An Entrepreneurial Approach to a Senior Design Course

Allen H. Hoffman
Worcester Polytechnic Institute
Worcester, MA USA
ahoffman@wpi.edu

***Abstract*—Most senior project based design courses focus on demonstrating that students have shown an ability to design a system, component, or process that meets desired needs within realistic constraints as described in ABET Criterion 3(c). This paper describes an approach that has been used for the past four years in a senior project based design course which embeds these criteria within an entrepreneurial approach to design. The entire class functions as a startup company with management, marketing and two design divisions. The instructor and teaching assistant play the role of the Venture Capitalists (VCs) investing in the company. The goal of the company is to develop two first generation working prototypes that could be used by the VCs to attract additional funds to produce the final product. All prototypes were successfully tested and evaluated against the appropriate standards and major performance requirements. Course evaluations indicate that this entrepreneurial approach is well received by the students.**

Keywords—design; entrepreneurship; project based courses; ABET outcomes; flipped classes;

I. INTRODUCTION

The goal of many senior level, project based, design courses is to integrate a student's past undergraduate disciplinary course work under the auspices of a significant design project. ABET Criterion 3(c) requires that students have shown an ability to design a system, component, or process that meets desired needs within realistic constraints. These constraints include economic, environmental, political, ethical, health and safety, manufacturability and sustainability [1]. Thus in many situations, the projects in these senior courses are also constructed so as to demonstrate that the student meets as many of the ABET objectives as possible. In order to introduce a more realistic setting, course instructors have frequently relied upon design problems developed by local companies. However, reliance upon company generated projects can result in some deficiencies and depending upon the project, this type of approach may lead to the introduction of some of the ABET objectives in a somewhat artificial manner. Since the design problems have already been vetted by the company, several of the important front end design activities have already been accomplished. The company may have narrowed the problem definition and need, as well as selected the most important design requirements. In addition, many design alternatives may have already been discarded prior to developing the problem statement given to the students. Under these types of situations, there may be limited opportunities for the students to engage in entrepreneurial thinking that involves areas such as market opportunity, researching competing products, and defining users and their needs. This paper describes a new approach in a senior level, project based, design course which embeds typical course content within an entrepreneurial approach to design.

II. BACKGROUND

The differences between classroom and workplace design problems have been well documented. Workplace problems are generally ill structured, contain conflicting goals and involve very complex interactions [2]. However, classroom problems tend to be much better defined, more limited in scope and may indeed be amenable to closed form solutions. McNeill et al. have shown that students make a clear distinction between classroom problem solving methods and those that are used in the workplace and thus recognize that the classroom design experience cannot be directly transferred to the workplace [3].

In recent years there has been increasing emphasis placed upon introducing and nurturing innovation and developing an entrepreneurial mindset within undergraduate engineering education programs. For example, Poirier et al. [4] have focused on the traits and characteristics of innovative individuals and how they might be cultivated. Shartrand and Weilerstein [5] have advocated letting students develop their own capstone projects and noted some of the disadvantages of having students solve a pre-defined problem for an industrial client. Recognizing these shortcomings, the Keen Family Foundation has actively promoted entrepreneurial activities in capstone design projects [6].

ME 4320 Advanced Engineering Design is a senior level course that is designed to integrate a student's mechanical engineering background within a one-term design project. The recommended background includes a wide spectrum of lower level mechanical engineering courses including stress analysis, kinematics, design of machine elements, materials science and manufacturing. Previously the course was organized around a pre-defined design project generated by an industrial client. While these projects have provided excellent challenges to the students' technical skills, they were narrowly defined in terms

978-1-5090-5920-1/17/$31.00 ©2017 IEEE

of the broadly based challenges found in the workplace environment. This paper describes four years of experience using an entrepreneurial approach where the entire design class functions as a startup company addressing an instructor generated problem for development of a new product. The instructor and teaching assistant play the roles of Venture Capitalists (VCs) investing in the company.

