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Fostering Entrepreneurship Through Targeted Adversity: A Senior Design Case Study

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Abstract

Engineering education has the potential for significant social and economic impacts through entrepreneurship. In this regard, most engineering curriculum falls short in three critical areas, thereby limiting its effectiveness. Firstly, students are often indoctrinated into the "specific approach to solve a problem" mindset when in fact real world technical problems are dynamic, nuanced and most importantly, can be solved many ways depending on the resources and expertise at hand. Secondly, aversion to risk is a side effect of the university grading system as thinking outside the textbook, trying new things and failing are typically not rewarded. These limitations exist in large part due to the difficulty of grading or ranking intellectual work outside of established boundaries. Finally, and most importantly, social intelligence is taught less, both implicitly and explicitly, than technical knowledge, especially in STEM fields. The ability to communicate, arbitrate and resolve tense social situation with empathy is as or more important than book knowledge when it comes to success in both entrepreneurship and industry as a whole. This paper outlines one methodology for entrepreneurial focused courses in engineering with the end goal of boosting students success in an existing company or with their own startup. This is accomplished using a highly social course format with gradually increasing assignment ambiguity, adversity and complexity while having fall backs and redundancy for predictable progression of the class as a whole. In our case study course, students design, assemble and test from-scratch IoT electronic products which are then entered into a university wide startup competition. A survey is created to determine students confidence in various areas related to success post graduation, either working in industry or starting their own venture. On average, 57% of students responded that the new format has advantages over other courses they are currently taking, with 28% reporting no difference and 15% indicating the opposite.

Introduction

Engineering professions face challenges requiring competence in uncertainty, problem solving creativity and the ability to balance conflicting demands with high level perspectives in mind. Rather than train students to 'know' things, they should be trained to 'understand' things[1]. To be effective in their industry, this requires not just a solid technical foundation but also skill in human relations, enabling them to function, both autonomously and simultaneously as part of a large team. Unfortunately, the standard method of teaching is centered around traditional lecture style formats with minimal to no social interaction, creative thinking or open ended challenges.

Research into instructional strategy show that when courses are designed around actively engaging students in the material, levels of understanding, retention and transfer knowledge are increased compared to lecture centric formats [2]. The popular flipped learning format, which advocates at home learning via online media with in class group exercises, has demonstrated benefits such as increased learning gain, flexibility, increased interaction, improved professional skills, and increased student engagement [3]. Despite these findings, mainstream engineering educators are hesitant to try new formats, partly as resistance to change but mostly due to the ambiguity and uncertainty of how to create an effective course with limited resources and personnel [1 4]. There is also concern about scalability, as more dynamic and interactive assignments often require significantly more setup and faculty workload as enrollment increases [5].

Another step further, beyond simply being part of an existing organization or company, is the need for fostering new ventures through creative design combined with understanding market needs and opportunities. It is well established that economic growth of a country lays heavily on the entrepreneurial ability of its people [6,7,8]. Standard educational practices are designed to be scalable, yes, however at the risk of not exposing students to the ambiguity and risk necessary for an entrepreneur to be successful. It is not enough that engineering students can solve problems they have seen before, they must know how to approach new problems that are to become relevant as societal and technological landscapes change over time. The majority of entrepreneurship education revolves around case studies [9] or guided role play [10]. While both important as part of a learning experience, it is secondary to preparing students socially and emotionally. In this paper we start by reviewing previous work, explaining the new course structure followed by presenting survey results and concluding remarks.

Related Work

Great work has been done on increasing the efficacy of teaching methods, specifically with focus on generating more self sufficient, self engaged students. These are traits which are important for students being successful in the job market or in starting their own enterprise. Lord et al. split two large biology classes into groups, one following the traditional teacher-centered format, the other a student-centered constructivist format. The latter format, which aims to coherently embed new information into a students existing map of knowledge, was shown to improve average exam scores by more than 5% when compared to the former [2]. The flipped method, also known as inverted learning, has been gaining popularity in STEM (science, technology, engineering, math) fields with 29% of higher education faculty reported in progress of implementing it [11]. Flipped learning aims to shift direct instruction from the classroom to home, thereby opening class time to dynamic, interactive learning experiences [12]. Karabulut-Ilgu et al. flipped a transportation engineering course and used questionnaires and class video recordings to show students had a positive view toward the change. The more broadly defined, blended learning method combines face-to-face interaction with online tools in a general sense. In order to better teach entrepreneurial skills to students, Sidhu et al. incorporated a mock startup company course which takes students from concept to low tech demo. By shifting focus away from the time consuming technical details, more teamwork, self-reflection, and inductive learning could be taught. In a very different approach Weaver et al. used a series of case studies of existing startups to give students a more holistic view of what it takes to bring an innovation to market. These case studies were

