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Board 137: WIP: Engaging Mechanical Engineering Students in Projects of Caring: Socially and Environmentally Responsible Projects that Go out into the Public Domain

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WIP: Engaging Mechanical Engineering Students in Projects of Caring: Socially and environmentally responsible projects that go out into the public domain

This paper discusses the piloting of a new undergraduate course, Entrepreneurial Design Realization, in the Engineering School at University of Maryland (UMD) over three semesters. This course is specifically aimed at tackling socially or environmentally responsible projects that include real deliverables that go out into the public domain. The course was originally conceived as a capstone followup where top viable projects with positive impact could be followed up with real opportunities for implementation. The course was developed as a part of a broader effort from the newly formed Environmentally and Socially Responsible Engineering group which aims to develop empowered, socially and environmentally responsible engineering graduates.

The student empowerment and agency arises from opportunities for real do-ing as a part of the undergraduate educational experience, with the ultimate goal of a product or service reaching the public domain. This intrinsically necessitates multidisciplinary approaches that merge engineering with other disciplines. Social entrepreneurial aspects are inherent to all of the projects, with a necessity to demonstrate positive impact in order to pitch for funding or support. Three projects have been tackled: a commercial oyster farming product with a prototype delivered to an affiliate research institution, an engineering outreach kit redesign for K-12 with over 4000 units delivered, and a therapy playground co-developed with the Department of Hearing and Speech Sciences in another college.

Discussed are the lessons learned in the process so far. These include: failures to recruit non-engineering students despite partnerships across campus, challenges in selecting projects that fit within the framework of an academic course structure, student successes and challenges, the existing funding structure and the challenges of developing this aspect within the course, and finally future directions and plans to continue the effort.

<u>Introduction to “Entrepreneurial Design Realization” (EDR)</u>

In Spring of 2020, the authors were awarded a small grant to integrate and track sustainability aspects into the undergraduate engineering curriculum. A major aspect of this effort is to consider the overall student impact across the multi-year experience. In exploring this programmatic impact, a question arose, “Are we preparing graduates who will *seek out* and successfully solve the complex social and environmental issues facing the world today?”

One portion of the sustainability curriculum reform is to identify and introduce specific technical skills that could be directly incorporated into existing coursework (ex. life cycle assessment of a physically produced artifact). This portion of the approach stays well within the traditional boundaries of technical engineering. A second aspect is to introduce awareness of impacts and develop a responsibility toward conscientious engineering. This begins to explore the interdisciplinary interplay necessary when considering systems-level effects and approaches. Responsible engineering competency is further motivated as a way to directly address specific ABET outcomes that have been traditionally difficult to address. But isolated technical tools and awareness of systems thinking falls short of *empowering* graduates to act. Action requires practice, and operationalization of real-world implementations within the undergraduate experience is rare.

Student empowerment and agency comes from opportunities for real do-ing, and so a pilot course aimed at providing opportunities for project-based experiences around enacting socially and environmentally impactful solutions was born. The course aims to produce products or services that actually get out into the public domain. With these projects, the technical aspects are only one part of the solution and there is a distinct need for multidisciplinary considerations for successful implementation. As such, this course aims, in the longer run, to meld skills of students from disciplines beyond engineering, e.g. Business, Journalism, Public Policy, etc. A necessary focus is exposing students to social entrepreneurial challenges that are required to support such efforts. An NSF iCorps model is used for customer identification and interviews, and close communication, and co-development with stakeholders is required in order to include the voices of those affected by proposed solutions in designs. So “Entrepreneurial Design Realization” (EDR), was born.

There have been 3 pilot semesters of EDR so far, each semester co-taught by 2 or 3 faculty members who bring different skills and experiences. The course was developed as a part of a broader effort by these faculty members as a part of the newly formed Environmentally and Socially Responsible Engineering (ESRE) group, whose aim is to develop empowered, socially and environmentally responsible engineering graduates. For the second semester, seed funding was received from VentureWell to establish the course, putting in place the materials, key people, and relationships to allow the course to run sustainably and to be adopted by other universities. Specific objectives are to educate at least 100 students on mixed-major teams and to have at least two projects actually implemented in the real world. The course has since been approved by the department’s Undergraduate Committee for a permanent course number and has recently been approved for a college-wide course designation. An overriding goal of ESRE is to imbue the students with a sense of interest and agency in the arena of sustainability. The EDR course was designed to be a direct conduit for that quality by engaging the students in projects with the goal of public domain integration.

