Entrepreneurial Engineering Training in a Freshman Design Course

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Abstract
University of Detroit Mercy requires three co-op placements as part of the engineering curricula. Recent changes have it such that students are now required to have their first placement at the end of freshman year. This, in turn, requires that they possess higher levels of marketable skills in order to secure placement. This paper describes the second of a two-course freshman engineering sequence that enables the students to build a significant portfolio of projects and skills. The course is centered on a recent technology (Sphero robotic ball in Winter 2014) where the students are tasked with analyzing the system and associated intellectual property. They are then tasked with proposing ventures in other markets using said technology and to do so in business terms. The pilot offering of the course has led to three credible, student owned initiatives to use the Sphero technology to create an autonomous sterilizing robot and a smart cane for the visually disabled.

Introduction

The pedagogical goals, academic motivation and models of freshman engineering design experiences are many. A survey paper[1] lists eight models: reverse engineering; creating something useful from a preset number of objects; full scale project; small scale projects; case studies; competitions; non-profit project; and, redesign of a local project. The reader is invited to read Reference 1 for details.

The last decade has witnessed a newfound emphasis on entrepreneurial engineering education, exemplified by efforts to develop engineering graduates with an entrepreneurial mindset[2]. Two of the preeminent organizations advocating for changing the education paradigm are the Kern Entrepreneurial Engineering Network[3] (KEEN) and the National Center for Engineering Pathways to Innovation[4] (Epicenter). This paradigm is intended to have engineers who brings an entrepreneurial attitude to the everyday practice of engineering and in the process, creating economic value to their employers and to society.

The course "Fundamentals of Engineering Design" was developed at the University of Detroit Mercy (UDM) in response to the need for introducing the entrepreneurial mindset to engineering students at a very early stage. The course is the second in a two-course freshman design sequence required of all undergraduate students in mechanical engineering, electrical engineering and robotic/mechatronic systems engineering. The course was developed and piloted in Winter 2014 (January-April). This paper describes the course, project and results as well as assessment and evaluation.

Course Objectives

The course is intended to train the engineering student to communicate with customers/end-users and management. Communicating with the former is done almost exclusively in terms of functions and value proposition. Communicating with management involves an ability to present ideas in economic terms as that plays a major role in decision making and engineers who are able to contribute to decision making have a distinct advantage in the professional world. The course is also intended to force the engineering student to think in terms of systems and not focus solely on particular technology details.

Course Outcomes

The course outcomes are given in the standard assessable format and related to the ABET outcomes.

Upon successful completion of this course, students should be able to:

1. communicate engineering designs and solutions in economic terms (ABET outcome **h**);
2. define problems, opportunities, and solutions in terms of value creation (ABET outcomes **c, e** and **h**);
3. carry out and apply the design process beginning from a recognized need and ending in a system-level design for a proof-of-concept prototype. (ABET outcomes **a, c, e, f, g, h, i and k**);
4. function effectively on multi-disciplinary and diverse teams (ABET outcome **d**);
5. use solid modeling tools to create designs, including complex assemblies (ABET outcome **k**); and,
6. use rapid prototyping tools and techniques to create physical prototypes (program outcome **k**).

Of the six outcomes, the first three can be considered somewhat distinct to this course with the last three outcomes considered somewhat generic.

Topics covered

The topics covered in the course are:

1. Opportunity recognition and value proposition. The main purpose of this exercise to have the students think beyond the technology and conceive of market opportunities for that technology. Another purpose is to drive the student to communicate in terms of value with a scant mention of the details of the technology.

2. Understanding intellectual property. Intellectual property is a critical component of engineering, particularly in the high tech industry. One cannot determine whether a market opportunity exist without knowing the intellectual property landscape.
3. Ideation and concept generation. Having determined and defined a market opportunity in terms of functions and value to the end-user, the students are taught to use ideation tools to define a concept.
4. Customer discovery. The students are then taught that the viability of any concept can only be validated by talking directly to customers. Students are required to talk to a number of people including end-users as well as people who are making purchasing decisions in case these are different from end-users.
5. Pro-forma financials. In most cases, adoption decisions are made based on economic factors such as pricing (customer viewpoint) and profit potential (company viewpoint). Thus, it is imperative that students learn to use basic profit and loss P&L statements to relate the pricing and number of sales to company balance sheet.
6. Manufacturing considerations in product design. The students are taught that the customer may or may not choose to buy a product but they will only have that choice if the product can be made. Thus, students are introduced to manufacturing considerations and work with the instructor to validate the manufacturing and pricing assumptions.
7. Technology roadmapping. The fact that this is a freshman level class with a one semester duration necessitates that the process be truncated. The students are required to make a technology roadmap, describing the technologies that need to be developed in order for the product to become a reality. They are, however, not required or encouraged to embark on the technology development during the course. Instead, the students are asked to make an initial plan to develop these technologies in subsequent years and in various courses.
8. Understanding return on investment (ROI). As part of the final presentation, the student are required to quantify the return on investment which require that they understand in basic terms the time value of money.
9. Venture creation within and outside of corporations. The students are introduced to the differences in venture creation as a start-up company (entrepreneurship) or as a unit within an existing corporate environment (intrapreneurship). The students are required, as part of the final presentation, to indicate whether they are presenting an entrepreneurial or an intrapreneurial venture.