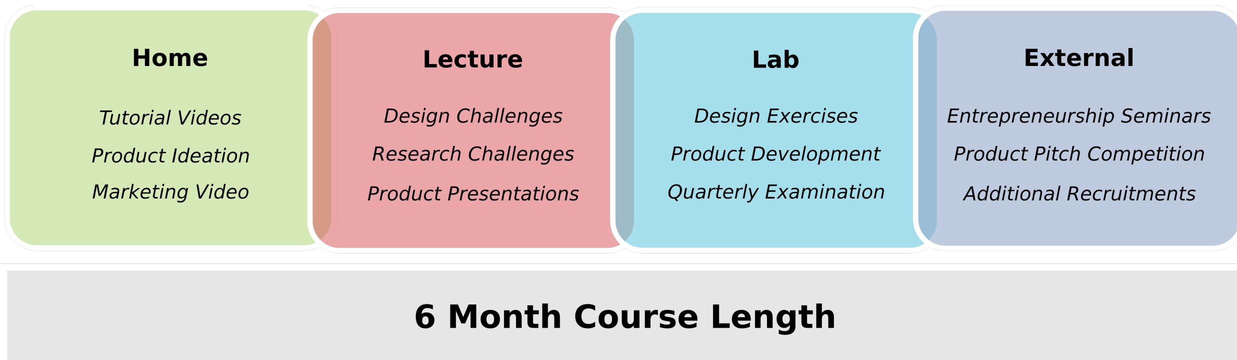

Figure 1: Course overview

given over many courses as a supplement to the existing curriculum. Somewhat in between the two former methods, Jarrar et al. formulated a case studies based course which also includes an elevator pitch and product formulation but no prototyping.

Course Structure

The method presented here is devised as a sharp departure from traditional curricula used by STEM courses. Instead of making small incremental changes year by year, a complete redesign is performed and the aggregate result collected. Most changes are based on prior research in education, and hence, have independent support. The overarching motifs used when developing the curriculum are as follows:

1. *Exploration*: Encourage risk and failure as this is part of working on real world problems. Make a safe environment for testing new ideas and solutions to problems.
2. *Socialization*: Give students opportunities to engage socially, with their peers, future users of their product, professors in the field, and industry professionals.
3. *Independence*: Increase the difficulty and level of independence students / teams are expected to handle. By the end teams should be fairly self sufficient.

An embedded systems senior design course at the University of California, Davis is selected for the entrepreneurship focused redesign. The goal is to guide students through the creation of a real internet of things (IoT) product. This includes designing a printed circuit board, assembling and testing by hand, modeling and 3D printing the enclosure and programming the firmware.

Course time is divided into four periods, at-home, in-lecture, in-lab and external to the course. At home, students are given links to tutorial videos designed specifically for the course. These are intended to replace traditional lecture material. They also brainstorm product ideas to pursue as a class project and when their startup prototype is completed, a marketing video is created to showcase their company. Lecture periods are designed to be interactive and students work together to complete various group technical challenges. This time is also used for presenting progress on their startup project. Lab time consists, at first of more controlled design exercises, and later full product development. A final examination is administered in lab time at the mid and endpoint of the course. Finally, a set of entrepreneurship seminars, partnerships and resources are provided externally to the course itself. In the following sections, our three themes of exploration, socialization, and independence are used to expand on how exactly course time and activities are designed around fostering skills that help students perform in industry or as an entrepreneur.

Exploration

For students to feel comfortable making mistakes and trusting their creative capacities they need to be allowed to fail and learn from those failures. Often times lab exercises and homeworks imply specific solutions and punish for not following the expected sequence. Other times problems are defined in a closed, highly constrained form which does not lend much to exploration.

To balance the need for creative risk without complicating grading, in-lecture challenges and in-lab design exercises are made to have clear and simple visual indicators of success. Examples of visual indicators are light, sound, console text, waveforms and debugger output. This not only allows for consistent grading but also gives students the creative freedom to approach problem any way they would like.

