AC 2009-828: INTEGRATING ENTREPRENEURSHIP THROUGHOUT AN ELECTRICAL AND COMPUTER ENGINEERING CURRICULUM

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Integrating Entrepreneurship Throughout an Electrical and Computer Engineering Curriculum

Abstract

Many engineering programs are attempting to emphasize the importance of entrepreneurship and an entrepreneurial mindset for all engineering students. Since many start-up companies are founded on the basis of a newly developed technology, it is a natural progression for at least some engineering graduates to become entrepreneurs. Even for those with a more conventional career path, entrepreneurial skills and an entrepreneurial way of looking at problems will help them to maximize their professional success.

Of course, practically all engineering programs are already overloaded with critical learning objectives ranging from highly technical skills to highly interpersonal and communication skills. As a result, it can be a great challenge to find an opportunity to incorporate even a small amount of entrepreneurship into an existing engineering curriculum.

The authors present an ongoing effort at their university to integrate entrepreneurial projects and modules directly into required ECE courses in all four years of the curriculum. The effort begins in the first-semester Fundamentals of Engineering course, builds in Advanced Digital Logic Design during the sophomore year and Embedded Microcontrollers during the junior year, and culminates for some students with an entrepreneurial senior design project.

Introduction

Entrepreneurship has become an increasingly important component of engineering education over the past decade, and it is foreseeable that its emphasis will continue to increase further. Of course, as with all other curricular pressures, it is difficult to see how entrepreneurship education can be further emphasized without eliminating other important elements from our curricula.

Many universities have introduced entrepreneurial topics by integrating them into capstone design sequences[1-3]. While this is an effective way to introduce the concepts of entrepreneurship, it further overloads a course that is already burdened with many non-technical issues and constraints, and it ensures that students do not fully experience entrepreneurship as part of their education until their final year. Other universities create special courses, certificates, and minors focused on topics of entrepreneurship[1,4-6]. This is probably the most effective way to introduce these important concepts to engineering students, but it comes at the price of increased teaching load and additional expense to the university. Another alternative is to focus entrepreneurial experiences for students in co-curricular activities such as Students in Free Enterprise (SIFE) and Collegiate Entrepreneurs' Organization (CEO)[7,8]. A potential concern for such an approach is that it seems to convey the message to students that entrepreneurship is a topic that is outside the normal engineering world and does not deserve a place in the engineering curriculum.

_____ University is attempting a different solution to this challenge—integrating entrepreneurship topics directly into existing courses throughout all four years of the Electrical

Engineering and Computer Engineering (ECE) curricula. In this way, it is hoped that ECE students will have many opportunities to learn about entrepreneurship, beginning with relatively simple experiences in the first semester and leading up to a significant entrepreneurial component as part of the capstone design project. In between those extremes, students will learn more about entrepreneurship and complete entrepreneurial design projects in a sophomore-level course on Advanced Digital Logic Design and in a junior-level course in Embedded Microcontrollers. These two courses were chosen because of their heavy design content and their emphasis on a final design project. By trimming less than 10% of the material in these two courses, we were able to add a few lessons on entrepreneurship that then allowed students to select and complete an entrepreneurial design project in each of the courses.

Illustrating the importance of cross-disciplinary collaboration in entrepreneurship, these course materials were developed by collaborative pairs of engineering and business faculty at _____ University. The business faculty brought both theoretical and practical knowledge of the business world, while the engineering faculty were responsible for determining how best to fit the entrepreneurship content into their existing course.

By integrating this material into existing courses, we eliminate the need to offer new courses, which in turn reduces curricular pressures and minimizes the cost of this program for the university. We also emphasize to students that entrepreneurship is an integral part of engineering work, and that all engineering projects are completed within the context of a business environment. These are valuable lessons that will serve the students well once they leave the university and begin their careers.