Choice of Project

The projects chosen for this class are high technology, requiring both mechanical and electrical development. They also need to be applicable to consumers as this will make customer discovery easier. There are cases, such as military applications, where it is nearly impossible for students to do a proper customer discovery.

The students are introduced to their project in the following manner: "You work for company X, maker of product Y. The Company owns the intellectual property and underlying technological knowhow for said product. Your assignment is to explore other possible commercial applications of the technology. Once you have identified a market opportunity and validated it, you are to propose a venture, either from within the company (intrapreneurship) or as a stand-alone venture (entrepreneurship) to bring the resulting product or service to market."

Winter 2014 project theme

The project for the pilot offering of the course in winter 2014 centered on a robotic, remotely controlled and hermetically sealed spherical object that goes by the trade name Sphero® and shown in Figure 1.

Figure 1 – Sphero 2.0 Robotic Ball

The students were given the following scenario: "You work for the maker of Sphero and while the Sphero is a fairly successful high-end toy. You are part of a team that is charged with expanding the market for the underlying patented technology."

Sample project 1: The EyeSphere, a smart cane for the visually impaired.

Project abstract: The mobility aids for the visually impaired range from the common "white cane" to the very sophisticated guide dogs. The white cane is light and easy to use, but offers very limited benefits in terms of navigation. The guide dog is fairly intelligent and can help the visually impaired navigate difficult surroundings, but requires extensive training and care. The proposed intelligent cane builds on the concept of the traditional cane but includes the latest technology advances in mobility, sensors and algorithms. The proposed cane includes a robotic ball at the end contacting the ground. That ball guides the user by providing tactile cues to turn left or right, speed up or slow down. The robotic ball gets its command wirelessly from a smart phone app, which executes navigation algorithms. The smart phone app interfaces with a GPS system as well as a suite of sensors that identifies obstacles. Figure 2 shows the EyeSphere.

Figure 2 – The EyeSphere prototype (left) and the associated technology elements (right)

Total market size: A 2011 study showed that 21.2 million American adults have “trouble seeing” and 39 million persons worldwide are completely blind.

Customer archetype: The customer archetype is a visually disadvantaged individual who: has a strong sense of independence; shops based on long-term value; is savvy about accessing online distribution channels; and, who can afford a $2000 assistive technology device.

Potential alliances: The venture as planned requires a licensing agreement with the makers of the Sphero robotic ball, the endorsement of University of Detroit Mercy, an alliance with the National Federation of the Blind and the American Foundation for the Blind as well as the Guide Dogs of America. The alliance with the Guide Dogs of America is based on their ability to offer the EyeSphere as an alternative option in case dog is not compatible with human.

Technology Roadmap: The team determined the milestones needed to push this technology up the development curve. These milestones are:

- Determine appropriate sensors given cost, weight and packaging constraints.
- Develop navigation algorithm and prototype on a regular computer.
- Build a fully operational mechanical prototype.
- Conduct initial field testing and refine algorithms and software.
- Map software onto a smartphone app.
- Integrate sensors into physical device and design for packaging.

Sample project 2: The Sterilight, a disinfecting robot using UV light

Project abstract: Infections are responsible for countless deaths and exert a significant burden, both economically and in terms of pain and suffering. The traditional methods of disinfecting surfaces using chemicals is generally effective but requires significant manual labor. One major failure mode involves operator error, where either a surface is missed, either by accident or because a surface proves hard to reach. Corners, grooves and areas beyond arm's reach tend to be missed during disinfection. The proposed system is an autonomous robotic system controlled and driven by Sphero to sterilize and disinfect floors, ventilation systems, and other surfaces to prevent illness and infections using ultraviolet light. It employs a unique drive system and algorithm that allows it to navigate autonomously while disinfecting surfaces. Figure 3 shows the Sterilight.

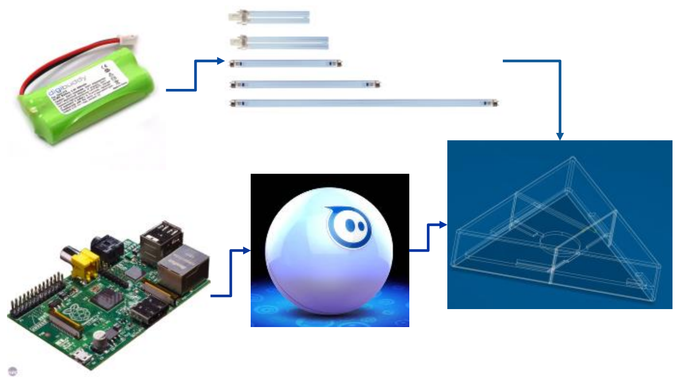

Figure 3 – The technology elements of the Sterilight

Total market size: In 2013, $1.1 billion was spent on UV disinfection, this is expected to nearly double by 2018. 75% of the $1.1 billion was spent of surfaces and water disinfection.

