reflections that they saw those connections, and in some cases, they were personally impacted by them. For example, one student hadn't previously considered engineering as related to social justice. She wasn't interested in pursuing a career in the technical-focused engineering field, but after seeing the connections between engineering and social justice, she had a change of heart and was reconsidering that decision:

> *I also learned that engineering can involve social justice issues as well. Before, I did not think I would end up pursuing any sort of career in engineering because I never enjoyed the technical aspects of what was previously required. Once introduced to our project, I*

> *was intrigued to not only address modern sustainable food systems through methods such as aquaponics, but also educating what is a very privileged audience to allow them to appreciate more where there food comes from was an important part.*

Students working on the youth outreach project felt that their project was contributing to an underserved community. More specifically, they saw a connection between the project and social justice for underserved communities. One student reported:

> *Our entire project revolves around helping underserved communities. Throughout the entire year, we were trying to cater our design to this user group. We did this by trying to make it as affordable as possible and easy to just pick up and learn. We wanted to make a product that was inclusive to all and didn't have any negative impacts on people.*

The waste-upcycling team saw their project as helping a disadvantaged community that was experiencing 'poverty.' One student shared the same general sentiments that were also expressed by his team members in writing:

> *We mainly considered the societal issue of poverty. One of the main goals of our project was to help children in [disadvantaged community] get through high school through the selling of our products. Since we created an effective process that creates products that these students can sell, hopefully this will have a hand in creating economic growth and helping them continue their education.*

We noticed that in this reflection, the student referred to the products as 'our' (as in the team's) products, rather than the community's products. This word choice is important and telling; it communicates to us that the students were not exposed to the the concept of community ownership in the project. This concept is critical to ethical, exchange-based community partering, and yet one that we don't cover in the capstone design course since it is irrelevent to most project teams.

We also noted the students labeling their communities in various deficit-based capacities, such as 'poor', 'disadvantaged', and 'underserved.' These words are subtle conveyors of a harmful power dynamic, remnants of the imperialistic and savior mentality that we are working to dismantle through the ExSJ, and indicators that we are operating outside of the equitable 'exchange' model that we are aiming for. In our communications with the students throughout the year, and in their reflections, we noticed numerous other gaps in the students understanding of the engineering exchange framework. These reflect back to us the shortcomings of the course in preparing the community-partnered project teams to work on and talk about their projects.

Connectivity

The students were able to identify connections within their projects that went beyond what an industry-sponsored team might typically consider in relation to their device or gadget connecting to a larger technical system. These connections included linkages to fields outside of engineering, the involvement of multiple stakeholders who had a vested interest in the outcome of their project, as well as connections to various communities.

Engineering capstone projects are intended to be multidisciplinary as it is a fundamental aspect of the design experience to combine knowledge from a variety of fields. Typically, students utilize knowledge from math and science courses, as well as communication skills such as public speaking and writing. However, students who worked on community-partnered projects were required to integrate knowledge from even more fields, including areas with which they may have had little to no prior experience. For example, one student wrote, “This [project] made me realize how interconnected engineering is with other departments and disciplines.” Another student stated, “Almost every single class that I have taken at [the university] has proven to be beneficial in one way or another for this senior capstone project.”

In any engineering design project, there are stakeholders, the parties with a vested interest in the project's outcome or those who may be affected by it in some way. In most industry-sponsored projects, there is typically a sole stakeholder, the industry 'sponsor' to whom the team reports to, and who ultimately receives the project deliverable(s). Conversely, students who participated in community-partnered projects experienced a different structure, in which each project functioned within an ecosystem of multiple stakeholders. This increased complexity in the project landscape also came with challenges. For example, each team cited communication as a challenge. Instead of a unidirectional line of communication between the team and their sponsor, teams had to communicate with multiple parties who at times had differing project needs an expectations the that the teams needed to learn how to navigate. One team collaborated with stakeholders from several organizations in a binational and bilingual setting, which made communication especially complex and challenging. In one student’s words:

> *Our project was a community based project so we ran into many communication issues, not just among ourselves, but with both of the organizations we were working with as well. Not only communication is important, but getting a solid basis of understanding of the topic for the whole group.*

This same team further reported struggles in communicating outside of their native language, and needing to rely on a ‘middle-man’ which complicated matters and prevented direct, clear, and timely communications. Though challenging for the teams to navigate, the multi-pronged networks of stakeholders the community-partnered project teams had to learn and work within were real, and representative of the complex networks that engineering practitioners in the ‘real world’ must also work within. As capstone design is meant to bridge the students’ academic experience to their professional one, this learning opportunity is an invaluable one for soon-to-graduate burgeoning engineers.

Instructor Reflections

The values underpinning the ExSJ set the standard for community-partnered projects and their unfolding through equitable partnership, co-defined problems, and co-created solutions during each project phase. Though we consider this implementation of community-partnered capstone design projects to be an overall success, we also acknowledge that we have fallen short of this ideal. During the two-semester course laden with engineering design process and accreditation-based learning requirements, there is not enough time to form a partnership with a community, engage in an exchange process, and allow for authentic problem identification. In our experience, this process is crucial, but it can take years, and it cannot be rushed to fit with the university's timeline. Instead, we have found that community-partnered capstone design projects like these must be part of a broader community partnership ecosystem in the engineering college or

university, such as the ExSJ, which provides mechanisms such as summer scholars programs, independent studies, and courses to help with community partnering, problem identification, and early stages of co-ideating solutions.

Though less ideal from a theoretical standpoint, we have learned that putting a project into the capstone design course before it has already gone through this process leads to frustration and poor execution. We discovered this by trial and error. For instance, the waste-upcycling project would have benefited from several more community visits before being introduced as a capstone design project. The students started working on the project when it was still being defined, which led to confusion, and the students struggled to complete course tasks which were based on having a clearly defined problem statement. In contrast, the youth outreach project was a multi-year project born out of a long-standing relationship with the community organization. In this case, the project was well-defined, the students thrived in the class, and the community was pleased with the final deliverables.

In some cases, the students referred to the communities as 'poor' and 'disadvantaged' in their reflections, and conveyed an overinflated sense of 'helping the communities' with their projects. These comments conveyed dominant and savior power structures, which the ExSJ framework aims to dismantle by promoting equitable partnership and exchange rather than service. However, we did not provide the students in the capstone design course with guidance on this perspective. The course content is already 'full', and most teams in the class are not working on community-partnered projects, so we chose not to formally include these teachings. Upon reflection, however, we recognize the responsibility we have to incorporate these teachings into the course because of the inclusion of community-partnered projects, and are brainstorming how and where to weave this content in.

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