III. METHODS

ME 4320 meets four times per week over a seven week term. Enrollment is capped at 25 students. Within the new entrepreneurial approach, the entire class functions as a startup company with management, marketing and two design divisions. The goal of the company is to develop two first generation working prototypes by the end of the course that could be used by the VCs to attract additional funds to produce a final product. By having two design divisions, the VCs are hedging their bets in the hopes that the company will produce at least one successful new design. The instructor has a background in the development of assistive technology and that has guided the selection of project topics. Past projects have included; development of a new type of indoor/outdoor wheelchair, development of a foot steering mechanism for a manual wheelchair for hemipleagics, development of improved walking aids for the elderly and development of a tricycle for persons with stroke.

In the first class students are presented with information about the course structure and a 1-2 paragraph description of the Market Opportunity that will be addressed by the class (i.e. the startup company). The following paragraph is a slightly condensed version of the Market Opportunity for development of a foot steering mechanism for a manual wheelchair.

Your company has been formed to explore the market opportunity of filling an existing product void for manual, one arm drive wheelchairs used by hemiplegics with moderate arm strength. Persons with stroke and those with an upper extremity injury represent the major users. Lever drive and dual pushrim drive wheelchairs are commercially available but also have significant deficiencies. A potential market niche exists for development of a foot steering mechanism that can be added to a conventional wheelchair to enable use by hemiplegics. It is important to maintain folding of the wheelchair so as to allow transport in an automobile. Thus the design could either be easily attached and detached from the wheelchair or be more permanently attached and foldable.

The first class meeting discusses the course structure and operation. The syllabus contains the schedule for progress reports and presentations from each division, design reviews, field tests and the final presentation and report. Four progress reports and associated oral presentations are required from each division at approximately weekly intervals. Each student is required to keep a very detailed design notebook which documents all of his/her course activities. The structure of the course requires that the grading rubric be designed to strongly encourage each student to contribute in a significant way to both the company and division goals. Consequently, each student's grade is based upon the overall success of the company (25%), the overall success of the student's division (25%), his/her individual contributions to the division and the company (25%) and the quality and completeness of the student's design notebook (25%).

Design specifications for the device are developed, vetted and agreed upon by the entire company. The management division oversees the overall operations of the company including the development of design features to insure that all legal, safety and other appropriate standards are met, developing testing protocols, budget control and quality control. Each design division is responsible for developing specific preliminary designs of their proposed final design that can be critiqued by all of the company divisions. Next, the division fully analyzes and manufactures a working prototype of their specific design in a timely manner that insures adequate time for testing and for appropriate marketing materials to be finalized. The marketing division is responsible for benchmarking, human factors research, avoidance of patent infringement, insuring that the products meet user needs, product testing and evaluation, as well as designing the packaging and determining the market price. Marketing also produces videos of the final products and leads preparation of the final company report and presentation.

For the second class each student submits a one page written application for a position within one of the company divisions and gives a one minute elevator pitch stating their qualifications. After these presentations, the students self assemble into the different divisions with the instructor providing guidance to insure that the divisions have a balanced set of the required skills and capabilities. A similar approach has been used in forming smaller teams in project based design courses [7]. The next assignment instructs each student to watch two one hour televised segments of Shark Tank and pick four of the show presentations to record in their design notebook. For each selected presentation the student writes a brief one paragraph description of the product, the request, and the result (funded or not funded). A second, longer paragraph must analyze what took place and how it relates to successful (or unsuccessful) product development.

Recognizing that large groups of senior students would have considerable difficulty scheduling meetings outside of class, the class is "flipped" and most of the class time is allocated to the student divisions for discussion within their divisions and with the other divisions [8]. The VCs are present during each class to offer comments, but generally do not lead the class discussions unless directly asked. As noted, four written progress reports and associated presentations are required from each division. The company submits an overall final report. Two periods near the end of the course are allocated for preliminary and final field trials of the prototypes. There is a preliminary assessment of each student's design notebook to insure that the entries are sufficiently detailed and to allow for midcourse corrections.