In addition, in-lab design exercises are constructed to have cross-use between teams. Cross-use of designs is implemented as a marketplace by which teams can use past implementations from other teams in current lab exercises. Given each lab builds and connects to the previous, students can worry less about taking a risk and having it fail. In addition, it also requires that teams understand how to deconstruct others implementation for incorporation.

Socialization

Creating a sense of unity within the class is important for the free communication of ideas, leading students to ask each other for help while reserving teaching staff time for more pressing issues. By the end of the course, each student will have been part of 25+ randomly assigned teams for a variety of short and long term tasks. The types of tasks that use randomized teams are in-lecture challenges and presentations, in-lab exercises, and at-home product ideation. The only assignments which do not use randomized teams are final examinations and final project teams. Final project teams are determined by student interest in a certain startup project idea.

Since lecture material is delivered in the form of online video tutorials, lecture time can be spent on two types of in-lecture challenges. A research challenge involves teams searching for answers to a mix of open and close ended technical questions. One individual in the group is then chosen at random to represent the entire group. This promotes both learning and teaching as everyone in the group has a vested interest in the entire team knowing the answers. A design challenge involves the team programming a solution to a hypothetical problem. The first teams to finish are given the highest score after which they separate and help other teams complete before time runs out. This gives students the opportunity to learn socially and take on both roles as mentor and mentee. In-lab design exercises are week long and more in depth compared to the one hour in-lecture design challenges. Students are encouraged to exchange ideas and brainstorm across teams, however work submitted must be original.

Once the class has performed product ideation and voted on final projects ideas, teams are allowed to expand outside of the course boundaries. This includes partnering with a computer science department senior design team to co-found the company, taking on partnerships with existing companies, or working in coordination with a researcher at the university. Students may also recruit individuals via startup mixers hosted by the university or incorporate acquaintances that share a passion for the product idea.

Independence

Until now most students have not experienced the level of independence and responsibility that will be required of them. To ease the process, the intensity is increased over the duration of the class. At stage one, students complete the at-home video tutorials. Each video is kept brief and focused so it can be easily referenced in the future. At stage two, research and design in-lecture challenges are incorporated. At stage 3, they are given in-lab design exercises which describe a final result and students are expected to use the resources at hand (video tutorials and internet) to complete. At stage 4, a three part individually taken midterms is administered. Unlike a traditional midterm there are very little instructions, students are given a high level design objective and it is their responsibility to use the resources at hand to solve it. At stage 5, they are officially assigned to a startup project and begin to engage with future customers (which they seek out), and modify their product design accordingly. They also start to build and pitch their design to judges at a startup competition. All teams are offered the opportunity to continue work on their product after completion of the course for university credit. The expectation is that at this point teams are fairly self sufficient.

Boost / Penalty

A new concept is introduced called the boost. Unlike extra credit, boosts, if not achieved, can lower a students overall final grade. Boosts are a measure of students performance above and beyond and creates an competitive environment. There are two situations in which boosts are used. First is to reward for finishing design exercises one or two days early for a 20% or 40% boost respectively (and an equal penalty for one and two days late). This pushes students to start early as well as helps trickle down design tips to struggling groups. On average, 26% and 28% of students submitted their assignment one and two days early with the incentive. Boosts are also made available for taking business seminars, recruiting additional members to their team and making progress through a university wide startup competition. Of the 7 teams, 5 received boosts for participating in a university startup competition with one team placing.

Course Results

As an experiment, the boost was removed from in-lab design exercises during the second half of the course. Without the boost it was observed that students would not start the lab, often times, until the day before. As a result more students underestimates how long the lab would take, resulting in late submissions (26% late vs 14% with boosts). When the boost was present, it was noticed that some students would start as early as 7 days before the due date, right after the previous lab was submitted. There were also large degrees of self organization in that students, without the instruction of teaching staff, created and organized out of class meet ups to work. A

