”Hiring Other Classes”: Working across Departmental Boundaries in Interdisciplinary Projects for Senior Engineers

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Abstract

Engineering students in upper level courses are often isolated from students in other majors. Project Based Learning (PBL) is a great tool for upper level students, where they can practice the various skills they will need to successfully address workforce projects after academia. However, PBL does not readily allow students to interact with the wide variety of people and fields that engineers regularly do during a post-academic ‘real world’ project, including environmental scientists, policy makers, technicians, interns, and managers.

To address these issues, faculty at Merrimack College in North Andover, Massachusetts, adapted Project Based Learning to include collaboration between different courses. “Environmental Design,” a Civil Engineering course with 25 seniors enrolled, “hired” other courses of students to conduct specific tasks of interest to our projects. An Ecology course was hired to conduct macroinvertebrate sampling. An Electrical Engineering course was hired to design and develop a water quality monitoring device. A STEM Education course was hired to complete some water quality measurements. Finally, the students of Environmental Design were hired by an Environmental Studies course to develop a water quality monitoring plan, and conduct additional water quality measurements.

Students in the involved courses encountered situations that they would not have otherwise encountered. Instructors enjoyed working together, but also faced many difficulties related to managing not just their own course. Deadlines not met in one course had rippling effects, requiring other courses to be flexible with their own deliverable contents and/or due dates. Although the endeavor was challenging for instructor and student alike, with some small adjustments we recommend the model and will try it again.

Introduction

There are many challenges in engineering education, including stimulating student interest, retaining students of diverse abilities and backgrounds, and preparing students to address the realities of the post-academic world and work-space. Many novel approaches have been developed to address these challenges, including problem- and project-based learning (Mills & Treagust, 2003), entrepreneurship (Täks, Tynjälä, & Kukemelk, 2016), and flipped classroom (Bishop & Verleger, 2013). These are all valid approaches that can enhance skills engineers will face in their future careers, however, they do not explicitly address the essential skill of working in conjunction with a variety of different disciplines. In the highly interdisciplinary field of engineering, students will:

- encounter co-workers, subcontractors, and individuals from other fields and backgrounds,
- be responsible for maintaining communication with and deadlines of subcontractors, and
- take the lead on their own learning: researching and becoming well-versed in a variety of topics for various ongoing projects.

Upper level engineering classes tend to have prerequisite courses that preclude students from other fields, ensuring that by the time engineering students are juniors, they will rarely complete projects with or interact in depth with students of other fields, except in general education courses (Richter & Paretti, 2009). However, students graduating in these other fields – technical writers, environmental scientists and educators, policy makers, technicians, and many more – play important parts in the future careers of our engineering students.

Engineers must also be prepared to be life-long learners, it is the rare engineer that repeatedly completes the same project or type of project year after year. However, students don't always "know what they don't know," and may not be prepared with the flexibility that employers want to see (Ramakrishna & Khandelwal, 2014). An individual course, or even a four-year degree, cannot provide exhaustive knowledge to serve for the entirety of a career. A well-designed course, however, can provide skills in flexibility: the chance to break down a given project, to identify potential holes in one's own education, and to address these holes outside of a formal educational structure. A professor, as mentor and as "manager," can guide students through these steps in a way that the student recognizes the need for the skills, and can replicate the steps on their own in the future.

To address all of these issues, we adapted Project Based Learning to include collaboration between different courses. Environmental Design, a course with 25 engineering students enrolled, "hired" other courses of students to conduct specific tasks of interest to our projects. The course also "hired" a directed study student to act as an "intern" for specific research required for several of the projects.

Merrimack College is a liberal arts college in northeastern Massachusetts. In 2016, Merrimack College was named to the US News and World Report lists of Best Regional Colleges North, Best Colleges Engineering Programs, and Best Colleges for Veterans. The college has approximately 3,200 undergraduate students, and 575 graduate students. The 90 academic programs offered include BS in Civil Engineering, BS in Electrical Engineering, BS in Mechanical Engineering, BA in Environmental Studies, and an interdisciplinary program in STEM Education program available to students majoring in Education.

Background

During the summer of 2016, the Andover Conservation Commission brought two different projects to the attention of faculty at Merrimack College, a liberal arts college whose majors include BS in Civil Engineering, BS in Electrical Engineering, BS in Mechanical Engineering, BA in Environmental Studies, and an interdisciplinary program in STEM Education program available to students majoring in Education.

These were ongoing "real" projects based in the community, that the Commission saw as having potential for collaboration with students.

1. Dam Removal Monitoring - The Shawsheen River is a 25 mile-long tributary of the Merrimack River in northeastern Massachusetts. Historically, dams along the Shawsheen were used to help harness power of the river for industrial mills. Removal of the two dams most downstream in the river, the Balmoral Dam and the Stevens Street Dam, has

been funded and was scheduled for Fall 2016. Downstream of these two dams, there are no additional barriers to fish passage before the Atlantic Ocean. The town was interested in pre- and post-monitoring of the removal.

