Sustainable Senior Design: MVP Engine

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(Work in Progress)

Introduction

This work in progress paper reports on preliminary results of the Sustainable Senior Design: Minimum Viable Product (MVP) Engine project, which addresses the gap in resources for addressing sustainable entrepreneurship in the engineering curricula. The two main objectives are to 1) incentivize students to pursue sustainable entrepreneurship in their selection and implementation of their senior design projects, and 2) equip faculty with industry connections, resources, and teaching modules to raise awareness of sustainable design and give students actionable steps to follow.

The use of the word sustainable is an intentional three-way play on words: 1) we mean environmentally and socially sustainable (considering things like materials selection and end of life as design requirements), 2) financially sustainable (laying the groundwork to accept monetary donations from sponsors to participate in the program), and 3) programmatically sustainable (revising the existing framework, with support from the administration, to support the program at scale). Since engines convert one form of energy into another, the word engine is used to conceptualize converting one resources (ideas) into another (MVPs). This work in progress paper reports on the initial efforts of the MVP Engine Project. It elaborates on the current framework, the projected improvements, progress to date, and the experiences of the first cohort of student teams to enter the new framework.

Current Framework

At Temple University, we currently have a 3-semester, multidisciplinary Senior Design course sequence: a 1-credit Engineering Seminar (typically taken junior year spring semester), a 2-credit Senior Design 1 (senior fall), and a 3-credit Senior Design 2 (senior spring). Each course runs every semester, and serves about 400 students in a given year between Senior Design 1 & 2 (approximately 100 teams of 4 students). The sequence is multidisciplinary in that every engineer in the college participates: Bioengineers, Civil Engineers, Environmental Engineers, Electrical Engineers, Mechanical Engineers, and Engineers (with multidisciplinary study plans). The 3-semester sequence allows ample time for design and development, and the multidisciplinary nature enables teams to form around specific project requirements and exposes students to working with other types of engineers. If organized well, this rich structural foundation for the program affords the teaching team many opportunities to create impactful learning experiences relative to one or two semester sequences common at other schools [1].

During Engineering Seminar students develop the professional skills required to be successful engineers, divide into teams, propose or align with a project for the next two courses, and (with the help of the teaching team) begin to determine design requirements. There are 5 kinds of projects the students typically have access to: Internal (College of Engineering Faculty), Student Competitions, External Sponsors, Internal (within Temple University but outside the College of Engineering), and Student Proposed. Next, in Senior Design 1 students continue to work in teams, identify their end goal, and work with the teaching team to start on a path that will lead to success. Finally, in Senior Design 2 student teams focus on implementing their plan and

delivering a prototype in time for the end of semester design showcase. However, the engineering design process has not been explicitly taught as part of this sequence, and concepts of sustainability and/or entrepreneurial thinking have not traditionally been included.

Course Improvements - Student Focus

One of our stated objectives for the project is to incentivize students to pursue sustainable entrepreneurship in their selection and implementation of their senior design projects. But before incentivizing them to do this with support from the grant we secured, we had to first introduce the concepts. To do this, new course topics have been included: sustainability (in the environmental/social sense), entrepreneurial mindset, and evidence-based entrepreneurship practices.

To address sustainability, a teaching module was created that demonstrates the use of several sustainability tools (ex. whole system design and life cycle thinking) and reasons to consider them. These were introduced in the context of the engineering design process. Part of the ABET definition [2] of engineering design includes "... examples of possible constraints include … sustainability…". The goal of this approach is to include sustainability as a constraint right next to manufacturability, usability, cost, etc. so students see it as just another thing they need to consider and not an extra requirement of sorts. This module was initially delivered in Engineering Seminar in fall 2018 as a small part of a class session, and will be expanded in the current spring 2019 Engineering Seminar to a full class period.

The entrepreneurial mindset was introduced in the context of the KEEN framework [3]. It is also convenient that the "3 C's" of the entrepreneurial mindset - curiosity, connections, and creating value - fit well within the first phase of the engineering design process. According to the ABET definition, engineering design begins with "identifying opportunities". This step is often overlooked by students as well as faculty, particularly when design projects have already been identified. However, we emphasized that even in a seemingly well-defined project, there are many reasons to ask "why", many design constraints to question, and that where the value is being created has implications in determining design requirements. This module was also initially delivered in Engineering Seminar in fall 2018 as a small part of a class session, but is being expanded in the current spring 2019 Engineering Seminar to span several class periods and include evidence-based entrepreneurship practices. So far, faculty in entrepreneurship were invited to give a guest lecture on opportunity recognition and customer discovery, including a short intro to the business model canvas [4] and the concept of product/market fit. Future sessions will further emphasize customer discovery and exploring product/market fit as critical steps that inform the first phases of the engineering design process.

