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Entrepreneurial Mindset Development in a Senior Design Capstone Course

Abstract

Capstone courses for senior engineering students may be organized in numerous ways. Usually, the goal is to give students a significant development and design experience that will prepare them well for their work following graduation. Sometimes the focus of a capstone course is on solving technical problems of an advanced project. Sometimes the focus is on getting the students to produce a design based on the scope provided by an industry partner. Sometimes the focus is on giving the students a rich experience in how a team works together. Sometimes the focus is on the business side of projects and engineering. Sometimes the focus is on covering material that doesn't fit in any of the other regular courses. Most capstone courses try to form some balance between these and other competing topics and expectations, but with ever-changing teaching faculty, maintaining a consistent, well-packaged, and well-delivered capstone course from year to year is a challenge.

For the past several years at Calvin College, we have been exploring a number of ways to cohesively bring our capstone experience together for the students and at the same time help our students develop an entrepreneurial mindset. Our goal is not to develop every student into an entrepreneur; our goal is to help all engineering students think like an entrepreneur when faced with multi-faceted problems. Our idea of an entrepreneurial mindset in our students is that each will be oriented and prepared to aid and abet entrepreneurism whether in a new business or an existing business (intrapreneurship). In the Engineering Department, we have allied ourselves with Business Department faculty such that all engineering students develop business plans for their projects. Furthermore, business students in an upper-level strategies course work with specific engineering design teams. This year we have also begun an emphasis on identifying the customer and responding to the customer's needs. Alumni, Business Department faculty, and Enterprise Center personnel are involved in assessing the initial ideas that each senior design team is proposing. In addition, specific lectures have been prepared and given to the class that introduce the concept and value of having an entrepreneurial mindset.

This paper will explore further the recent changes to our capstone course and provide some early feedback from students and constituents on the changes. We plan to work with our Industry Advisory Council to get their feedback on the proposed changes and plan to provide detailed questionnaires to the students at the end of the second semester of the course.

Introduction

Entrepreneurship and Engineering used to be distinct concepts; however, with the globalization of business and engineering and with the high levels of competition between countries for developing technology, many in North America have emphasized that tomorrow's engineers need to have an entrepreneurial spirit. In response, many engineering colleges and universities have implemented changes to their traditional engineering programs to incorporate entrepreneurial aspects. Merriam-Webster defines an entrepreneur as "one who organizes, manages, and assumes the risks of a business or enterprise." Engineering students who think like

an entrepreneur should be able not only to recognize opportunities, but also have the tools to assess the opportunities. To do that, the students need a strong technical background; the students need to understand the language and principles of business; students must be able to accurately define the customer and what "pain" their project will relieve; and, students need to appreciate the operational values in each situation they encounter. Some schools have developed optional minors or special entrepreneurial certificates. Other schools have revised existing courses to include new entrepreneurial topics. The most common place to focus such changes is the capstone course. In this course, students are challenged to use learning from prior classes to solve specific, and sometimes real-world, problems. This paper will describe our approach at Calvin College for instilling the entrepreneurial mindset in each of our engineering students, particularly in the capstone design course.

Previous Work in This Area

A number of schools have been in the process of integrating entrepreneurship into engineering capstone (senior design) courses. A survey of the various approaches highlights two common themes: 1) the programmatic goals for the courses are quite similar and 2) the detailed implementations differ as much as the institutions themselves differ. Although duplication of the successful aspects of another program is rarely easy, surveying the range of possible approaches and leveraging the creative ideas in one's own situation and institution is valuable.

Ochs, Lennon, Watkins, and Mitchell[1] from Lehigh University present a 5 phase product development model; they specifically look at how that model supports the ABET outcomes for their program. Lehigh's IBE (Integrated Business and Engineering) program also ties into their capstone course. The fourth and fifth phases of the product development model, which look at manufacturing/production issues and customer service/maintenance, are emphasized. The authors emphasize that many capstone courses do not effectively address these areas.

Archibald, Clauss, and Dupree[2] from Grove City College have described how their business plan competitions and the use of multidisciplinary teams have been used in their capstone course. The goal of this integration is to help students better plan for the financial aspects of projects and to understand real-world constraints.

The Integrated Technology Ventures (ITV) program at the University of Florida (Stanfill, et. al[3]) gives opportunities to undergraduate business and engineering students to work with startup companies. An entrepreneurial version of their capstone course connects students with the ITV program and places them in multidisciplinary teams to work on an innovative project.

At Washington State University, Davis and Rose[4] have described their work on an entrepreneurial capstone course, with a well-developed outcomes assessment. The entrepreneurial capstone course is an optional course for students interested in the business of technical innovation. Students are expected to learn about product, business, and personnel development.