Entrepreneurship in the Freshman Year

Every first-semester engineering student at _____ University takes GE 100: Fundamentals of Engineering. This course provides students with foundational knowledge concerning the fundamental topics of mechanical, civil, electrical, and computer engineering[9-12]. The course is structured as a series of modules, each of which consists of a lecture (with associated active learning exercises) followed on the next day by a 50-minute laboratory experiment. The students complete a total of 26 of these modules, on topics ranging from statics to electronic circuit design and thermodynamics. In addition, they complete a mid-term design project and a final design project as part of a team and give an in-class oral presentation on each. This course is also complemented by GE 199, a required zero-credit seminar course that meets once a week and features a series of guest speakers to help the students understand the field of engineering. It was decided that one of the existing modules in this course (Communication System Design) should be replaced by a module on entrepreneurship. Introducing the concept this early in the curriculum and across all engineering disciplines provided a unique opportunity to encourage all engineering students to begin to think about entrepreneurship from the beginning of their engineering careers. Approximately halfway through the course, the Dean of Business Administration was invited to speak to the seminar course and provide a foundational introduction to the entrepreneurship. At the end of his presentation, students were asked to break into teams of two or three and to begin brainstorming a potentially entrepreneurial idea that could be used to benefit college students. The next day, the lesson was focused on active learning exercises in which students brainstormed the characteristics of an entrepreneur,

considered how entrepreneurs share many characteristics with engineers, and worked again on their entrepreneurial ideas. The third class period (which would normally have been a laboratory experiment) was devoted to student teams giving in-class "elevator pitches" to promote their ideas. At the end of that class period, each student in the class was given 10,000 fictional dollars to invest in any combination of the other teams in their section. The team receiving the highest total investment received a small prize and recognition at the next class meeting.

This structure was found to be very effective, as it immediately involved the students in thinking of entrepreneurial ideas. Focusing on an elevator pitch (three minutes and three slides) gave them a structure to express their ideas but also gave them the flexibility to pursue an idea of their own choosing. We believe that this experience effectively introduces first-semester students to the principles of entrepreneurship and prepares them for the more intensive experiences that will follow in the next three years of their curriculum.

Entrepreneurship in the Sophomore Year

In the sophomore year, all electrical and computer engineering students take a number of fundamental courses necessary for advanced study. These include courses on linear circuit theory, computational techniques and logic design. The logic design topic consists of a two-course sequence. The first course introduces the basics of digital systems design including both combinational and sequential logic. There is a lab associated with the course where the students implement designs using both standard TTL logic and programmable logic devices. The second course builds upon the first with emphasis on larger more complex designs as well as creating digital designs using a hardware description language. There is also a laboratory component to this course. Students create designs using hardware description languages and then implement them in programmable logic on the DE2 development and education board from Altera Corporation. Incorporating entrepreneurship into this second logic design course, ECE222 – Advanced Logic Design, was a natural choice because of the emphasis on projects in the course. The objective of the entrepreneurship portion in ECE222 is for students to learn the first three steps in the entrepreneurial process, from the generation of an idea to the development of the concept to the creation of a working prototype.

Instead of teaching a separate section on entrepreneurship, activities are added in the course throughout semester so that the students could see how logic design and entrepreneurship are linked. Early in the semester two new lectures are given, one introducing the students to basics of entrepreneurship and the second describing how new ideas are generated. Both lectures are highly interactive where students discuss the importance of entrepreneurship, investigate the link between engineering and entrepreneurship, and practice generating ideas that are both problem and resourced focused.

After the students have been introduced to entrepreneurship, they are tasked to carry an "Ideas Logbook" with them for six weeks and document any new ideas or observations they have for entrepreneurial projects. Each of their ideas serves as an entry in their logbook. At this point there is no evaluation of the ideas, they are simply asked to document any idea that they generate. These ideas may come from problems that they identify, enhancements to current products, or other students they survey. They are not given a specific format for their entries in

the logbook but are asked to include enough detail so that they can look back at a later date and understand what they were thinking. Also, by having detailed entries, there is the hope that the students may see connections between their entries that could lead to even more ideas.

At the end of the six weeks, the students form teams of two or three. In their teams, they narrow the list to two or three viable ideas to research in more detail. During this research phase, students learn how to evaluate ideas and from their list, teams select one that they want to conceptualize and develop a prototype. Once they have decided on their one idea, each team pitches their idea to the rest of the class at the beginning of one of the laboratory periods. They then take their idea and create a digital design concept that incorporates all or a significant part of the project. From that concept they finally develop a prototype using a design evaluation board containing programmable logic devices. This prototype development extends over the last two laboratories of in the semester. The culmination of the project is when the teams present their concept prototype at the end of the semester during the annual college of engineering design exposition.