The three-year plans for the integration of sustainable entrepreneurship into the senior design curriculum are summarized in Table 1.

Table 1: 3-year Sustainable Senior Design: MVP Engine Plans

YEAR 1	Summer 2018	• Team begins recruiting industry sponsors • Team develops sustainability modules and schedules entrepreneurship guest lectures for fall and spring semesters
	Fall 2018	• 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 1 teams apply for E-Team Stage 1 grant
	Spring 2019	• Attend VentureWell OPEN and share progress • 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 1 teams apply for E-Team Stage 2 grant • Cohort 2 teams apply for E-Team Stage 1 grant • E-Teams apply to Temple Be Your Own Boss Bowl
YEAR 2	Summer 2019	• $2,500 support for student E-Teams available • Team continues recruiting industry sponsors and scheduling entrepreneurship guest lectures • Lessons learned retreat
	Fall 2019	• 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 2 teams apply for E-Team Stage 2 grant • Cohort 3 teams apply for E-Team Stage 1 grant
	Spring 2020	• 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 3 teams apply for E-Team Stage 2 grant • Cohort 4 teams apply for E-Team Stage 1 grant • E-Teams apply to Temple Be Your Own Boss Bowl
YEAR 3	Summer 2020	• $2,500 support for student E-Teams available • Team continues recruiting industry sponsors and scheduling entrepreneurship guest lectures • Lessons learned retreat
	Fall 2020	• 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 4 teams apply for E-Team Stage 2 grant • Cohort 5 teams apply for E-Team Stage 1 grant
	Spring 2021	• 2x Entrepreneurship guest lectures • Sustainable Design modules delivered in all 3 senior design courses • $2,300 competitive student project support available • Cohort 5 teams apply for E-Team Stage 2 grant • Cohort 6 teams apply for E-Team Stage 1 grant • E-Teams apply to Temple Be Your Own Boss Bowl

Augmented Design Process Objectives

During Senior Design 1, all student teams focus on ideation, comparing concepts, and evaluating these concepts relative to their established design constraints. Efforts in Senior Design 2 revolve around prototyping, testing, and iterating. The final deliverable is a functional prototype which must demonstrate accomplishment of the design objectives. Entrepreneurial teams add to these deliverables by emphasizing purposeful prototyping which leads to commercialization. The prototypes are demonstrated to potential customers in a "looks like" and/or "works like" MVP - the minimum feature sets needed to deliver on the value propositions for a given customer (from a technical and aesthetic perspective). Successful student groups will be encouraged to pursue opportunities for internal and external funding to continue work on their projects. An example is the three-phase VentureWell E-Team program, which supports early development and ultimately positions the students to become investor-ready. It should be noted that applying for this funding is encouraged but not required for completion of the Senior Design course sequence.

This work is funded by an external grant which enables the faculty team to incentivize student groups to pursue sustainable entrepreneurship. Projects which include sustainability and entrepreneurship in their overall plan are encouraged to seek these incentives in the form of extra resources for prototyping and travel support for customer discovery.

Course Improvements - Faculty & Framework Focus

Although externally sponsored projects have traditionally been one of the 5 project types students have had access to, recruiting and retaining such projects has not been a priority in our program to date. To kickstart this effort, we reached out to the local startup network of entrepreneurs who often need an MVP to support their own development efforts. In this context, we define an MVP as a works-like prototype with a minimum feature set, consistent with Steve Blank's definition [5]. Although this is not a new approach in general, it is new for our students. Prototyping has long been a part of senior design, but the purpose of prototyping has not been well defined. There are many types of prototypes (feasibility, works-like, looks-like, engineering, etc.) and many reasons to prototype (spatial reasoning, customer validation, design studies, testing) but the MVP framework helps link entrepreneurial thinking with engineering function.

To date, we have about 7 startups either committed to sponsoring a student team or in the process of finalizing a project description to do so. We are also pursuing other industry sponsors and community partnerships, many through alumni connections, to add to the bucket of externally sponsored projects the students have access to. With all of these external sponsors, we have communicated that initial sponsorship does not require participation fees, but we will be working towards this as the program matures and sponsors gain confidence that the teaching team can coach the student teams into delivering quality results.