Cook and Cuper[5] from Lawrence Technical University describe how they are developing the entrepreneurial mindset through their senior projects course. Their goal is not to develop

entrepreneurs but to develop engineers that are able to think like entrepreneurs. Through the course, the students will 1) participate in a product development cycle, 2) complete a patent or market survey, 3) explore how they could start a business around their project, and 4) present their project to an advisory panel. Students are drawn from a variety of majors to form the design teams.

Finally, Kriewall and Mekemson[6] (Kern Family Foundation) describe how schools that are part of KEEN (Kern Entrepreneurial Education Network) are working together to instill the entrepreneurial mindset in all of the engineering graduates at each school. This paper gives a good definition, along with the attributes of the entrepreneurial mindset and discusses a theory of change on how best to instill the entrepreneurial mindset in students.

Hochstedt, Zappe, Kisenwether (all of Penn State University) and Shartrand[7] (National Collegiate Inventors and Innovators Alliance) have looked at the broader question of how faculties look at entrepreneurship education and the entrepreneurial mindset. The paper presents early results on an NSF-funded study of those key questions.

Overview of Program and Capstone Course

Specific program implementation details are strongly dependent on the context in which they function. The organization of the department or school, the general education requirements, the semester scheduling, the available facilities, and many other aspects all affect the decisions made about how to structure an engineering program. The capstone course described below is part of the Engineering Program at Calvin College. Students at the school can graduate with a Bachelors of Science in Engineering (BSE) degree, with a concentration or specialization in chemical, civil/environmental, electrical/computer or mechanical engineering. After a common set of courses during the first two years, students separate into one of the four areas, taking upper-level, concentration-specific engineering courses and appropriate cognates for the final two years of the program. During the final year of the program, all of the senior engineering students are rejoined into a single capstone senior design course, bringing the four concentrations back together into a multidisciplinary environment. The course is a two-semester sequence, beginning with the problem definition and ending with a design and prototype.

Prior to the capstone course, students will have been introduced to the concepts of entrepreneurship in a variety of lower-level courses. In our Introduction to Engineering course in the first year and first semester, our students spend a couple of days learning about the connection between entrepreneurship and engineering. In more advanced courses, real-world problems are used in class to demonstrate the broad disciplines that have to be considered. Finally, the students take a Business Aspects for Engineers course concurrently with their capstone course sequence. As part of that class, students develop a business plan for their senior design project.

Description of Capstone Course

In the capstone course sequence, students participate as team members, working on a design project that integrates prior and current learning. By the end of the first semester, teams will have produced a project proposal and a project feasibility study. By the end of the second

semester, teams will have completed a detailed design for their project, built and tested an appropriate prototype for their project, and presented their project to their peers, families and interested community members. Four faculty members, representing all of the major engineering disciplines, conduct the course and work with the teams. Teams and projects are self-selected by the students and ultimately approved by the four faculty. Some projects are tied to a specific engineering discipline and some projects bring together students from a variety of engineering disciplines. For example, electrical, mechanical, and chemical concentration students sometimes combine on a single team; in fact, such combinations are encouraged. The four faculty function as engineering managers. They also invite industry-based engineers to mentor teams; this review and guidance does not directly impact the team's grades, giving the teams some freedom to make mistakes, ask open-ended questions, and get strong advice. These mentors supplement the efforts of the faculty managers. In the course, students split their time between lecture material in class, project work, and project presentations to their peers and often in more public forums.

In past years, the students in the final semester would focus primarily on the technical issues needed to successfully complete their prototypes, essentially ignoring the broader issues of customer needs, financial management, and production challenges. Entrepreneurially-thinking engineers would not let themselves get bogged down in the technical issues, missing the broader and more significant issues. To help our engineering students think broader with an entrepreneurial mindset, we have made several changes to the course in recent years, described in the following paragraphs.

One of the first changes was to the Business Aspects for Engineers course taken concurrently with the capstone course. The final project of the business course is now the development of a business plan for the student's senior engineering design project. The material covered in the course prepares them to put together a business plan. During the last two offerings of the capstone course, engineering teams used those business plans to compete in a college-wide business plan competition and in each case, the engineering teams took the top spots in the competition.

Business students at Calvin College are required to take an upper-level Business Strategies course. During the past two years, teams of business students have been paired with some of the senior design teams such that the business students evaluate the business side of the design project. The business professor meets with one of the engineering professors at the beginning of the semester to select appropriate engineering projects that have a product or service that the business students can evaluate for its potential to achieve profitability. Then the paired teams meet several times during the semester. The engineering students provide technical explanations and basic cost estimates – usually centered on development hours (labor), and the Bill of Materials (BOM). This helps the business students to gain some practical experience with the real level of effort necessary to develop technological products and the real cost of technological components. The business students build in the myriad of additional financial considerations that lead to a final retail price based on volume, market conditions, and more. They also examine the market potential and summarize the overall business case for the product using the Porter Five Forces analysis model. This helps the engineering students to understand that their labor and their piece price is only one part of the overall financial considerations (and sometimes just a small fraction of the total) and to understand how market forces can drive technical

decisions. The engineering teams incorporate the analysis from the business teams as part of a "business plan" chapter of the final design reports. In true multidisciplinary fashion, the teams each focus on their strengths and contribute to the overall project, but they also teach one another so that the overall project integrates all results appropriately. There is overlap but not duplication of effort so that each person makes a unique contribution, but one that builds on the knowledge and contributions of other team members. One challenge we currently face is that the Business Strategies course is a semester-long course that meets both semesters, while the senior projects engineering course is a two-semester sequence that meets all year. Thus, we must match up a first set of business teams with the senior engineering teams in the fall: then we must match up a second set of business teams with the continuing senior engineering teams in the spring.

