Engaging Engineering Students with Non-Engineering Majors in Interdisciplinary Service-Learning Projects: A Model for Engineering Everywhere for Everyone

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Abstract

The ability to function in multidisciplinary teams and understand the impact of engineering solutions in a global, economic, environmental, and societal context are important learning outcomes to prepare engineers for a global workforce.[1] And, there are increasing calls to enhance undergraduate engineering education with opportunities to engage in real world experiences.[2-3] This paper describes the rationale and design of a two-tiered service-learning course model, which provided a new organizational structure to promote interdisciplinary engineering and a socio-technical approach to community problem-solving. Using inquiry-guided learning to scope and implement community projects coupled with the assets of student leaders in the role of project managers, disciplinary silos and resource constraints were overcome to establish a model that was both accessible to students of all levels and majors and adaptable to meet the complex and varying needs of local and international partners. Re-centering the needs, interests, and constraints of community partners created opportunities for interdisciplinary work, as students needed to identify, mobilize, and integrate knowledge and resources from multiple fields to develop and implement effective projects. However, this approach also presented instructional challenges due to multiple degrees of complexity involved in the course design, diversity of student majors and experience levels, the broad range of community partners, and the nature and scope of projects. Implications of teaching in this community-engaged context will be discussed.

Keywords

Service-learning, interdisciplinary projects, instruction/pedagogy

Multidisciplinary Teams and Interdisciplinary Projects in Engineering Education

The ability to function in multidisciplinary teams and understand the impact of engineering solutions in a global, economic, environmental, and societal context are important learning outcomes to prepare engineers for a global workforce.[1] The engineering education literature is full of examples of engineering courses that incorporate project-based learning opportunities in which students engage in multidisciplinary teams to practice a variety of engineering design and professional skills, including capstone experiences involving design work for external clients.[4-6] Teams often are constituted of students from various disciplines within engineering rather than engaging engineering students with non-engineering majors on collaborative projects.[7-9] Although less common, there are also course collaborations that pair engineering students with marketing, fine arts, business, or liberal arts majors to work on interdisciplinary projects.[10-14] Researchers have found that engineering students engaged in interdisciplinary service-learning design projects not only gain design experience, but also report gains in soft skills such as communication, teamwork, global awareness, professionalism, and sense of social responsibility in engineering.[15] After working with non-engineering students on cross-disciplinary projects some engineering students report enjoying and being motivated by the experiences, perceived that they put them at an advantage over other engineering students when competing for jobs and graduate school, enhanced their abilities to communicate technical content to non-technical majors, and increased their likelihood to work on cross-disciplinary projects.[16]

Despite the prevalence of courses that engage engineering students in multidisciplinary teams, the potential value of learning from interdisciplinary and transdisciplinary approaches to problem-solving is left under-realized. Often where non-engineering majors are included on project teams, students' work on the project is divided based on presumed knowledge and capabilities. This tendency is manifested in divisions such as "technical" versus "education" sub-teams on international development projects or "design" versus "business" sub-teams for product development projects. Although this may capitalize well on students' existing interests or strengths and achieve efficiency from the perspective of students trying to optimize their time investment, they often are not challenged to learn from and adopt the knowledge, methods, and approaches common to other fields of study, and they do not fully collaborate between these static sub-teams. Without strong incentives or course structure to facilitate this process, it is unlikely that many engineering students will engage in a process that might appear ill-structured or "inefficient" and with no guaranteed pay off for the collaboration. Evidence of these patterns of compartmentalized work is reflected in inconsistencies across sections of students' written team assignments and in project status updates about the work of the respective teams.

