Engineering Design using an Entrepreneurship Model

Catherine E. Brawner
Research Triangle Educational Consultants
Raleigh, North Carolina 27612

Thomas K. Miller, III
College of Engineering
North Carolina State University
Raleigh, North Carolina 27695

Abstract *- The Engineering Entrepreneurs Program at North Carolina State University (USA) is a program in which undergraduate students participate in design teams formed around corporate themes. Through the sponsorship of SUCCEED (Southeastern Universities and Colleges Coalition for Engineering EDucation), an NSF coalition, the Entrepreneurs Program seeks to provide a meaningful undergraduate experience which properly prepares students for the engineering workplace of the 21st century. The purpose of the Program is twofold. First, it aims to retain student interest in engineering by exposing early undergraduate students to the design process early in their academic careers and by providing senior and other upperclass students as mentors. Secondly, students learn "real-world" skills such as teamwork, leadership, and the dynamics of small, entrepreneurial companies.*

Project teams are led by seniors fulfilling their capstone design requirement while other team members may be anywhere in their academic careers. The program draws most of its students from the Electrical and Computer Engineering Department at NC State, however it is suitable for students in all disciplines. Students are encouraged to participate for multiple semesters, eventually growing into the leadership role. In addition to the hands-on design experience, students attend required weekly seminars on topics such as: teambuilding, developing a business plan, obtaining venture capital, consulting, legal matters, and marketing. This paper discusses the course philosophy, content, team formation, and project activities, as well as the impact of the course on student retention and learning of real world skills. It should be of value to anyone who is interested in providing a vertically integrated, multidisciplinary, practice-based engineering design experience.

Introduction

Many have complained that engineering education today does not adequately prepare graduates for engineering jobs. Employers argue that graduates tend to be skilled in the academic requirements of engineering without having learned and practiced other skills which are also important on the job - skills such as teamwork, leadership, and understanding of the relationship between engineering and business operations. In addition to lack of training in workplace skills, engineering students often get little exposure to the design process until the end of their senior year when they participate in a capstone experience. In recognition of the need to include these workplace skills in the formal training of engineers, the Accreditation Board for Engineering and Technology (ABET) has revised the criteria by which undergraduate programs are accredited in the US to include: designing to meet desired needs, teamwork (particularly multidisciplinary teamwork), communication, problem solving, and the understanding of engineering practice and its place in society. [1]

Through the sponsorship of SUCCEED (Southeastern Universities and Colleges Coalition for Engineering EDucation), a National Science Foundation (NSF) sponsored coalition of eight colleges of engineering in the southeastern US, the Electrical and Computer Engineering Department at North Carolina State University (NC State) has developed the Engineering Entrepreneurs Program. The Entrepreneurs Program is a multi-semester experience in which students participate on project teams oriented around a corporate theme. The course seeks to remedy some of the failings of undergraduate engineering education mentioned above by introducing students to the design process early in their academic careers and preparing them for the workplace by exposing them to the dynamics of small, entrepreneurial companies. Students participating in the Program may be at any level (freshman through senior) and from any discipline, although most participants are electrical and computer engineering majors. This paper will discuss goals, organization and operation of the Engineering Entrepreneurs Program at NC State.

Program Goals

There are six goals of the Entrepreneurs Program which focus on improving the students' educational experience and their ability to function effectively in the workplace. They are:

1. Retain the interest of students in engineering by involving them in meaningful design experiences early in their academic careers.
2. Improve the quality of engineering students by involvement in multi-semester design activities.
3. Improve retention by providing senior leaders as role models for underclassmen.
4. Improve teamwork skills by involving students in team-oriented projects, similar to what they will encounter in the workplace.
5. Improve leadership skills by assigning seniors management responsibilities for the project and team personnel.
6. Prepare students for the 21st century workplace by exposing them to the dynamics of small, entrepreneurial companies, which are expected to generate most new jobs in the foreseeable future.