Customer archetype: The Sterilight would appeal to hospitals for sanitation of floors and ventilation ducts.

Potential alliances: The venture as planned requires a licensing agreement with the makers of the Sphero robotic ball and the endorsement of University of Detroit Mercy. The lamps, lamp ballasts and batteries to power the Sterilight are to be sourced from Panasonic.

Technology Roadmap: The team determined the milestones needed to push this technology up the development curve. These milestones are:

- Develop and test algorithms for navigating the Sphero around arbitrarily shaped spaces.
- Test the efficacy of the ultraviolet light system with regards to pass speed, number of passes, intensity of light, power usage, etc…
- Develop the mechanical structure and test the Sterilight’s ability to negotiate terrain, especially obstacles and steps.
- Finalize packaging and make working prototypes for field testing.

Evaluation

Students were asked in an anonymous survey to indicate their level of agreement with the following statements:

1. Because of this class, I am better able to vet a product idea through feedback from customers, superiors, peers and external investors.
2. The class helped me build my confidence and ability to present my product ideas and design solutions in economic terms.
3. After taking this class, I am better able to integrate customer and investor feedback into improving my product idea.

The students were given a choice of selecting "strongly agree," "agree," "neutral," "disagree," and "strongly disagree."

The survey was sent to thirty (30) students who took part in the pilot offering of the course in Winter 2014 and twelve (12) responded by filling out the survey. In response to the statement "because of this class, I am better able to vet a product idea through feedback from customers, superiors, peers and external investors," two (2) students responded with "strongly agree", nine (9) responded with "agree" and one (1) responded with a "neutral" response.

In response to the second statement "the class helped me build my confidence and ability to present my product ideas and design solutions in economic terms," six (6) students responded with "strongly agree", three (3) students responded with "agree" and three (3) gave the "neutral" choice. The third statement "after taking this class, I am better able to integrate customer and investor feedback into improving my product idea," engendered two (2) responses of "strongly agree," eight (8) responses of "agree" and two (2) "neutral" responses. The results are summarized in Figure 4.

The students were also asked to give written comments in response to the following prompt: "Can you identify areas of possible improvement in this course? Briefly explain." Many respondents indicated that they would like to see more structure but that's a reflection on the teaching style of the instructor and not the course content. The more relevant discussion centered on the balance between business content and engineering content. One student responded with "more projects and less business side" and another asked for "more CATIA based training to produce an official product or 3D print a prototype so that each project could be saw [seen] rather than visualized" in reference to the lack of time allocated to design and engineering work in favor of business content. On the other side of the opinion spectrum there were some who valued the business content with one student writing that "the course was definitely useful in helping me understand a more business minded approach to the engineering process."

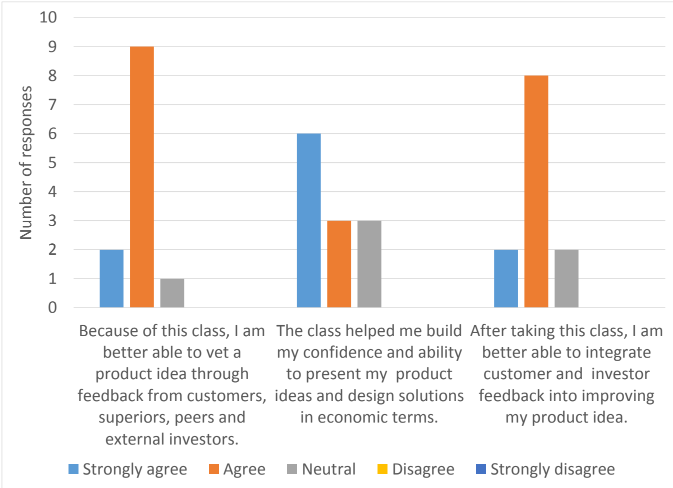

Figure 4 – Survey results of students who participated in the pilot offering of course

Conclusions

The course "Fundamental of Engineering Design," piloted in Winter 2014 serves to have freshman engineering students emerge with the ability to think of technology and design in the business terms of value creation. The work also leads to an excellent portfolio element which can be leveraged in co-op placements. Initial assessment reveals that some students were uneasy about the business emphasis while others welcomed it. Future assessment will try to relate the affinity of the student towards business to demographics and student background. Second offering of course is set for Winter 2015 with lightfield photography being the target technology.

Acknowledgment

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