IV. RESULTS

All of the final prototypes demonstrated functionality in meeting their primary design goals. In the initial offering of the course, the four company divisions were operations (management), marketing, design and manufacturing and were charged with producing only one prototype. This company structure proved to be problematic since the manufacturing division remained relatively inactive in company (i.e. class) discussions and meetings with other divisions until the drawings for the final design were produced. Subsequent offerings of the course created two design divisions and included manufacturing within the responsibilities of each design division. Each design division was required to have members that could lead that division's manufacturing activities. The inclusion of two design divisions introduced greater and more realistic challenges for the management and marketing divisions in terms of utilizing their own manpower. While not intended, having two design divisions seemed to result in a gentle competition to stay on schedule and be the first division to produce a working prototype.

The Marketing Opportunity for the foot steering manual wheelchair was introduced in the Methods section. Results from that class are presented here and are typical of the results obtained in the other three offerings of the course. Two different designs were successfully produced and evaluated. Both designs replaced the front trailing casters of the commercial wheelchair with custom straight (i.e. vertical axis) casters.

The first and simpler design consisted of a removable bar connecting the two front casters. Steering was accomplished by moving the bar left or right with one foot and required a force of 11-12 lbs. (Figure 1). The foot steering bar needed to be removed to enable the wheelchair to be folded. It took a user less than one minute to either attach or remove the foot steering bar.

Figure 1. Design1 utilized a steering bar with an optional wooden footrest.

The second design utilized a rotatable footrest on the more able bodied side and a connecting toothed rubber belt to rotate the straight caster on that same side (Figure 2). A removable differential was connected to an axle between the two rear wheels. This arrangement allowed the steering caster and hand driven rear wheel to be accommodated on either side of the wheelchair (Figure 3). The prototype differential was obtained from a go cart and was heavier and considerably overdesigned for the application. Due to its bulk and weight, removing it from the prototype required some aid from a second person.

Figure 2. Design 2 used a single rotatable footrest and a toothed rubber belt to rotate the front caster.

Figure 3. Removing the differential connecting the two rear wheels allowed the wheelchair to fold.

Both designs were evaluated using the major requirements of the ANSI/RESNA Wheelchair Standards including; dimensions, weight, turning radius and static stability [9]. The pushrim force and footplate forces to operate each wheelchair were measured and found to be acceptable (Figures 4 and 5).

Figure 4. Measuring the horizontal force required to operate the turning bar on design 1.

Figure 5. Determining the minimum turning radius of design 1.

V. DISCUSSION

Course evaluations and peer and self evaluations indicate that the course format utilizing the company based entrepreneurial approach was well received by a majority of the students. Many commented positively on the realism introduced into the course environment and how they appreciated the decision making freedom that resulted. The course format involves a clear tradeoff between providing the students with a more comprehensive entrepreneurial design experience and a traditional instructor led course which presents more detailed advanced material in a structured manner. While most students were enthusiastic about this new approach, a small minority of students was uncomfortable with the format and indicated that they would have favored working on a more traditional structured problem. Although the students clearly acknowledged that the course aligned more closely with the workplace environment, some students were still uncomfortable with the management and marketing divisions critiquing and having input into their design decisions.

While flipped classes have been shown to have potential educational benefits [8], the primary motivation for adopting this method in ME 4320 was dictated out of the necessity to allow meetings between individuals, divisions and the entire company without undertaking complex scheduling activities. None the less, the advantages of a flipped environment such as creating an environment promoting student centered cooperative learning, enhanced student engagement, group problem solving and peer to peer learning were clearly noted.

