Building Teaching Collaborations across Disciplines

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Abstract

Current engineering curricula provide few opportunities for students to interact with their peers in other disciplines. However, the engineering profession, and society as a whole, is becoming more and more integrated requiring communication skills for discussing a variety of topics with a variety of audiences. Engineering students need opportunities to practice communicating technical information with non-technical audiences. One way for engineering instructors to facilitate these opportunities is to collaborate with faculty in non-technical disciplines. Developing and sustaining cross-disciplinary learning experiences requires collaborating instructors to model strong communication and team-working skills for their students. The objective of this paper is to discuss best practices for incorporating cross-disciplinary experiences for students into engineering coursework. This paper describes the implementation of a cross-disciplinary experience between engineering and elementary education students. Lessons learned by the course instructors and the subsequent adjustments to the project implementation are discussed in the hopes that future instructors of cross-disciplinary experiences will benefit.

Introduction

Communicating technical information across disciplines increasingly plays an important role in graduate success. However, the college experience provides few formal opportunities to learn and develop these skills [1, 2]. One option is to provide opportunities for students in different disciplines to work together on class projects. Cross-disciplinary experiences between engineering and education students have shown potential to help students develop communication skills [3, 4]. In addition, students develop self-efficacy in their discipline through participating in cross-disciplinary experiences [5]. Cross-disciplinary experiences also help students learn to value expertise outside their area of study and appreciate the limitations and constraints of information in other fields [6]. Course instructors can also benefit from sharing responsibility for a course and learning about other disciplines [7].

The unfamiliarity of cross-disciplinary activities can lead to frustrations despite their many benefits. Students often struggle to connect topics from other disciplines with their narrowly defined fields of expertise and don't identify the contributions of 'multiple fields to complex problems' [6]. The breadth of cross-disciplinary projects can also make students uncomfortable [8]. These difficulties can be alleviated if instructors provide sufficient support and guidance to their students.

Cross-disciplinary experiences can take many forms. Students may be taught by one instructor that incorporates various disciplines in one class. A team of instructors from different disciplines may teach a single course. Students in separate courses may work together on a shared project. The latter is the case for the cross-disciplinary experience discussed in this paper. While the modes of implementation vary widely, many of the same techniques can be used to improve instruction of cross-disciplinary experiences. This paper will focus on instructional techniques for cross-disciplinary experiences led by multiple instructors.

Leading students through a cross-disciplinary experience is a complicated and involved process. Instructors naively assume that students will learn the necessary skills to navigate the new experience simply through participating in a cross-disciplinary activity [6]. However, coaching from the instructors is vital to provide a meaningful student experience and scaffold student learning [5, 6]. The uncharted territory of the new experience may lead students to depend more on their instructors than they would in a single discipline course. Students may become frustrated if they feel that time with the instructors of both disciplines is limited or not occurring regularly [8, 9].

Different disciplines likely contribute in varying ways to a given cross-disciplinary problem. Students may not have the skills necessary for effectively contributing to the cross-disciplinary team. In addition, they may have no experience measuring the contributions of their teammates from different disciplinary backgrounds. Students become frustrated when they perceive a disparity in the contributions of different disciplines to the team project [9]. Instructors must help students navigate this experience by providing fair feedback to student concerns or complaints about their teammates. Students also quickly realize that additional time and effort is required to have a successful outcome. Instructors should alert students about cross-disciplinary course activities before the semester begins to ensure they can devote the necessary time and commitment to the team project [10].

The collaborating instructors must model effective team collaboration for their students. It is vital for the instructors to put in extra time teaching each other about their disciplines, developing and refining course structure, and monitoring the student experience throughout the course [7, 8, 11, 12]. Clear communication of their individual course objectives during the planning and implementation phases ensures both instructors achieve their learning goals [10].

This paper describes the experience of two instructors leading a cross-disciplinary project between engineering and education undergraduate students. Their experiences support the importance of implementing the instructional methods discussed in the literature. Lessons learned are shared to guide other instructors interested in incorporating a cross-disciplinary project to their course.

Methods

This work is part of a larger study exploring the effects of cross-disciplinary team experiences between engineering and elementary education undergraduate students on two learning outcomes: improved technical communication skills for engineering students and increased subject matter knowledge for teaching science and engineering content for elementary education students. In this paper the role of the instructors from the two disciplines (engineering and elementary education) facilitating the cross-disciplinary project is examined.