Interdisciplinary Service-Learning Projects as Opportunity for Curricular Breadth

Research has shown that many students struggle to contextualize their design work. There is an over-emphasis on technical design with relatively little attention given to the maintenance and sustainability of a system or to the experiences and perceptions of individual users, communities, or organizations receiving the work. As such, there are increasing calls to enhance undergraduate engineering education with opportunities to engage in real world experiences.[2-3] In particular, there is a growing body of research related to learning through service in engineering, which demonstrates positive learning outcomes for students and benefits for communities.[17-18] Despite the importance placed on creating globally competent and community-engaged engineers trending in engineering education, [3, 19-21] newer educational settings such as service-learning and international education programs are not perceived as particularly important by many engineering faculty nor are they widely used, in part due to curriculum that is packed with technical content.[22] As engineering education has evolved, so have demands by industry and academic leaders for universities to graduate "T-Shaped" engineers, those with deep technical knowledge in at least one specific discipline, but who also possess knowledge and skills spanning multiple disciplines, an understanding of broad systems, and transferrable competencies to work effectively in a diverse workplace.[23]

Some aspects of engineering culture and training might actually teach students to devalue social consciousness and community engagement [24] and treat interdisciplinary endeavors as threatening to engineering rigor, credibility, or perceived technical "neutrality".[25-30] In addition, non-engineering majors are often excluded from the benefits of learning from the engineering curriculum, including problem-solving and design skills. This may be in part due to curricular, organizational, and financial constraints on campuses which make it difficult for non-majors to enroll in engineering courses, as well as social climate issues which discourage broader participation by non-engineering majors in highly competitive and elite engineering colleges.

However, curricular breadth has a number of potential benefits for students. Breadth encourages understanding of context and interdisciplinary connections, which can promote higher levels of cognitive complexity in problem-solving.[23] This emphasis has a number of educational advantages for career preparation, including helping students to 1) identify alternative applications for technologies across sectors, 2) analyze interdependent problems, models, and systems, 3) understand that engineering decisions and the development of technologies are not neutral endeavors, and 4) learn engineering fundamentals and transferrable skills to prepare for work in fields both within and outside of engineering.[23] An interdisciplinary, rather than multidisciplinary, approach to teamwork and community problem-solving implies taking into account that genuine community problems and complex solutions to address community needs may be best discovered from the knowledge, skills, methods, practices, and perspectives of multiple diverse disciplines rather than a single discipline. An interdisciplinary approach encourages more interaction between disciplinary knowledge sets. Further, a transdisciplinary approach would reflect a more holistic way of understanding problems and developing projects. Utilizing these latter two approaches, students can develop a deeper understanding of social and environmental issues, which can lead to new insights and innovative problem-solving.

Re-Centering the Role of Community Partners in a New Service-Learning Course Model

A two-tiered interdisciplinary service-learning course model was created to enable teams of engineering and non-engineering students to work on problems, opportunities, and projects proposed by community partners. Using an inquiry-guided learning approach and student leaders in the role of project managers, disciplinary silos and resource constraints were overcome to establish a model that was both accessible to students of all levels and majors and adaptable to meet the complex and varying needs of diverse local and international partners across multiple semesters, thus addressing some of the challenges common to short-term service-learning.[31]

Graduate students and upper-level undergraduate students interviewed through a competitive process to become project managers for the program. A pair of project managers was assigned to each of the *Learning in Community* service-learning course sections, with sections designated separately for each of the community partners. The project managers participated in pre-semester training to learn about the course curriculum and teaching strategies tailored to the service-learning context. These student leaders were responsible for facilitating class sessions, evaluating students' work, and serving as the primary liaison for their respective community partners. The project managers enrolled concurrently as a cohort in the upper-tier service-learning course, *Applied Project Management*, where they received ongoing instruction, coaching, support from their peers, and instructional resources to use in their course section.

Although the course aimed to develop skills necessary to work with diverse clients in students' future careers, students were encouraged to think critically about what might be different and expected in working effectively with community partners rather than in a "client-consultant" relationship, as relations typically are framed in engineering and business courses. Students committed their time, energy, resources, disciplinary knowledge, and creativity to benefit the community partners and their respective missions. And, community partners benefited students by providing experienced guidance and feedback, opportunities to learn about and develop a deep awareness of social and environmental issues, and access to real-world experiences, authentic problems, and community-based projects to foster professional skill development. Students were explicitly reminded to look for opportunities to learn from others and recognize that community members have valuable professional and life experience, community and context-specific knowledge, and important insights and project-related knowledge that needed to be considered carefully if projects were to have a positive impact in the community.