A previous study showed from student focus group statements that “real world” examples overlapped substantially with sociotechnical thinking [1]. Furthermore, researchers report that “real-world” projects increased the students by the fact that other people were affected by the project decisions [2]. More explicitly, four key characteristics of sociotechnical integration identified in the paper included that it “must illuminate the complex interplays between people (communities, etc.) and the technical side of engineering, that it must be explicit, that it must be contextualized, and that it generally relies on open-ended problems” [3]. The limitation of those reports and others [4],[5] is that the results are based on surveys and reflections, rather than on actual project-producing entities.

Brief project descriptions

To date, three pilot semesters of EDR have been completed. Class sizes were kept small and single projects were tackled each semester.

Semester 1: A commercial oyster farming product that significantly reduces time and effort for periodic exposure of oysters to air (desiccation) to help eliminate parasites in longline oyster farming. Oyster farming brings numerous environmental and economic benefits to the region. The capstone design from a prior semester showed promise for implementation, and the EDR team explored physical implementation and testing. The capstone project was utilized as a starting point and the design concept was reviewed, modified, prototyped, tested, and a final production design was proposed. The EDR process included real-world customer discovery and market assessment. Along with the production concept, a business model canvas and pitch deck was developed which was presented to a venture capitalist. The resulting prototype was delivered to an affiliate research institution involved with the original problem specification and ultimate design.

Semester 2: An engineering kit redesign for the established Get Outside And Learn (GOAL) outreach program. The program is a partnership with Women in Engineering (WIE) and produces low-cost, scalable, hands-on STEM kits and curriculum to local middle and high school students (of all genders). The redesign introduced all new physical componentry, curriculum, and challenge event programming. The development included teacher input and extensive stakeholder testing which came in the form of wide-scale hands-on test events involving hundreds of local participants. The redesign moved manufacturing completely on-campus through the university’s fabrication facilities, and component costs dropped to ⅓ of the original cost. Over the next 1.5 years over 4000 of this new version kits were distributed, including at 3 culminating events ranging from 60-650 participants. A more in-depth look at the GOAL program can be found in [6].

Semester 3: An implementation of a redesign for an existing outdoor playground utilized by the Department of Hearing and Speech Sciences (HESP) for preschool therapy programs. Working with HESP therapists, three custom therapy-related play devices were designed, built, and installed. The installation included architectural board inspection and approval. The project also included establishing a collaboration with the Art Department to create murals which have also been installed. A full playground redesign proposal was also drafted as a part of the EDR project which includes safety flooring and additional off-the-shelf equipment. This proposal is currently seeking funding from HESP and Facilities Management. This was a followup of a capstone project specifically intended to feed into EDR for implementation.

<u>Semester 4 (*currently underway*):</u> Two projects: 1) expansion of the GOAL project to a new artifacts and curriculum; and 2) improving a design of a new method for cooling dairy cows in order to reduce resource needs.

<u>Successes, Challenges and Lessons Learned</u>

The following outlines several key lessons learned through the first 3 semester pilots of EDR.

<u>Project selection</u>

With a single semester to produce a real-world output, there is not enough time to begin a design cycle from scratch and then implement. The ME capstone courses at UMD are also a single semester, and in that class there is time to pursue a reasonable theoretical design, but not enough time to fully explore implementation. EDR provides a natural follow-up for viable capstone projects. EDR must more integrally involve stakeholders, physically prototype and test, and pursue full scale implementation. The semester 1 oyster project is an example of starting with a semi-developed theoretical design from the capstone class to explore further implementation. The playground project is another, where the original capstone project was always intended to be passed forward to the EDR group for implementation. The passing of projects from one group to the next does present some challenges. The transfer of information through documentation (typically reports and progress documentation as students between courses have not overlapped) requires considerable effort and time. Additionally the ownership and connection to the project only starts to blossom after the follow-up group feels they have contributed significantly to the work. This transfer can be observed via changes in ownership references ("our design" vs. "the design") that seems to happen midway through the semester.

The short time scale also means that stakeholder partners should be readily available. There is not enough time to explore and make first contact. With the oyster project, a researcher at an affiliate institution was pre-identified with a willingness to collaborate and to provide a location for testing. For the GOAL project, existing teacher partners within the effort made reaching out for feedback and testing viable. This design cycle included a 60-student field trip to campus to test the curriculum. Current efforts on the GOAL project include specific teacher stipends to reward the teacher engagement. The therapy playground also had identified partners in student therapists and faculty program directors who were necessarily integrated into the design and planning process.