Undergraduate students in a junior-level introduction to biomedical engineering course were placed on teams with undergraduate students in a junior-level elementary education science methods course. Both courses are required in the relevant major. The engineering course covers a wide-range of biomedical engineering topics including biomaterials, bioinformatics, and imaging. The elementary education course covers the role, trends, content, and materials of science in childhood education.

The undergraduate student teams worked together (Figure 1) to design and implement afterschool club activities for elementary students in Community Learning Centers (CLCs). The CLC programs target low-socioeconomic schools that are underperforming in science on local and state tests. The afterschool clubs met once per week for 6-7 weeks. The experience of the elementary students that attended the afterschool clubs facilitated by the undergraduate student teams is not considered in this paper. The cross-disciplinary project served as a final project and was a major graded component in both courses. The engineering and elementary education students were expected to bring different skills to the club and were assessed accordingly. Elementary education students were responsible for teaching the engineering students to create lesson plans and classroom management strategies. Engineering students were responsible for teaching the elementary education students about science and engineering and ensuring accurate information was presented to the afterschool clubs. Individual course instructors graded their respective students.

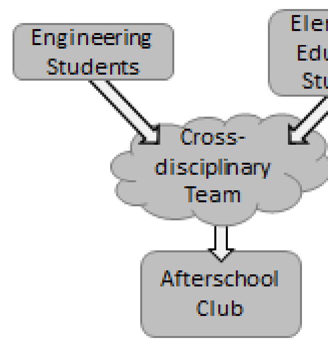

Figure 1: Project overview

The first year was considered a pilot test of the project and provided feedback to improve the student experience. Modifications during the second and third years included providing more opportunities for students to meet with their cross-disciplinary teammates during class time, providing additional structure to define project deliverables, decreasing team size, and moderating communication between the team members through a virtual community (Table 1).

Table 1: Comparison of project details over three years of implementation

Year	Group Size	Engineer: Educator	Example Club Topics	Lessons Learned & Modifications
1	10-16	7-10:3-6	Ladybugs, Bubbles	Group sizes are too large, need more structure to facilitate team communication, need more flexibility in club topics
2	6-7	4-5:2	Chemical reactions, states of matter	Smaller clubs & virtual community improve team collaborations, need more structure to choose club topics, elementary education class moved to building near engineering class at the same time, weekly meetings between instructors ensures common message
3	5-7	4-5:1-2	Tissue engineering w/ 3D printers, cardiovascular mechanics	Primary literature to guide club topics improves connection to biomedical engineering, weekly reflection questions on virtual community may be excessive, in-class work time is helpful, don't neglect weekly instructor meeting!

Year One

Undergraduate students worked on cross-disciplinary teams of ten to sixteen during the first year of the project. The two courses met at the same time however they were on different campuses in the same town. Students self-selected teams based on their availability to attend the afterschool clubs during the only in-class meeting. The overall club topic and name were chosen at this meeting. The instructors encouraged students to work together and draw on each other's strengths, however their roles were disconnected. The education students were responsible for facilitating the first four to five weeks of the clubs. The engineering students were responsible for designing an engineering project for the final club meeting.

Year Two

Team sizes were decreased during the second year. Students were assigned to teams based on their reported weekly availability to attend the afterschool clubs. The education course was moved to a building near the engineering course on the same campus. This allowed for more in class meetings between the education and engineering students. Unlike the first iteration, the engineering and education students taught in the afterschool clubs at the same time. An engineering student might be the main teacher while the education student served as the assistant or vice versa. Another change to the project included team-building activities during the first in-class meeting. Teams worked through three stations (Figure 2) to build communication and respect between the two disciplines.

