Educating Changemakers: Cross Disciplinary Collaboration Between a School of Engineering and a School of Peace

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***Abstract*— This Innovative Practice *Work In Progress* Paper reports on a course that challenged interdisciplinary teams of students from a School of Engineering and a School of Peace to design and build drones as platforms for social good. Here, we provide a brief review of other efforts to offer similar interdisciplinary courses. We then report on our pedagogical approach for the course, examining the ways in which student learning was enhanced in a course co-taught by faculty from the School of Engineering and School of Peace. We describe a successful approach for engaging faculty across departments and piloting a pedagogical approach to engineering education that is explicitly sociotechnical in nature. Qualitative and quantitative data suggest the class was successful in meeting the learning objectives. Based on our experience, we offer insights for others interested in trying a similar course at their own institutions.**

***Keywords* — Interdisciplinary, Drones, Peace Studies**

I. Introduction

This paper focuses on progress towards the University of San Diego's multi-year project to revolutionize engineering education with the goal of developing "Changemaking" Engineers [1]–[11]. Funded by an NSF REvolutionizing Engineering and Computer Science Departments (RED) grant, we are developing an innovative engineering culture that is inherently interdisciplinary. This approach engages faculty across campus in order to train graduates capable of improving society by practicing engineering within the contexts of sustainability, humanitarianism, and increased peace and social justice. We are developing a curriculum that infuses these themes directly into engineering courses.

In Fall 2017 we offered "Engineering Peace," our first new course developed to achieve these goals. This project-based course challenged interdisciplinary teams of students from the School of Engineering and the School of Peace to work together to collaboratively build a small drone using open source and affordable technology and design a drone that could be used to have a positive impact on society [12] . Drones were an ideal focus for the class because of the combination of the technical and ethical challenges they present.

II. Project Overview

USD has a strong Liberal Arts tradition and is the only engineering program in the United States to award a dual BS/BA degree to all undergraduates. One challenge we have identified, however, is that students often struggle to connect what they have learned in their liberal arts courses to engineering. One of the explicit goals of the RED project is to engage faculty across campus in order to create a truly interdisciplinary learning experience for our students. The work presented in this paper is the result of collaboration between a faculty member from Engineering (GH) and a faculty member from Peace (ACF). This collaboration made it possible to truly integrate content from both our respective disciplines.

A second overarching goal for the RED project is to provide students with an engineering education that is explicitly sociotechnical in nature. Engineering is traditionally taught as a purely technical discipline, where "society" is treated as if it is separate from engineering. In engineering classrooms, society is often understood narrowly in terms of the final impact that engineered technologies may have, rather than the context in which they are imagined, developed, and implemented. Our goal in "Engineering Peace" was to help engineering students recognize that it is impossible to disentangle technical and social problems. Similarly, we aimed to help Peace students recognize that social problems are surrounded and supported by technology. This focus is in line with the Peace and Justice Studies Association's commitment to the "liberatory use of technology and media research in support of community needs" [13].

III. Teaching Drones

We work in schools which actively encourage cross-pollination between the arts, business and finance, social justice, and engineering. A preliminary analysis of the field suggests that in drone education there appear to be two general approaches: engineering practice or social-science theory. While other courses on drones exist, our interdisciplinary approach is unique.

Several universities across the United States offer classes on the construction, repair, and flight of unmanned aerial vehicles (UAVs) [14]. Kansas State Polytechnic has one of the first and only bachelor's degrees in unmanned aircraft systems (UAS) [15]. The degree combines general education requirements and the coursework for a degree in aircraft piloting with a series of classes on electronics and control

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systems. Similar degrees are on offer in low air-traffic parts of the country, including Oklahoma State University [16] and the University of North Dakota [17]. These courses do not appear to train students to evaluate the sociotechnical challenges of this technology.

Closer in nature to our project is the Center for the Study of the Drone at Bard, where CSD co-founder Arthur Holland Michel ran a 2016 class called "The Drone Revolutions" in Bard's Human Rights Program [18]. This class pioneered a critical approach to the important uses and users, as well as emerging issues around technical innovation, culture, politics, and ethics. Michel's class focuses on key themes that UAV-specific programs appear to leave to the side. However, this course does not appear to give students a hands-on experience with the technology.