Through structured reflection, reciprocal relationships and ongoing communication with community partners was emphasized. And, communications management and development of those relationships was facilitated by way of course requirements and assignments, including opportunities for partner feedback and evaluation of deliverables. To manage expectations, students were instructed to be mindful about common goals and motivations of community partners seeking a relationship with service-learning programs (e.g., having needs they want addressed to expand their organizational capacity, passion for inspiring and educating students to engage in short- and long-term community problem-solving related to issues for which they are knowledgeable, and desire to connect to and strengthen relationships with the University).[32] Students were prompted to approach partners with an asset- rather than deficit-based mindset and to build on each other's strengths in order to problem-solve together more effectively. This approach discouraged students from trying to "reinvent the wheel" or work independently from partners when leveraging or building upon existing organizational, community, or University assets proved more appropriate. This mindset fostered collaboration between students and partners as well as buy-in from community stakeholders, influenced how students defined problems and scoped projects, and prompted consideration of issues of maintenance, succession, and individual and organizational capacity.

An important aspect of re-centering the role of community partners was that it fundamentally changes the way that student teams developed their understanding of problem definition and the range of solutions available to address problems or opportunities. Through an inquiry and engagement process, they were guided to co-construct an understanding of the community partners, their needs, interests, and opportunities. This serves in contrast to identifying community partners who are "in need of" pre-determined projects for which students are apt to learn required disciplinary course content. This re-centering approach influenced the nature of relationships, but also challenged students to learn how to tackle ill-structured problems through a transdisciplinary lens and to work through an iterative inquiry process in consultation with partners. The students gained practice in formulating and prioritizing useful questions for research, checking for understanding with stakeholders, identifying and mobilizing appropriate resources, making critical judgments related to information literacy, and taking responsibility for project decision-making in terms of consequences and potential value added to the partners.

Using Assignments to Structure Inquiry-guided Learning for Interdisciplinary Projects

By working collaboratively as a team, students were asked to conceptualize, develop, plan, implement, and evaluate a project with their respective community partners. Students individually conducted research and submitted *Learning through Inquiry Reports* to support the project. This inquiry-guided learning involved a process of asking questions, investigating solutions, creating new knowledge and products, discussing experiences and processes, and reflecting on new-found knowledge and understanding.[33] Students were encouraged to value diverse methods of inquiry, including research that resulted in decisions about what not to do in the project. For example, reports might document work with artifacts like sketches or design renderings, draft iterations of a survey, a results summary of a setting analysis, resource procurement documents, a descriptive log of stakeholder interviews, technical calculations, internet research searches and results, descriptive field notes, a log of lab testing, an analysis of archival documents, or a record of consultations with practitioners or technical experts.

The projects were organized with complementary team assignments, which built successively throughout the semester. Each course section team presented a unified project (set of deliverables) to the partner. Team adaptability and agility were important for successful projects, as the evolving nature of the projects and feedback from partners required students to contribute to tasks charged to various working groups in the team and/or to be re-assigned to working groups as the needs of the project demanded on a weekly basis. All work product accomplished was integrated into a single team submission for each of the following assignments: 1) *Partner Profile and Issues Analysis*, 2) *Pre-Proposal Presentation*, 3) *Project Proposal*, 4) *Project Charter and Scope Statement*, 5) *Final Report and Deliverables*, and 6) *Poster Presentation*.