Specific lectures have been added to the capstone course to define the entrepreneurial mindset attributes and their importance to engineers in their future; the goal is to challenge these soon-to-be graduates to adopt the entrepreneurial mindset. The coverage of intellectual property has been expanded to begin with communication about finding intellectual property through public resources (presented principally by Calvin College's Library Director), understanding a patent's structure, analyzing a patent for technological information, basics of patent law, how to get a patent, and trade secrets. One lecture concentrates on deploying innovation in existing corporations (intrapreneurship) at all levels of the business and technology from small operations improvements to initiating new business units; the goal of this lecture is to demonstrate to students that they can be part of innovation in their future employment with an entrepreneurial mindset and an innovation focus. This lecture is followed by a later lecture that focuses more on the skills needed to be an intrapreneur, contrasting with the more public characteristics attributed to the entrepreneur; we recognize that most or our graduates will become engineers in well-developed corporations. To empower our engineers, another lecture delivers 8 key ideas from Technology Management; the goal of this lecture is to generate awareness of useful analytical and decision tools for various situations so that when the engineers encounter these situations they can consider learning more about the tools and using them to their advantage. New lectures have been tested to introduce students to the concepts and practices of Quality Management, and Quality Functional Deployment. Students are also introduced to some business management concepts including business startup management and small business management. The course already contains extensive lectures that cover a wide range of other topics including, for example, personal and professional ethics (three lectures), written and oral communications (two lectures), team dynamics (two lectures), project management, legal aspects of engineering, etc. The new topics that we have added fill in the critical gaps in the content of the course.

At the start of this academic year, shortly after making their topic selections, each team was required to present their project ideas to a panel of engineers and business people that were not faculty who would be grading the student projects. Each team was given 5 minutes to make a presentation and then the panel of engineers and business people were given 5-7 minutes to ask questions. The teams were asked to present 1) what problem they were solving, 2) who are the customers and what competing options do they have, 3) what is the business model which can sustain an enterprise that pursues it, and 4) what do the team members bring to the project? The context of the situation is that the presentation and discussion are not graded, allowing the students to freely seek the advice of the experts on the panel. The absence of grading at this point aims to help the students be less defensive and more open to the suggestions and guidance that is

provided. Later, in the execution and presentation of the project, evidence of their response to the guidance is graded.

During the few weeks after the informal project presentations, teams have an opportunity to consider the advice and feedback from the panel. The next step is for each team to prepare an elevator pitch to their peers and to the faculty who will be grading them on their project. For their elevator pitch, the students are given guidance and a minimal template. Their elevator pitch is graded by at least two of the panel members, as well as the other faculty team mentors.

Assessment

Since the capstone course is the last opportunity with the students as a group for measuring the effectiveness of the program toward meeting the ABET outcomes , assessing the work of our students in the course is very important. A new method of evaluating our students in the last couple of years has been to schedule each team to meet with 2 or 3 members of our engineering Industry Advisory Council—a body of practicing engineering managers that regularly review our program and improvements that are in progress. We have specifically asked our Advisory Council members to look at each team's understanding of the customer/business aspects of their projects. The past year's assessment by our Advisory Council on those aspects showed some mixed results. Since this assessment was prior to some of the changes recently completed, the results at the end of this school year will be a good indication of the success of this new approach.

We are currently exploring other methods of assessment. One approach is to use a values and traits assessment tool (used by many employers for screening candidates) to assess our students progress over their four-year tenure. Another approach is to use a much simpler tool that is a survey developed by faculty at other schools to evaluate the changes in the student's mindset toward innovation and entrepreneurialism over the course of their senior year; this assessment comes after they have developed through the Business Aspects for Engineers course, their capstone course, and their engagement with business students doing a strategic analysis of their projects. Finally, we are looking into ways to generate longitudinal evaluations that will extend into the years after our students have graduated.

Conclusions

Shifting to a more entrepreneurial mindset within an engineering education process is not easy and requires a determined approach and practice to achieve a sustainable and consistent result. This paper describes several steps that have been taken to implement this change in one engineering program in a broad-education based college. Approaches included adding course processes--including additional reviews, adding course lectures and reporting requirements, and increasing the integration with the Business Department. Tools and techniques for assessing these changes are presented and are in continual development.

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