In designing this course we worked to bridge the gap between theory and practice. This effort is rooted in a commitment to equipping thoughtful engineers and practically-minded social scientists and humanists.

IV. Project Framework

We designed this course so that Engineering and Peace Studies students would work together to talk about the impact and role of new technology, think and talk about their disciplinary lens, work in teams to build drones, and develop a novel way of using drones for the greater good. Drones were chosen for two reasons: they are of topical interest to the students and they present an ideal combination challenges that require students from different disciplinary backgrounds to wrestle together with unfamiliar questions.

A. Learning Objectives

Our learning objectives focused on students' abilities in relationship to broader contextual issues (process), the technical challenge and its social implications (project), and their role in the process (reflection). These were operationalized in the syllabus as follows:

Process: describe the "lens" of one's disciplinary framework; find, read, and incorporate information from across multiple disciplines; and communicate one's perspective and decision-making process to colleagues from other disciplines.

Project: design and build a drone using open source technology; create a proof of concept for a pro-social use of this technology; plan and implement projects in an interdisciplinary team environment; and collaborate with others to describe this concept in a compelling way.

Reflection: Objectives for reflection included: articulate in verbal and written form the role of interdisciplinary teams; identify the strengths of others when working on team projects; and leverage a sense of empathy to see things from a different perspective.

B. Three Phases of the Course

Programmatically, we spent the first third of the course in a combination of mini-lectures and class or group discussion about disciplinarity, technology, and social change. This allowed students to gain familiarity with the basic assumptions, weaknesses, and strengths of the disciplines represented in the class.

The second third of the course was spent building a small drone. In this stage very little reading was assigned, other than a handful of technical documents needed to support the build process. The objective here was to move students through the build phase so that engineers both experienced some modest technical challenges and were able to assist non-engineers as they took on what were, for them, novel and daunting tasks.

The third and final stage of the course was spent developing a pro-social use for the a drone and preparing a project pitch to deliver at the semester's end. This phase relied on a number of modules designed to help students think about rapid prototyping, develop a minimum viable product, and pitching their ideas to others.

V. Methods of Data Collection

We collected a substantial amount of data throughout the semester to evaluate the impact of our pedagogical intervention on students. We collected qualitative data (including focus group discussions, faculty reflections, ethnographic observations, student work) and quantitative data (pre/post student surveys and student work). All instruments and processes described here were vetted and approved by USD's Institutional Review Board (IRB) to ensure ethics in the research process. Our class was attended by 24 students. 14 of these were engineers (3 women and 11 men) and 10 were non-engineers (8 women and 2 men).

In this work we focus on just a few of the data sets we collected. To evaluate our learning objectives we examine results gleaned from a pre/post survey. We asked students both before and after their class experience a number of questions related to teamwork. We anticipated that students would report confidence upon starting the course, only to later discover that interdisciplinary work is considerably harder than they realized. This is known in the literature as the Dunning-Kruger Effect, as Dunning explains, "poor performers … seem largely unaware of just how deficient their expertise is" [19]. In our post-survey we added several additional questions requiring students to reflect on the class' impact to address this potential bias. We also report on anonymous student evaluation data, collected using Washington IASystem Form K, a validated instrument for measuring student performance [20]. Lastly we discuss some student feedback from a focus group.

VI. Findings

"This class made me think very creatively about problems facing the world today, and how interdisciplinary teams can be useful in solving those problems." – *Anonymous Student*

To students we framed our class as an experiment – a chance to try out a new pedagogical approach to interdisciplinary education. We were unsure how students would react, as courses integrating engineering and issues of peace and justice are often met with student resistance.

Our students, however, proved receptive. In the anonymous end-of-semester quantitative survey, engineering students (n=15) rated "The course as a whole" 4.7 out of 5 (between Excellent and Very Good). The non-engineering students (n=8) also had a positive experience, reporting on the same measure 3.8/5 (between Good and Very Good). Due to the small sample size, the variation between these two groups is not statistically significant (Welch's t-test, t=1.73, p=0.11). We noticed nonetheless, that engineering students seemed to be getting more out of the course than the students from the humanities and social science, possibly because we dedicated more class time to deconstructing engineering than on exploring peace and justice work.