Finally, we are building out our capacity to successfully mentor student proposed projects and teams. Traditionally, these projects have been among the lower-quality, less successful projects that the students have attempted - mostly due to lack of focus and mentoring. However, we are currently working with 3 Senior Design 1 teams within the logistical constraints of the existing course to provide a higher quality experience. The 3 teams meet weekly in the same room with both authors available for mini-lessons on design process, sustainability, and entrepreneurship as

well as targeted group advising. Although this is a work in progress, we are already seeing positive results in both the mindset of the students and the work products they are generating.

Pilot Projects

The pilot program for this work involves three Senior Design teams which have completed Engineering Seminar and are enrolled in Senior Design 1 at the time of this writing. Each team represents a unique starting point and will illustrate three different approaches to achieving the goals mentioned earlier.

The first team, nicknamed ESR, began the experience with a specific device in mind. Their idea involved an emergency seat belt release mechanism to free passengers trapped in a submerged vehicle due to an accident. They began by interviewing representatives from industries that may have experienced aquatic accidents such as helicopter pilots, owners of passenger vehicles, construction workers, and first-responders. The results of these interviews indicated that the team was a "solution looking for a problem." Their target customers in every segment did not identify a strong interest in the product or the need that it sought to fulfill. Through these interviews, they arrived at a new customer segment: arthritic, weak, or similarly challenged people that have trouble with the daily use of their seat belts. This pivot enabled the team to identify an interested customer segment and begin development of an assistive solution to meet their needs.

The second team began with a specific customer need in mind: mushroom farmers who harvest their crops by hand. The pains of this customer segment include waste due to picking the mushrooms too early or too late and a dwindling labor force due to restrictive immigration policies. The team is led by a person who was raised in a mushroom farming community and is deeply familiar with the issue. They entered the project with many preconceived ideas about how to solve the problem and struggle with "expert blindness." Their focus is on translating their ideas into actual design requirements that they can verify with their target customer segment before proceeding with design.

Finally, the "dust collector" team began this experience with no ideas and no target customer segment, but a desire to be on an entrepreneurially-focused team. They spent time early on exploring various segments and settled on two that interested them: senior citizens and home renovation contractors. After conducting several rounds of interviews they identified a strong need in the construction industry for a vacuum that can effectively deal with fine dust particles during construction and renovation. New regulations are increasing the pressure that contractors face to mitigate the effects of dust on workers and residents of renovation projects. This team is in the process of exploring solution technologies and setting quantifiable design requirements. Their biggest lesson to date is to involve their customer in the process through multiple rounds of interviews.

Outcomes & Early Progress

Each of the three pilot teams is in their second semester of the Senior Design sequence. To date they have identified the design requirements for their MVPs based on numerous interactions with their target customers. The seatbelt team aims to reduce the forces and range of motion associated with fastening a seatbelt using an aftermarket device which can adapt to and passenger vehicle's restraint system. The mushroom harvesting team is developing a food-grade

robot arm system which utilizes optical detection and machine learning to select mushrooms for harvesting, picks the mushrooms, cleans their roots, and places them in a collection bin without bruising. Lastly, the dust collector team set specific goals for the particle concentrations in air which will be achieved through a multistage portable vacuum system.

The three outcomes we are tracking are: 1) number of students exposed to sustainability concepts, 2) number of VentureWell Student E-Teams (both applied and accepted), and 3) number of students and/or teams submitting to our University's pitch competition. In the Fall 2018 semester, we gave guest lectures in both the Seminar and Senior Design 1 classes, so ~350 students were exposed to sustainability concepts. So far in the Spring 2019 semester, the Engineering Seminar class of 274 students received a modified version of this lecture, so we're up to ~620 students. The three teams above (and potentially others) are preparing to apply to the next VentureWell E-Teams deadline of May 8, 2019. Finally, there has been an uptick in applications from engineering students in our university's pitch competitions, and we are working closely with our colleagues that run those programs to track the progress of these teams.

Next Steps

We will continue to scale the creation of teaching modules, recruitment of external sponsors, and mentorship of student-proposed teams for the duration of the project. In addition to merely tracking exposure to sustainability concepts through teaching modules, we are working on adjusting the learning objectives for the class to explicitly include these concepts and create corresponding means of assessment. We plan to submit a full paper in a year with more details on our progress towards these outcomes.

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