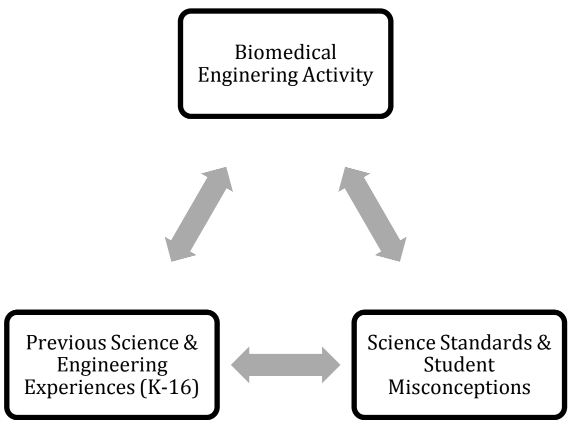

Figure 2: Year 2 team-building stations

At the first station, teams participated in a biomedical engineering activity designed for elementary students. The teams used the engineering design process to create and test a stabilization device made out of office supplies for a broken chicken bone. The goal of this station was to introduce the elementary education students to biomedical engineering and provide an example for teaching engineering to elementary students. At the second station, teams discussed their prior experiences with science and engineering from kindergarten through college. The students were also encouraged to bring a representative object (e.g., calculator, crayons) that reflected their profession. The goal of this station was to help the students compare how their prior experiences with science and engineering affected their current interests and career goals. This station also helped the students begin to understand their teammates' disciplines. At the third station, teams discussed elementary science standards and common student misconceptions about science. The goal of this station was to orient the engineering students to appropriate levels of science for elementary students and help the teams begin brainstorming club themes.

Year Three

Students were again assigned to teams based on their reported weekly availability during the third year. Teams participated in team-building exercises during the first in-class meeting. Students drew a scientist or engineer at work and discussed the similarities between the education students’ and engineering students’ drawings. As with the second year, the two groups discussed their prior experiences with science and engineering. Each team developed a plan to support communication throughout the project to promote healthy team development. The plan included specifics on the responsibilities and practices the group would follow in order to complete the project. When the afterschool clubs began, both education students and engineering students were in attendance for almost all club meetings. The largest change during this iteration of the cross-disciplinary project was the process for identifying the club theme. In prior years, teams independently chose their club topic at the first in-class meeting. In the third year, the engineering students on each team identified a research article that exemplified biomedical engineering. At the next in-class meeting with the education students, the engineering students used the identified paper to explain biomedical engineering to their education student teammates. This paper then served as a real-world biomedical engineering concept to guide the development of their afterschool club.

The instructors of the engineering and education courses met regularly throughout each implementation of the cross-disciplinary project to discuss team dynamics and progress. These discussions often resulted in reflection questions to help the students identify and address communication successes and weaknesses. The instructors monitored student experiences and encouraged team discussion throughout the semester on a shared Google+ page (years 2& 3). Each team had their own Google+ on which to respond to weekly reflection questions and share concerns and successes.

Informed consent was obtained for this study (IRB #20140814591EX) and placed in a sealed envelope to be opened at the end of the course to ensure that there was no impact to student scores or treatment. Student coursework was collected over three years of implementing the cross-disciplinary project in the two courses. Coursework included selected responses to quiz questions related to the team project and responses to reflection questions in the virtual community (years 2 & 3). The students also participated in focus groups to discuss the team collaborations and wrote individual reflections on their experience at the end of each semester. Prompts for the individual reflection included:

- What did you learn about thinking like a scientist or engineer?
- What did you learn about communicating science and engineering to non-engineers?
- How did you define success for your team?

Qualitative analysis of the data consisted of reading the collected student work. After reading all responses, the qualitative data were coded to identify themes.

Results and Discussion

The purpose of this paper is to suggest best practices for instructors attempting to implement cross-disciplinary teams in their courses. The results in this paper are from a study determining the impact of collaborations between undergraduate elementary education and engineering students. Student struggles and feedback are provided along with instructor modifications to reinforce best practices in the literature.

During the pilot year of the cross-disciplinary project, only one team discussed spending time collaborating with their engineering/education peers despite encouragement from the instructors to work together. Most of the teams designed and implemented the afterschool clubs with little to no communication between the engineering and elementary education teammates. The authors were guilty of naively assuming students would figure out how to work as a team simply as a byproduct of facilitating the afterschool club. Due to a lack of support, the students struggled to communicate with each other [3, 4]. Despite this shortcoming, students in both disciplines reported that they recognized the positive impacts of meeting and working together. Improvements were made during the second year, including more meeting times during class and a virtual community group, to better support communication within the teams.