Entrepreneurship in the Junior Year

Microcontrollers are integrated circuits (computer chips) that act as the brains of the electronic devices we are surrounded with every day. They can be found in devices as diverse as refrigerators, cars, MP3 players, cell phones, DVD players, clocks, toys, coffee makers, and GPS satellites. In ECE322, engineering students are introduced to the capabilities and operation of microcontrollers. However, in past years, ECE322 students examined microcontrollers and to a limited extent their application in a vacuum. The class has not considered the factors and decisions that weigh upon corporations upon selecting microcontrollers. Nor have the students been instructed in the tremendous opportunities present for individuals well versed in the operation, programming, and application of microcontrollers. In this project, we have endeavored to include in the ECE322 curriculum selected topics in entrepreneurship. The topics chosen were selected to complement the entrepreneurial lessons and activities being introduced in other classes within the electrical and computer engineering department curriculum. While many popular entrepreneurs are self-employed or presidents of their own companies, we have selected lessons specifically intended to embolden entrepreneurial attitudes of individuals within larger organizations.

Rather than dedicating entire lectures or weeks to the topic of entrepreneurship, we have developed a plan to include various entrepreneurial topics throughout the entire semester. It is our intention to weave these lessons and activities into the microcontroller topic at hand. This should reinforce the applicability of the entrepreneurial lessons without distracting the students from the technical material at hand. For this purpose, we use a supplementary textbook, *The Art of the Start: The Time-Tested, Battle-Hardened Guide for Anyone Starting Anything*[13]. The very name of the book speaks to the heart of what we expect to accomplish in our ECE322 entrepreneurship education. Unlike many books, which focus their attention on individuals wanting to start their own company, Kawasaki aims to motivate readers into simply starting. The various entrepreneurial topics and the corresponding chapter from book are given in Table 1.

Table 1 - ECE322 Weekly Entrepreneurial Topics

Entrepreneurial Topic	Chapter in *The Art of the Start*
Introduction	1. The Art of Starting
Internal Entrepreneurs	2. The Art of Positioning
Team Formation - Resumes and Recruiting	6. The Art of Recruiting
Product Concept	9. The Art of Branding
Value Proposition	
Elevator Pitch	3. The Art of Pitching
Elevator Pitch to Faculty Members and Engineers	
2 Page Description of Proposal	4. The Art of Writing a Business Plan
Introduction to Business Plans	
Introduction to Business Plans	5. The Art of Bootstrapping
Project Proposal	10. The Art of Rainmaking
Product Proposal Presentations	11. The Art of Being a Mensch

In the first two weeks of class, students are introduced to the concept of entrepreneurship and the characteristics of entrepreneurs. Comparisons are made between engineers and entrepreneurs. Students draw the conclusion to look past their stereotyped expectation of an entrepreneur and to simply see them as individuals motivated to solve problems, much like engineers do. The idea of a person behaving entrepreneurially within a larger organization (an "intrapreneur") is then introduced.

In the following three weeks, students assemble themselves into teams, develop an idea for a final project, and determine the project's value proposition. During team formation, students are introduced to the idea of appropriate self-promotion through discussions on resumes and recruiting. The teams are then required to develop a short (1/2 page) description of their product. From this document, students are expected to refine their product concept by focusing on their project's value proposition and eliminating "feature creep." The teams are then required to submit an updated project description and value proposition. This second document must again be short (1/2 page).

In the next two weeks, students are introduced to the concept of elevator pitches. Each student is required to develop a two-minute elevator pitch for his or her updated project description and value proposition. After some time for practice, each student is required to deliver their elevator pitch to two other faculty members or engineers to obtain feedback on their final project concept.

In the following three weeks, the students will gather all of the feedback they received from the elevator pitches and individually develop a two page beachhead product proposal for their project. From these proposals, the students will reassemble in their teams and develop a brief (approximately four pages) business plan for their project. This capstone of the entrepreneurial activities will be their project proposals and final project presentations to their classmates.