In future semesters we plan to make two changes. First, we will have smaller groups build drones that they can each keep after the class is finished. Second we will discuss non-profit and advocacy work more often and more explicitly. We suspect that variations in student engagement may also have been due to a self-selection bias. The engineering students all sought out the course. In fact, there was more demand than we could accommodate. For the Peace students, a scheduling conflict meant that some of the students most excited in the course could not enroll, while others enrolled because it was the only course that fit their schedule.

Although we have plans to develop the class, we are happy to report that when they were asked in an anonymous survey "Do you find this class to be intellectually challenging?", every student indicated that they did. The quote that begins this section is representative. In open ended responses to the same prompt, most students addressed creativity, interdisciplinary thinking, and the rewards of being forced to consider problems from range of different perspectives

A. Did we meet our learning objectives?

While we are pleased to have offered a class that students enjoy, what students learn is far more important. We broke our learning objectives into three groups: process, project, and reflection. In this Work in Progress Paper we focus on just process and project objectives, the rest we leave for future work.

1) Describe the "lens" of one's disciplinary framework

Students' self-assessment suggest that the course improved their ability to describe their disciplinary frameworks. In our pre/post survey we asked students to respond to the question "How capable do you feel in describing the disciplinary lens/perspective of your degree (major or masters)?" on a a 5 point Likert scale (1 - Very Incapable to 5 - Very Capable). Student responses moved from an average of 4.3 to 4.7 over the course of the semester, a statistically significant increase (paired t-test, $t = 3.94$, $p < 0.001$, 95% conf. interval [0.2,0.7]).

2) Find, read, and incorporate information from across multiple disciplines

Students' assessments of their own abilities to synthesize information indicated that the class had helped them on this front as well. In our pre/post survey we asked students to respond to the question "How comfortable do you feel about your ability to synthesize information from across multiple disciplines?" on a 5 point Likert scale (1 - Very Uncomfortable to 5 - Very Comfortable). Students' responses began the semester at 4.2 and ended at 4.5, again a statistically significant result (paired t-test, $t = 2.35$, $p = 0.03$, 95% conf. interval [0.03,0.57]).

3) Communicate one's perspective and decision-making process to colleagues from other disciplines

At the beginning of the semester, we asked students to respond to the question "How comfortable do you feel about your ability to communicate with colleagues from other disciplines?" on a 5 point Likert scale (1 - Very Uncomfortable to 5 - Very Comfortable). Students were very positive about their own abilities. 15 of 20 students chose "5-Very Comfortable". Interestingly, in the post-class survey, even with all of the practice they received working in interdisciplinary teams, three of those students actually revised their answer down to "4-Somewhat Comfortable." We believe this is likely an example of the Dunning–Kruger Effect, though other explanations are possible. As we suspected that students, having had little practice working on interdisciplinary team projects, would be overconfident in their ability to communicate across disciplinary boundaries, we also asked students on the post survey "What kind of impact has your experience in this course had on the comfort you feel with colleagues from other areas of study?" (1 - Decreased Comfort Significantly to 5- Increased Comfort Significantly). Here, the students reported that the class had a very positive impact. The class average response was 4.3, between "Somewhat Increased Comfort" and "Increased Comfort Significantly." We feel we achieved this learning outcome.

4) Project Learning Objectives

All student teams successfully completed the class project and the associated learning objectives. As they built small prototype drone platforms with their teams, we challenged the engineers to be as hands off as possible and serve as mentors to the Peace students who had considerably less technical experience than they did. Concurrently with the build, teams developed and refined their pro-social drone design. We encouraged them to dream big, and they were not required to match their proposed use case to the diminutive size of the platform we built in class. Likewise, we made the challenge as broad as possible. Viable approaches could envision new ways of managing existing technology or design new attachments for drones, Several teams adopted off-the-shelf technology and others built CAD designs of and 3D printed samples of unique platforms.

B. Did we meet our broader objectives?

Explicit goals of the RED project include 1) engaging faculty across campus in order to create interdisciplinary learning experiences for engineering students, 2) providing students with an engineering education that is explicitly sociotechnical in nature, and 3) developing a revitalized engineering educational culture.