Dead-ends and showstoppers are another risk to manage. Hurdles toward implementation cannot be fully vetted, and in fact they should not be because uncovering the implementation pathway is inherently part of the course experience. This leads to potential issues, however. For the oyster project, the initial market potential shrunk considerably once additional background research and stakeholder interviews were conducted. Uncovering market and feasibility constraints is sometimes a part of an entrepreneurial effort. The GOAL project was selected the following semester specifically because it was an established project with established relationships and distribution networks, thus reducing the likelihood of a dead-end implementation. The therapy playground faced challenges from Facilities Management and the Campus's Architectural

Review Board. These entities were on the radar but only became active toward the end of the project. An 11th hour approval was required for installation, but these entities quickly became partners and are now spearheading the full renovation proposal. Possibilities for failure are always eminent and the projects must be ready to navigate these hurdles. Again, this is a valuable part of the project experience.

There is a narrow window for viable projects. They must be impactful enough to be worthwhile and complex enough to require stakeholder engagement, yet implementable and deliverable within the semester. Local projects are somewhat of a Goldilocks balance for this type of effort. They can be complex and multi-faceted, but with accessible stakeholders, manageable barriers, and feasible scaling and logistics. Other student project constraints, such as aligning with the Fall/Spring academic calendar also further limit the pool of potential projects to those with flexible or compatible scheduling.

Funding

Funding is an aspect that was originally intended as a course topic for the project teams to figure out as "entrepreneurship" is in the course title. However, the ability to source necessary in-semester finances, such as what is needed for prototyping and testing, is simply infeasible. For any ground-up projects (such as with the semester 1 oyster project), any pitch for funding will likely occur as a part of a final deliverable once the value proposition can be fully articulated. Pre-existing funding is required within the course itself to design and develop. During semester 1, expenses were charged to the capstone course, and the instruction team sought course funding starting semester 2. Current EDR projects also operate with existing funding (external and internal sources), and this is necessary for the course to function.

Social entrepreneurship and value representation are intended to be part of the course experience, and teams are expected to seek funding. The GOAL semester included a proposal submission. The therapy playground pitched to a construction company on campus, and ultimately produced a proposal plan that is being utilized by HESP and Facilities Management. However, one challenge encountered is that because in-semester support exists, funding propositions are only for future aspects (post-semester), so these activities often feel auxiliary to project progress. Additionally projects that close at the end of a semester do not have any need for post-semester funds. During recruitment, student interest in the course specifically included the entrepreneurship aspects, so formulating specific efforts, or even entire projects, around funding may be a future direction. These efforts would involve course-level fundraising refilling course coffers by demonstrating the impact of the projects as a whole, rather than being tied to specific efforts.

Semester timing and the completion of projects

Despite the intentional selection of projects for semester feasibility, all three projects have experienced semester overrun. In all cases followup work was voluntary. The fact that the students continued with the projects after course completion is indicative of the positive connection to the projects, but there is a definite drop in engagement post-semester. Remaining completion aspects are left to the faculty. With the multitude of physical and logistical unknowns, projects of adequate complexity will often run the risk of overage.

A thought is that instead of focusing on one specific project, future teams may be tasked with taking several prior projects to completion. This may alleviate a constraint with project scaling, opening the door to implementations that may take 0.5, 1.5, or 2.5 semesters. Additional mini-completion projects can stem from capstone. For example, a local non-profit works with several local university capstone courses building custom solutions for local persons with disabilities. The capstone teams often have enough time to create viable designs, but final builds, tuning + adjustments, or redesign elements are often required before delivery. These follow ups are often not full semester projects, or ground up designs suitable for a follow-up capstone project, so these efforts may provide fruitful possibilities for EDR. However, the risk of this approach is a lack of ownership and enthusiasm from the students.