Entrepreneurship in the Senior Year

During their senior year at _____ University, electrical, computer, and mechanical engineering students enroll in a two-semester capstone design sequence, GE497 and GE498.

Throughout the sequence, the engineering students work in multidisciplinary teams of four to ten students. Depending upon the size of the team and the project's complexity, the teams will have one or two faculty advisors[2].

Unlike our Advanced Digital Logic Design and Embedded Microcontroller classes, we deliver the entrepreneurial lessons throughout the capstone sequence in two ways. On occasion, we dedicate entire lectures to the topic of entrepreneurship. At other times, we again weave these topics into traditional engineering lectures and discussions. A summary of the capstone design sequence and the corresponding entrepreneurial lessons is shown in Table 2.

Table 2 - Capstone Design Sequence

Weeks	Project Topic	Entrepreneurial Topic
0	Project Proposals	Brainstorming
1	Team Definitions	Customer Needs
2 - 4	Specifications	Project Management
5	Design Constraints	Ethics
6	Alternate Solution Analysis	Patents
7 - 8	Design Proposal	Business Plans
9 - 12	Critical Design	Business Practices
13 - 26	Project Implementation	Professionalism
27 - 28	Project Evaluation	Starting Your Own Business
29	Project Presentation	Oratory Skills
30	Lessons Learned	Lessons Learned

The opportunities for entrepreneurship education in the sequence actually starts before the classes begin. Students are invited to submit project proposals to the faculty advisors prior to the start of the class (week 0 in Table 2). This provides students the opportunity to demonstrate and hone their brainstorming and initiative skills they have developed in prior semesters. Successful proposals are implemented in the class sequence. The authors of the successful proposals can either serve on the project development team or as the customers of the development team.

In the first several weeks of the sequence, students are familiarizing themselves with their teammates, their customer, and their customer's expectations. Students are taught the differences (and similarities) of internal and external customers. The teams are then required to develop a complete specification of their project with their customer. As the specification is developed, students are introduced to the concept of program management and the tools used by system engineers to manage product development.

In the next week, students are introduced to some of the design constraints they will have to work under. This is a perfect segue for the students to recall some of the professional ethics they must have as engineers. Engineers are expected to hold paramount the safety, health, and welfare of the public[14]. These same ethics will serve engineers as leaders in their organization and society[15].

The following week is dedicated to exploring alternative solutions to meet a customer's need. During this time, the students are introduced to patents and how they influence engineering organizations. Students are instructed on their inherent responsibility to use an engineering notebook to protect their employer's and their own future interest. Students are then challenged with the opportunity to creatively solve their customer's needs and submit a patent proposal to college dean at the end of the capstone design sequence.

In the next 6 weeks, students develop an initial design proposal and then iterate a final project design through a series of peer and faculty advisor design review. During these weeks, students are taught about the fundamentals of business plans and how they can influence engineering organizations and business practices. These lessons are often a surprise to students, and they are some of the lessons that receive the most positive feedback throughout the year.

Following a final design review, the student teams engage in the implementation of their project. This 14-week activity spans the end of the first semester and the majority of the second semester in the sequence. During this time, students are often faced with stress and pressures beyond which they have experienced in other classes. Faculty advisors work closely with the teams to discuss proper professional behavior and accountability throughout these weeks.

Following the completion of the project design, teams evaluate their project to determine if they were successful in meeting their customer's needs. This is followed by a final oral presentation (approximately 40 minutes per team) and an opportunity to review the capstone sequence in a lessons learned discussion. During the final weeks of the sequence, we have a guest speaker with significant entrepreneurial experience talk about his/her own familiarity starting an engineering business.

Conclusions

At _____ University we have incorporated entrepreneurship into courses each year in the electrical and computer engineering curriculum. The goal in adding this very important topic to the curriculum was not to increase the number of courses that the student would have to take but to integrate it seamlessly into existing courses and thereby illustrating the natural link between entrepreneurship and engineering. In this paper we have outlined how entrepreneurship has been added to four specific courses in our curriculum. After completing these four courses, our students will understand the importance of entrepreneurship, have participated in several entrepreneurial projects, and realize that they can be entrepreneurial whether they work for a large company or have their own business.

Acknowledgment

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