The *Partner Profile and Issues Analysis* required a description of the partner(s) and their mission that demonstrated a deep understanding, an in-depth analysis of the social/environmental issues that were critical to the partner and potential projects, and an assessment of key needs and opportunities for the partner. The *Pre-Proposal Presentation* included the project concept with a high-level outline of the project scope, proposed activities, outputs/deliverables, and intended outcomes and impact. This assignment was presented to community partners, project managers, and instructional staff for review, feedback, and revision requirements. The *Project Proposal* integrated a synopsis of key elements of the *Partner Profile and Issues Analysis*, components of the *Pre-Proposal Presentation*, elaboration on the project's scope, a work breakdown structure, evaluation plan, and analysis of safety, environmental, and ethical issues. This assignment was reviewed by the community partner, and students in another course section team provided feedback during a structured *Project Review Session*. This *Project Proposal* was revised and expanded to address the feedback provided during the review and by the project managers. The resulting document became the *Project Charter and Scope Statement*, an agreement among stakeholders about what the semester's project would entail. This assignment included details related to project planning and implementation, such as a project schedule, well-defined milestones and deadlines, budget and resource estimate, and roles and responsibilities of major stakeholders. The *Final Report and Deliverables* documented the team's work and evaluated the outcomes of the project. The *Project Charter and Scope Statement* served as the foundation for this report, and teams edited this assignment to reflect what actually happened (versus what was planned) in the project. This report included changes which were made to define and implement the project, documentation of the work accomplished to produce deliverables, and outcomes of the project. Documentation of all deliverables was included with the report. The community partner's evaluation of the project deliverables was utilized as a component of the report grade.

Students demonstrated project results during the end-of-semester *Poster Presentation*. This public culmination event was an opportunity for students to learn about the accomplishments of the other teams and to participate in a collective celebration with all of the participants in the program. To enhance their learning, each student engaged with other teams and used an evaluation form to provide feedback on the presentations. Community partners used the event as an opportunity to network with University and community colleagues and to generate new project ideas inspired by the student teams. The event also served as an opportunity to encourage new students to get involved with the program and the work of the community partners.

Instructional Possibilities and Challenges

A benefit of re-centering the needs, interests, and constraints of community partners is that it fosters truly interdisciplinary work. Student teams must identify, mobilize, and integrate knowledge and resources from multiple fields to implement effective projects. In this way, opportunities are created for both engineering and non-engineering majors to work together on community-based projects, utilizing knowledge and skills from engineering—as well as other disciplines—as the needs demand to create potential impact. However, this approach also presents instructional challenges due to multiple degrees of complexity in the course design, diversity of student majors and experience levels, the broad range of community partners, and the nature and scope of projects. Students struggled with the demands of the course—teamwork, communication, time management, the ambiguity and self-directed nature of inquiry-guided learning, technical and reflective writing, project scoping, and being accountable to partners.

The curriculum, assignments, and class activities needed relevance for a broad range of partners and projects and to have scaffolding and flexibility to enable student managers to facilitate effectively in their respective sections. A balance had to be struck with scoping projects that met genuine needs of partners while being within the zone of proximal development for students' achievement. Task-oriented management was necessary to delegate project work efficiently, but project managers were also expected to practice learning-oriented management to encourage students to take on unfamiliar tasks with greater potential for learning. And, they used class time for structured reflection and activities intended to strengthen students' knowledge and skills in developing community-based projects, albeit not always connected to immediate project tasks. A balance also was needed with assessment—students were rewarded for growth in the course, but a level of mastery was necessary to complete a project that satisfied partner requirements.

A risk of this model is that engineering students may or may not work on strictly technical projects. This presents a challenge for gaining broader endorsement among engineering faculty who value depth of technical knowledge over gains in other knowledge domains, transferrable skills, and shifts in attitudes, values, and dispositions that are endemic to experiences in interdisciplinary service-learning. If we are to heed the calls in engineering education to provide more training and experience for "T" learning and gains in social responsibility in engineering, it might be constructive to consider that educational innovation could include crossing boundaries and re-defining what is central to developing knowledge and skills to train effective global engineers. Perhaps not all projects and teamwork experiences need to be framed primarily in terms that students or faculty define comfortably as "engineering." If engineering students aren't put into situations in which interdisciplinary knowledge, inquiry methods, and values are viewed as important, rather than "add-ons," it is unlikely they will incorporate these new ways of working and thinking into their roles as engineers. And if non-engineering majors rarely have collaborative interactions with engineering students on technical projects, we miss the opportunity to build their confidence and enhance interest and efficacy in problem-solving that involves a technical component. This would be a loss for students and communities everywhere.

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