These goals follow from two basic principles under the unifying theme of entrepreneurship. First, engineering students should be exposed to the design process early and continuously throughout their academic careers and second, students should be prepared for the working world that awaits most of them upon graduation.

Program Organization

The Engineering Entrepreneurs Program builds on the capstone design course which is currently required at the senior level in most engineering curricula. However, it is not organized as a traditional engineering course. Students attend mandatory weekly seminars on business topics and work on their team project outside of class. There are no prerequisites; students at all levels, freshman through senior, can participate.

Students participating in the Program are classified into two categories: "senior leaders" and "team participants." The senior leaders are earning capstone design course credit by their participation while team participants earn one credit hour for each semester of participation. The senior leaders, in addition to being responsible for the "deliverables" of the design team, are also expected to play a leadership role. It is their responsibility to define the team's mission, organization, goals and objectives. This contrasts with the traditional student role in a capstone design course where teams of peers work on a project. The team participants who are not in leadership positions play a supporting role. They are expected to participate at an effort level commensurate with one hour of credit, and to contribute to the team activities at a technical level consistent with their academic expertise.

Each team has a faculty advisor. The primary role of the faculty advisor is to serve as mentor and facilitator for the team, and to make sure that team organization and role definition takes place. Managing the group dynamics is probably the most important and challenging role for the advisor.

While the Program does not include a formal lecture, it does include a weekly seminar. The seminars are best if presented by outside speakers, and may be on any topic relevant to the theme of the program. Seminar speakers have included attorneys, management consultants, marketing specialists, founders of entrepreneurial companies (successful and unsuccessful), venture capitalists, plant managers, manufacturing engineers, and others. The seminar series has proven to be an important part of the program, providing the students with a viewpoint on engineering and technology in the "real world" which is seldom seen in the classroom.

In addition to the seminars, student presentations are emphasized in the program. Each team presents three times during the semester. At the first presentation, each team presents its corporate philosophy, mission, goals for the semester, and strategy to achieve those goals. By scheduling the first presentation as early as possible in the semester, the teams are forced to organize and develop their goals and strategies quickly. At the second presentation, the team reviews its mission, goals, and strategy; gives a midterm progress report on how well those goals are being achieved, and documents any changes in strategy or organizational structure. The final presentation documents the achievements of the semester. The teams present and demonstrate the prototype technology they have developed and outline their plans for the future of their company and product.

Team Formation and Organization

Teams are composed of senior leaders and team participants. Team sizes may vary, but teams of 5 to 10 students (including two senior leaders) have worked well. Class members are recruited in a number of ways. Freshmen students are informed about the class through summer mailings and visits by faculty advisors to "Introduction to Engineering" classes. Previous Program participants also recruit new members to their teams and faculty advisors steer other interested students to the Program. Senior leaders who have not previously participated in the Program are recruited from the Senior

Design classes. Students are encouraged to take the class for multiple semesters, although generally only about 25% of the class has taken it previously.

Teams are organized around company themes. During the first class meeting, students who have not already been recruited to a team join a company whose theme interests them. Company themes have included: portable medical devices, software development, and others. The students and the faculty advisor work together during the start-up phase to define potential customers and a particular product consistent with the company's theme. Some companies also have industry sponsors such as IBM or Nortel. Students typically develop a name and logo to go with the theme. Hence, the portable medical devices theme became Body Systems Innovations.

During the first team meeting, students begin the process of organizing their team into a business around the corporate theme and begin the process of deciding what their product will be. The teams' organizational structure may vary, but teams are encouraged to assign team members responsibility for leadership (president, CEO), record keeping (secretary), product development and testing, and business development. The senior leaders develop an organizational structure with defined areas of responsibility for each participant. We have found that it is best if each participant has a well-defined responsibility, even if the responsibility is small. This ensures up front that each student feels that he or she is part of the team and minimizes the risk that the seniors will end up working in isolation from the rest of the group just to get the job done. It also forces the seniors to make their first critical leadership decisions.