2. Pond Water Quality Monitoring – An invasive species had been identified in Field Pond, a waterbody in the nearby Harold Parker State Forest, less than 5 miles from campus. Proposed methods of removal, including hand pulling and herbicide application, sparked debate. Hand pulling was seen as potentially ineffective, while herbicide application was seen as potentially dangerous to pond ecology and local drinking water wells.

An engineering firm might be engaged for either of these projects. Dam removal and monitoring of the subsequent impact is an important current topic (O'Connor, Duda, & Grant, 2015) (Tullos et al., 2016), as is addressing the impacts of invasive species and herbicide application on ecosystems (Mykleby et al., 2016). But with limited budget, the town was interested in what our students could do. An engineering firm would likely have sought subcontractors to assist with different aspects of the work, especially as smaller firms may not have the needed expertise in-house. Modeling our class as a small engineering firm, we did not have the budget to hire outside contractors, but we could engage students and courses with the skills we needed to make progress on these projects.

Faculty agreed that the proposed projects would be a great learning opportunity for students, and looked for places to incorporate them into curricula. As we are a relatively small school, faculty that had previously worked together collaborated to select appropriate courses. At a larger school, more elaborate proposal processes or even RFQ (Request for Qualifications) procedures might be initiated. However, the additional time requirements should be considered.

Seniors majoring in Civil Engineering at the school, must take at least one advanced elective in the “Environmental and Water Resources” technical area of Civil Engineering. A potential technical elective is offered once a semester. The choice for Fall 2016 was “Environmental Design,” a project-based course focusing on environmental monitoring, Low Impact Design (LID), and integrative approaches to site design.

During the fall semester of 2016 in Environmental Design, each student selected two projects to which they would contribute, one from a list generated by the students, and one from a list generated by the instructor.

First, five student-proposed projects were approved by the class, and students self-selected to work on the projects, and develop a Scope of Work, midpoint and final presentations, and a final report. These projects, including septic design, site planning, stormwater management proposal for campus, and solar farm proposal for campus, are not the focus of this paper.

For their second project, each student decided if they wanted to work on (1) a dam removal monitoring program, or (2) pond water quality study. Students had different reasons for picking one over the others. Dam removal monitoring included some surveying, while water quality work required more sample collection and laboratory work. Both of these projects are real, local projects identified by faculty during the summer of 2016.

Both first and second projects took the entire semester. Students were expected to set and to meet deadlines, and to seek information and resources as needed to complete the projects.

Working with other courses gave the engineering students experience working with others having a variety of expertise, handling real world deadline setbacks outside of their own control, and managing resources and people. More detail on the conservation commission projects follows.

Project: Dam Removal Monitoring

Historically, dams along the river were used to help harness power of the river for industrial mills. Removal of the two dams most downstream in the river has been funded and was scheduled for Fall 2016. Downstream of these two dams, there are no additional barriers to fish passage before the Ocean.

Dams, dam maintenance, and dam removal are important topics. With removal, since the goal is to return the river ecosystem to a more natural state, it is important to study and document the changes taking place.

The dam removal was presented as a project in several courses during the Fall 2016 semester. Students in the Biology Department's Ecology course and Civil Engineering's Environmental Design course planned to collect, analyze, and share the data. For example, students in Environmental Design advised on the best sampling sites for certain parameters, and surveyed the existing conditions at the dams. The Ecology students collected water quality and macroinvertebrate data at the dams. The Biology Department hopes to integrate Directed Study/Research students into the project during subsequent semesters to ensure project continuity and provide additional project support.

In addition, the Environmental Design students contracted a group of students in the Electrical Engineering course Energy Generation, Conservation, and Technology to design and build an in-situ monitoring device to measure temperature, turbidity, and stage/depth/pressure.

Project: Pond Water Quality Monitoring

Less than 5 miles from campus, our local State Forest is a wonderful opportunity for environmental study. The forest has many ponds and miles of trails and logging roads, in addition to private residences and a campground.

The advocacy, or "Friends" group for one of the ponds contacted the Environmental Studies Department at our college with concerns. The state is planning to treat the pond with herbicides to control invasive species. The Friends volunteer group was concerned about the impacts the herbicide might have to pond ecology and to local drinking water wells.

The pond project was presented in several courses during the Fall 2016 semester. Students in the two semester Environmental Studies course, Senior Project, would manage the work, conduct a survey of residents regarding their drinking water wells, and assist the Friends group with hand-pulling of the invasive plants, while Civil Engineering's Environmental Design students would plan and implement a water quality sampling program.

In addition, the Environmental Design students contracted one Environmental Studies student to complete a directed study as a "Policy Intern," to research local regulations and policies, and to write short briefs. The professor for Environmental Design served as official oversight for the directed study.