These goals require rethinking engineering itself to include interdisciplinary and sociotechnical projects. However, when we asked students in focus groups what they thought this class was about, students did not think it was about engineering. It did not seem like an engineering class. Nor, for that matter, did they consider it to be a Peace class. In two focus groups in particular, students took time to discuss their perspectives on this topic. One engineer reflected that "The design aspect just wasn't very engineering . . . it was more of like a hard Lego kit to put together." While a colleague disagreed with him, pointing out that there were plenty of engineering positions in which design didn't mean building everything from scratch, the opinion that the course was not precisely engineering because of the limited design and calculation was widely held. It was very "plug and play," requiring that teams follow instruction rather than analyze power or structures or design or modify parts.

We agree with this characterization for the drone build: we provided components for the students and they had to figure out how to put them together. However, beyond this superficial agreement there is an interesting gap between our own assessment (that we focused too much on engineering-related issues) and the perception of engineering students (that this wasn't *real* engineering, i.e., exclusively and explicitly technological).

We spent nearly half the class on the engineering topics of problem definition, ideation, and prototyping. These are critical skills for engineers, but they make up a proportionately small part of standard engineering curricula. As Leydens and Lucena discuss in their work [21], the current emphasis on engineering sciences within most degree programs trains students to think of engineering only as solving narrow technical problems, with answers in the back of a textbook. In future offerings, we will be more explicit about this dichotomy. Hopefully by inviting students to critically reflect on their own education, we can help them broaden their own working definition of what counts as engineering. Our interactions with non-engineering students left us with the sense that they felt sufficiently challenged, and had indeed experienced and engaged engineering on its own terms.

For Peace students, the technical work set the class apart from others they had experienced. In a focus group, one commented that she may have learned about Peace and Justice but reflected that "...this is not how we do it over there." It was not just a matter of working in a shop that set the course apart, however. With engineers, Peace students could experiment with new ways of approaching problems where, as one put it, they could learn about "Pitching an idea that's, like, not just a positive social impact, but, like, practical… doable."

Engineering students found that working with Peace students had benefits. One engineer suggested that: ".. when you talk to an engineer you get one perspective, and because of the way we've been trained that's usually the same. But when we talk to a peace and justice student, I'm like, 'Oh, I never thought about all these other possibilities.'"

All students were quite pleased with the results of the course. Students often conveyed that they felt that working in heterogeneous teams was very useful. In four of the six focus groups, students described working in these teams as a great benefit to their projects. There, students described how early brainstorming, critique, and practical project planning benefitted from heterogeneous team composition.

VII. CONCLUSION

In this article we have provided an overview of an experiment in which we combined students from Engineering and Peace schools into a class that draws across the strengths in both fields.

Our findings have implications for engineering education. We believe that we have piloted a replicable model for engaging students from multiple schools and backgrounds around a particular sociotechnical puzzle, its attendant social and technical challenges, and associated implications. While we tested our model using drone technology, we could just as easily have run the class with students from Engineering and Medicine focused on a medical device or from Engineering and Environmental Science/Studies focused on citizen science. Regardless of topic, future iterations of the course must encourage not only an appreciation for creativity and interdisciplinarity but also a capacity to think in terms of social justice.

Our experience raises other questions, especially in relation to measuring learning. In this work we focused on student's self-reported learning through surveys. In future work we plan to carefully analyze our other data sets, particularly student work, to examine if the students self-reported findings can be corroborated. While we set out with the idea that empathy mattered for student learning and teamwork [1], we found the idea too fuzzy to implement programmatically or test empirically. Finally, this effort has been resource-intensive in terms of both human capital (we spent one year developing this course, have relied on the excellent support of two TAs and one post-doc, and were both in the classroom at all times) and financial capital (we have drawn on summer research funds, material costs for equipment, and so forth). While much of this work has been conducted under the auspices of funding from the National Science Foundation, further refinements will be necessary before this class can operate according to the usual laws of institutional gravity.

In the final analysis, however, we trust this study contributes to important ongoing conversations relating to engineering education as well as solutions-oriented social science. Furthermore, it demonstrates the potential for administrators, individual units, and individual faculty to work together on a joint multi-disciplinary classroom engagement.

Acknowledgments

We would like to thank all of the NSF RED PIs, particularly Chell Roberts and Susan Lord, for their invaluable insights and guidance as we developed this course. We also acknowledge the support and advice of Patricia Márquez.

Author Contributions

GH and ACF planned and taught the course. ER lead data collection efforts, including conducting focus groups, designing surveys, and making ethnographic field notes. All authors wrote and reviewed the final manuscript.

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