The classroom entrepreneurial model used in ME 4320 required the development of a different type of grading model. In the workplace, the overall success or failure of a small startup company depends critically upon the successful integration of the activities of all of its divisions and employees. In this type of workplace, all employees have a significant stake in producing successful outcomes for the company as a whole as well as their own division. In this setting, outcomes can only generally be assessed when the product is finalized. The grading rubric for the course was developed to more accurately model this workplace environment and encourage all students to fully participate and provide input in all areas of the company operation. The fact that the company grade (25%) was the same for all students and the division grade was common to all students in the that division clearly motivated each student to actively participate and become involved in the broader issues associated with producing successful overall outcomes. The marketing division is in charge of producing the final company report with input from the other divisions. In addition, each company division produces a 4-6 page report detailing the specific activities of that division which resulted in successful outcomes for the company as a whole including interactions with the other divisions. This report must identify the three most important contributions of the division to the overall success of the company. Each student is also required to submit a 2-4 page report which contains specific details of his/her contributions to the overall success of the company and the division including references to specific entries in his/her design notebook. This report must also identify the student's most important contribution to the company's success. Classroom observations by the instructor and teaching assistant are also used to establish individual accountability. At the end of the course, each student also submits a confidential peer and self-evaluation form for their division. These forms are mainly used to insure that a significant contribution made by a particular student has not been overlooked

Since a large portion of the actual class time is unstructured and unscripted, it is necessary that the instructor be comfortable with this approach. In this type of setting it is unlikely that the instructor and/or teaching assistant will be able to immediately answer every question that might be asked of them. However, they should be able to guide the student(s) as to approaches that could be taken to resolve the question. In one sense this type of format encourages more of a mentoring approach rather than a "teaching" approach.

Developing the Market Opportunity statement requires that the instructor have a reasonable working knowledge of the project topic. Sufficient background research should be performed to insure that there is a sufficient need for the product and that the need has not already been adequately addressed. However, the most important role of the instructor is to set the schedule for progress reports and their expected content so as to insure timely completion of the product development cycle.

VI. SUMMARY

The goal of this work was to develop a more realistic and broad based senior design course format based upon an entrepreneurial model. In this model the instructor identifies a real market opportunity and the students use a startup company format to design, develop and evaluate working prototypes of their new designs. This course structure enables individual students to take on self-selected roles such as marketing and management which may more closely align with their career objectives while still being deeply involved the actual design.

REFERENCES

[1] ABET, Criteria for Accediting Engineering Programs, 2016-2017, http://www.abet.org/accreditation.

[2] D. Jonassen, J. Strobel and C. B. Lee, "Every day problem solving in engineering: lessons for engineering educators," J. Engineering Education, vol. 95, pp.139-148, 2006.

[3] J. McNeil, E. P. Douglas, M. Koro-Ljungberg, D. Terriault and I. Krause, "Undergraduate student's beliefs about engineering problem solving," J. Engineeering Education, vol. 105(4), pp. 560-584, 2016.

[4] V. Poirie et al., "Thoughts on improving innovation: what are the characteristics of innovation and how do we cultivate them," Technology and Innovation, vol. 18, pp. 319-330, 2017.

[5] A. Shartrand and P. Weilerstein, "Strategies to promote entreprenuerial learning in engineering capstone courses," Int. J. Engineering Education, vol. 27(6), pp. 1186-1191, 2012.

[6] T. J. Kriewall and K. Mekemson, Instilling the entreprenuerial mindset into engineering undergraduates" J. Engineering Entrepreneurship, vol. 1(1) pp. 5-19, 2010.

[7] A. H. Hoffman and J. R. Court, Using a company based model to organize project teams in an introductory design course," *Proceeding of the 38th ASEE/IEEE Frontiers in Endducation Conference*, Saratoga Springs, NY, Oct. 22-25, 2008.

[8] A. Sterbak, T. Volz and M. Wettergreen, "Implementing and assessing a flipped classroom model for first-year engineering design, ASEE Advances in Engineering Education, Fall 2016, pp. 1-16.

[9] RESNA WC-1:2009 – American National Standard for Wheelchairs Volume 1: Requirements and Test Methods for Wheelchairs (including Scooters).