<u>Campus logistics</u>
Unique logistics exist with a new course of this nature. The first issue encountered was student recruitment. First and second semester recruitment was mainly through personal connections with students. These groups were highly engaged in the projects. The third semester recruitment was mainly left to word of mouth. With the small number of prior students and the relative newness of the course, the student rapport with the class wasn't fully developed. General course descriptions also did not provide students with a good sense of the project work. Enrollment was low and dropped further after project selection (student chosen) as some students were uninterested in pursuing the selected project for that semester. Student engagement and ownership of the project was also slower to develop in the third semester. Advertising with the specific projects (or at least project options) has greatly enhanced student recruitment and retention in the current fourth offering which now has two projects running concurrently.

The course was always intended to grow to include out-of-major students. Despite several concerted efforts to leverage partnerships across campus to recruit students from other majors (eg. Business and Public Policy), all students from the first three semesters came from mechanical engineering. The main barrier is that courseloads during the junior and senior years are often already filled with in-major requirements. EDR was always open to all majors but with its listing as an ME course, it provides little potential curricular credit for degrees in other majors.

For the fourth offering currently underway, a new course listing with a college-wide designation helps broaden the appeal by making it easier for non-majors to take the course. The course was also added to a Science Technology Ethics and Policy minor, and a GenEd designation is currently being pursued. The cohort from the current semester now includes electrical engineering and computer science majors. The college-wide course designation certainly generated additional interest from students outside of ME, but there were barriers in getting the course approved for degree credit within home departments in time for registration. These department requirement restrictions can be met, but they must be considered in advance. These connections need to be handled on a case-by-case basis as each unit has different curricular requirements. It should be noted that the course has required a short questionnaire application, and this step may also keep some students at bay.

Other partnerships such as the one with the Art Department with the therapy playground project, have been explored and integrated. However, this was implemented as two separate courses, EDR on the component installation side and a separate art course for the mural. This is the easiest method to begin collaborating, but a cohesive single effort with all students in one class would be more desirable. Since these collaborations occur on a project by project basis, it is unclear how these connections and partnerships will be developed.

Another challenge is the amount of faculty time involved in establishing a new course, particularly for an initially small number of students as it is piloted, compared to the amount of course credit that can be allocated by the department. If the course is co-taught by 3 faculty members, each receives ⅓ of a course credit, or less. This becomes untenable alongside other faculty responsibilities. As the number of projects increases, the demands on faculty time increase commensurately, since each has its own logistics, sponsors, etc. The bespoke nature of the course poses challenges for scaling up. At the same time, larger teams would be ineffective. Multiple teams working on different aspects of the same project could be considered.

Future steps include scaling the course to include more students and a larger number of projects. The current semester is the first in which multiple projects are being explored concurrently. This offering provides an opportunity to examine the instructional personnel requirements and the alignment of the projects (or not) within the semester. When there is more than one project, each team may be on a different timeline. At the same time, there are certain elements of the course that must be addressed, regardless of specific project. For example, if a project is solely about constructing an artifact all the way through manufacturing, there is little time for the entrepreneurial aspects. Yet, they need to be included. Modules are planned to be incorporated that address key aspects of the course.

Important factors for the long-term success of the course are its inclusion in the curriculum and that it is included in the instructors' regular teaching load, rather than treated as an overload. For the first two semesters, the course was taught as an overload. The department has now committed to offer it every semester, giving the instructors credit for teaching it.

Key learnings have included the process for enrolling students from different colleges into a course (navigating the various requirements), how students feel about this course in relation to the ME capstone course, how the course might be scaled up to more than one project, and how we might approach introducing LCA into the curriculum. What helped us with this work was the commitment of the PIs and our network (e.g. with UMCES, WIE, and HESP). What hindered the effort was teaching this course on top of our other commitments.

Conclusions

Detailed conclusions are included within the lessons learned, but some overarching aspects can be summarized.

Careful project selection is necessary for meaningful results. This means selecting projects that are mature enough for implementation, with stakeholders who are readily accessible. Additionally, timing constraints need to be carefully considered. Local projects provide viable opportunities, and exploring multi-semester projects (or multi-project semesters) is an area of future exploration.

Funding sourcing is another challenge, and fitting the social entrepreneurial aspect within a semester has proven to be disjointed and infeasible if trying to acquire funding real-time. A dedicated communications and funding project for the course as a whole is being proposed as a way to incorporate these aspects into the student experience, and as an avenue toward financial sustainability.

EDR is a course about navigating the logistics of implementation, and campus logistical hurdles are one challenge the course must overcome. Ad hoc partnerships and case-by-case implementations have been the approach so far. Sustainment, multi-disciplinary growth, and scaling are major unknowns moving forward.

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