The difficulty in assessing team member contributions was apparent in the cross-disciplinary teams all three years. This was especially apparent during the first year of implementation. Individual students from both disciplines discussed concerns with their instructors that their cross-disciplinary team members were not contributing or communicating sufficiently. The instructors encouraged students to come to them with their concerns and attempted to help the students accurately assess the situation and make a plan for moving forward. This experience highlighted the fact that instructors must provide guidance to help build an appreciation for the unique skills the different disciplines bring to the team [9]. This empowers students to reflect on their role they fill in the project and see themselves as real participants in the cross-disciplinary task [10] in addition to acknowledging the contributions of their teammates.

Often the source of the concerns was due to simple miscommunication. Students heavily relied on technology to communicate within the teams. However, they often didn't use the technology effectively. As one student pointed out, we 'pretty much sent many emails and overwhelmed them, until they sent one back…' Students in the engineering and education courses truly felt that they spoke different languages. As a result, the education students did not receive the necessary support from the engineering students to understand engineering practices and make connections between the science and engineering concepts. Similarly, the engineering students needed more guidance from the education students to share their technical expertise with the elementary students.

The instructors in this paper responded by providing each team with a virtual community using Google+ to host discussions (years 2 & 3). Reflection questions were posted on the community by the instructors to encourage discussion. Questions included:

- How are decisions made in your team?
- What is your role on the team? What do you hope to learn from your teammates? What are you depending on your teammates to bring to the team?
- What was your biggest win as a team?
- What are some of the significant differences among team members? In what ways did these differences strengthen or hinder your team?
- What is your funniest story from the afterschool club?

The reflection questions provided through the virtual communities ensured communication was happening within the team at least once a week and provided structure to assess team development.

The engineering students initially struggled to implement club topics and activities that clearly presented engineering practices to the elementary students. Many of the teams focused on general science topics during the 1st and 2nd years, such as the states of matter. These topics easily connected to science standards and allowed students to draw on common science experiments they experienced in elementary school. These results support prior work suggesting that students struggle to make connections between different disciplines and rely on the instructors to provide support to make these connections [6]. During the third year of the project, students were required to use biomedical engineering research articles to direct club topics. This modification strengthened the biomedical engineering connection of the club topics. The resulting club topics included 3D printing of artificial organs, mechanical properties of teeth, and cardiovascular function to design a heart valve. These new topics stretched the undergraduate students to develop new activities related to the biomedical engineering.

Similar to the student experience, consistent communication and clear definition of expectations were key to forming a successful collaboration between the instructors. For example, students became frustrated due to a lack of clarity in project expectations during the pilot implementation of the project. This was largely due to a difference in the expectations each instructor had for her class. Both instructors had to clearly articulate their course objectives and expectations for the student experience. This was improved in subsequent years by sharing project deliverables for both groups of students during a combined meeting. However, students continued to struggle with grasping the breadth and expectations of the project [8, 9]. Student responses (11 out of 45) to a formative assessment quiz question during the third year of the cross-disciplinary project highlight the general confusion and anxiety felt by students prior to the start of the afterschool club.

> *'Right now everything feels disorganized and I'm not quite sure about all the details of teaching yet'*
>
> *'I think there could be better communication about what is expected from the student clubs'*

The course instructors continually evaluated student development throughout each semester to support student learning. Yearly modifications improved the overall student experience. The extra effort required to implement the unique cross-disciplinary learning experience allowed students to gain a deeper appreciation for their discipline and begin to envision their future role as a professional in the community. These advantages were evident in the individual student reflections during the 3rd year of the project.

> *'It's given me skills that I otherwise wouldn't have learned in a classroom setting, being able to adapt to others and certain situations, understanding responsibility, and even passing on our knowledge to the leaders of tomorrow.'*
>
> *'Working on a collaborative project with teachers for kids had broadened my perspective of what engineering is. Engineering isn't only knowing math and science, it's also communication, application, management, etc. It's using what I know to impact others, for this project I was able to impact teachers and children alike.'*
>
> *'One big impact this experience could make on my professional career is to encourage myself and the engineers I work with to do outreach with the community… We do have*

the opportunity to learn the latest scientific breakthroughs and read frequently through primary literature. It is our responsibility to share the developments we learn with the public. Keeping others informed is vital for social, economic, and political spheres.'

Integrating cross-disciplinary activities into undergraduate courses takes considerable time and communication between the instructors. However, these cross-disciplinary activities help students develop communication skills, value professionals outside their own discipline, and begin to see themselves as real contributors to the world. The positive outcomes associated with providing opportunities for students to work with their peers in other disciplines makes the extra effort worthwhile.

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