Assessment

Each group of students submitted one Scope of Work at the beginning of the semester, including proposed deliverables. During the class period that the Scope of Work was due, Google Spreadsheets was used to develop a timeline schedule jointly. Due dates for each of the deliverables, as well as a mid-semester progress presentation and a final project presentation, for each of the projects were determined. The Google Spreadsheet was revisited several times throughout the semester to remind students of their commitments, and to encourage students to consider if they will be able to make deliverables and ask for extensions early if needed material from others had been delayed.

Scope of work, deliverables, and presentations were instructor-graded. The instructor was primarily looking for clarity of communication – if the submission was shared with members of the public or of the Conservation Commission, would it be understood? Was there enough background on the project and on any results or conclusions?

Peer review on presentations, using the rubric found in Table 1, was a part of the students' overall grade. One class period was devoted to peer review on draft deliverables, which was done in a round-robin method, with each group providing each other group feedback on their draft. The instructor did not provide feedback at this point. Although not a part of the grade, this peer review provided valuable information on draft revision for both reviewer and reviewee.

Table 1: Peer Feedback Rubric for Presentations

Category	**Scoring Criteria**	**Total Pts**	**Pts**
Content and Organization (50 points)	*Information:* Presentation contains accurate information; type of presentation is appropriate for the topic and audience.	10	
	Organization: Information is presented in a logical sequence that flows smoothly and is easy for the audience to follow. Material included is relevant to the overall message/purpose.	10	
	Introduction: Introduction is attention-getting, and defines background and objectives of presentation.	10	
	Conclusion: Conclusion accurately summarizes major points and provides audience with a "take-home" message.	10	
	Visuals: Text/figures are readable, clear, and understandable; visual components support the main points of the talk.	10	

Presentation (40 points)	*Eye contact and body language:* Speaker maintains good eye contact with the audience and is appropriately animated (e.g., gestures, moving around, etc.).	10	
	Voice and delivery: Speaker uses a clear, audible voice; speaks at an understandable pace with clear pronunciation; and delivers presentation in a smooth, poised, and controlled manner that is well rehearsed.	10	
	Mastery of the subject: Speaker is able to answer questions professionally and accurately without hesitation; offers a clear communication of information.	10	
	Timing: Length of presentation appropriate; amount of material presented is reasonable for the allotted time.	10	
Coordination (10 points)	Presenters seem to have communicated about the day, know what order they are going in, do not duplicate each other, etc.	10	
Score	**Total Points**	**100**	

Results, Conclusions, and Lessons Learned

Students that completed and submitted draft deliverables were most successful. These students were not necessarily those that were typically "good students." The most successful students seemed to be those willing to ask questions, to submit drafts, and to try, fail, and try again. The opportunity for a low-risk attempt (draft) and feedback from a manager before the final due date to a client is something young engineers just starting out in their careers should expect, but this experience is not familiar in the classroom setting. Many of the traditional "good students" submitted a lab-report-style document at the last minute that would not be suitable for delivery to a client, missing much of the background information required for non-engineers to understand lab results or computer modeling. Not having been exposed to a variety of different styles of writing, students needed the practice that drafts provided. Drafting was heavily encouraged, but not required.

Communication between the classes was the most challenging part of the project – as the courses did not run at the same time, it was difficult to get students to meet *en masse*. While students in Environmental Design attempted to open communication, our letters to the other courses did not tend to be answered promptly, leading to discouragement and further failings in communication. In future semesters, we could mitigate this by appointing a student or group within each class as a liaison to the other classes, or scheduling the courses to run at the same time.

As participating students had not worked previously with people from other departments, they were not certain what to expect or what could be asked of these other courses. For instance, what water quality parameters can be analyzed in the Civil Engineering laboratory, what level of macroinvertebrate sampling is possible in the Ecology course, and what type of information can be gathered through historic documents and maps. This experience provided an important lesson for students who will be future project managers: to ask questions of subcontractors. Now that samples of the kinds of work that can be expected from other classes are available, future such collaborations are likely to run much more smoothly. For example, Beta testing of the water quality sensor the Electrical Engineering students provided has led to significant improvements, such that a similar project will have a better instrument to utilize, which will be available earlier in any future semesters.

All faculty members involved still believe strongly in the method and thoroughly enjoyed the projects. The faculty had worked together previously and knew in advance that they worked well together. With proper course planning time and adjustments, the joint courses can provide even greater benefit to both faculty and students.

- As drafts were identified as a crucial part of student success, drafts should be a required part of deliverables and timeline.
- Method of communication between students should be more formalized, perhaps with courses scheduled at the same time, particular individuals assigned to communicate with specific other groups in other courses, or joint writing of drafts.
- A "menu of services available" or samples of previous work from a course, lab, or department could help students understand more clearly what could be requested from others: for instance, "the Civil Engineering lab is capable of performing the following lab tests on water samples…", "the Ecology lab capabilities include…"
- Target dates for important deliverables could be set by faculty to ease student collaboration. For instance, if the engineers need to see a draft of the ecology field work before moving forward on their own field work, a deadline for the ecology draft or raw data tables could be set by faculty independently of the classes.

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