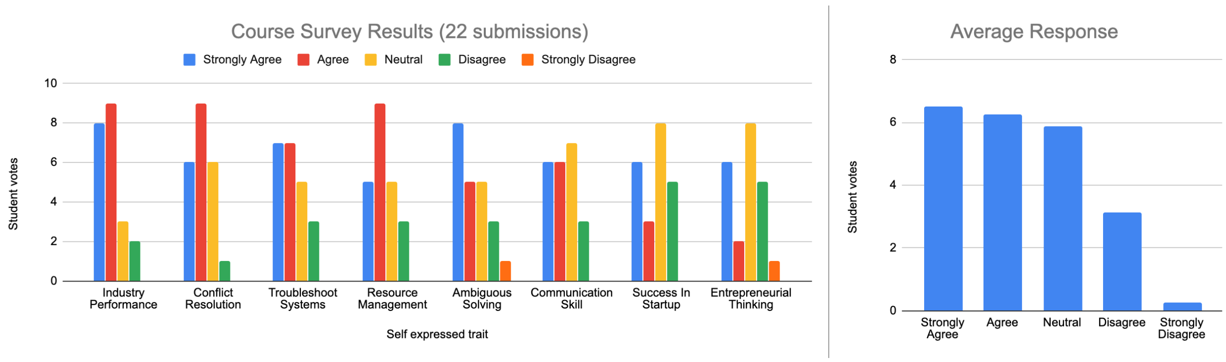

Figure 2: Survey results

facebook chat was put together with (according to the students) everyone in the course so multiple teams could meet and work together, as well as for exchanging ideas about design exercises.

In order to understand students sentiments towards the unique course structure, a survey is administered. Eight questions are selected to provide feedback on a number of desirable learning attributes. The questions are listed below and prefaced with "Compared to other courses taken this quarter, senior design helped you ...". Students rate each item from strongly agree to strongly disagree with other courses they are currently taking as baseline.

1. learn skills relevant to your future job in industry
2. learn conflict resolution in your team and otherwise
3. learn to troubleshooting complex systems
4. learn resources management (time, people, money)
5. tackle ambiguous problems more confidently
6. improve your general communication skills
7. have skills that will help you succeed in a startup
8. become more confident with entrepreneurial thinking

The response to all questions are net positive with average response showing strong agreement that students perceived the new course format as having benefits. The plots are sorted from highest (left) to lowest (right) net response. Overall, 58% of students reported strong agree or agree over all 8 questions with 15% reporting strong disagree or disagree, indicating that the majority of the class found the new curriculum advantageous compared to other courses currently taken. 77% (vs 9%) of students reported that their experience with senior design provided skills more relevant to their future jobs when compared to other courses currently taken and 68% (vs 5%) of students thought the course gave them better conflict resolution skills. 64% (vs 14%) found they were better at troubleshooting complex systems and managing resources, 59% (vs 18%) felt they could tackle ambiguous problems more confidently, 55% (vs 14%) reported better communication skills, 41% (vs 23%) felt more likely to succeed in a startup, and 36% (vs 27%) thought they had better entrepreneurial thinking.

Development and Execution

The course is executed with one professor and three assistants for 28 students over 6 months. The design of the course took significantly more time than the execution. A total of 13 video tutorials are recorded, each covering specific technical aspects of the course. Videos are designed to be concise, stream of consciousness, with both overt and sub communicated ideas. For example, when teaching how to design a circuit board the video will go through the motions, click by click without discontinuities, sometimes being unsure and visiting google or explicitly referencing commonly used documentation. Lack of discontinuities means the student can be assured that everything will work if followed exactly, putting them at ease. By acting less like an oracle and more like a student, the videos convey technical information as much as they do how to use the internet. Each video is kept about 10 min so it is easy to reference. Between brainstorming, scripting, re-recording and video editing, the commitment was about 6hrs/video. Once the course is in progress, however, time investment significantly reduces compared to the average senior design course. Strong community bond results in questions being directed to peers, this along with lack of formal "chalk and talk" lecture shifts the image of the teacher away from information source and towards mentor. This allows staff to spend more time conveying nuanced technical points and wisdom on inter-personal skills, and less time repeating basic information. The overall effort put into the course, to our estimate, is not more than any other with the exception that the effort is front loaded. The re-use of the tutorial videos lend to a mid to long term benefits depending how quickly underlying technical software becomes obsolete.

Conclusion

Given this is the first attempt at the new course format the results are compelling at minimum. There were many difficulties during the execution of the course ranging from mistakes in recorded video tutorials, circuit board fabrication delays and teaching staff mistakes with component selection. The expectation is future revisions of the course will be more streamline. Changes in education are desperately needed for the future of society. Here a novel curriculum was proposed and shown to have a positive impact on a range of skill sets that are often neglected in a traditional course format.

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