Team Operation

The teams are responsible for designing and building a working prototype of a product that is consistent with their company's theme and mission by the end of the semester. Recent projects have included: a hovercraft, a home security system, computer game software, and a lap counter for swimmers in training. Senior leaders are ultimately responsible for the outcome but team members can be valuable contributors if their skills are used well. For instance, one team which was developing prototype software used the freshman students on the team to test the software to ensure that it could be used and understood by people with minimal technical competence. All teams are required to document their work, including design drawings, decisions made, etc. which are turned in at the end of the semester with other project documentation.

Senior leaders say they spend at least 12 hours per week on the class and related project work. This is to be expected from a 4 hour class and a capstone design project. Other team members say that they generally spend between two and five hours per week on class activities. The level of effort required of the faculty advisor is initially high (about 4-8 hours per week), but soon decreases to about 1-2 hours per week in the steady state. When a substantial number of the team members, particularly the senior leaders have participated in previous semesters, the start-up burden for the faculty advisor is greatly reduced.

Grading and Evaluation

The Entrepreneurs Program attempts to employ a success-oriented approach to evaluation and grading. There are no tests. Attendance at seminars, student presentations, and weekly team meetings is required. Grading is based on assessment of how well each participant filled the role set out for him/her at the beginning of the semester.

The seniors are additionally judged on their leadership skills and their fulfillment of the requirement that they define a role for all team participants and ensure their involvement in the project. Team participant evaluations of senior leadership effectiveness and senior leader evaluation of participant contributions are also used as factors in grading. These evaluations can alter a students final grade by one letter grade. Knowing that the leaders and participants are each evaluating the other encourages both groups to make sure that their roles are well defined and well understood by the other. Due to the subjective nature of the grading, it is important for the faculty advisor to attend the weekly team meetings and monitor individual activities, contributions and problems.

A formal evaluation was performed after the course had been offered for six semesters to determine how well the course was meeting its objectives outlined above. Overall, the findings of the evaluation were very positive. Interviews and surveys were conducted with many students who had participated in the program to get their perspective on their experience. In addition, university data were available from over 100 students in the entering classes ("cohorts") of 1990 through 1994 who had taken the course. These students were compared with other NC State University students for their retention at the university and in their majors. End of course survey results from 120 students over the six semesters were used as well to get a complete picture of how well the course was meeting its objectives.

With regard to the retention of student interest in engineering, students who participated in the Entrepreneurs Program were much more likely to remain at the university and in their declared majors as other students. Program participants who began their careers majoring in engineering were also much more likely to remain in engineering than non-participants. The Program even caused a few students to change their majors to Electrical

and Computer Engineering from other disciplines. Some of the younger students surveyed indicated that the Program was one of the reasons that they decided to remain in their engineering major.

With regard to improving the quality of the engineering design experience, seniors who participated in the Program did not appear to have a significantly different experience from other Electrical and Computer Engineering students taking capstone design. However, those interviewed agreed that this experience was the best design experience they had in their academic careers because it was the most practical. The multi-semester nature of the course was appealing to many students. Two-thirds (14/21) of the underclassmen surveyed said that they would sign up for the course again. Only two students said that they would not sign up again because of a bad experience. In practice, about 25% of students take the course for multiple semesters. This is most likely due to the fact that the course currently must be taken on an overload basis (i.e., the credit doesn't count toward any requirements) and students find that they have scheduling conflicts.

Teamwork and leadership skills did seem to improve for the students. Seventy eight percent of the students overall felt that their teamwork skills improved, including 93% of the senior leaders. All of the senior leaders felt that they were effective leaders although only 80% of the team participants agreed. The faculty advisors observed the improvement in teamwork and leadership skills throughout the semester and felt that those senior leaders who had participated in the Program earlier were the most effective. Students who have had work experience (through co-ops, internships, or full-time) found that the leadership and teamwork skills that they learned in the Program were extremely valuable and transferable to their jobs.

Although few students go to work immediately after graduation for a small company or start one themselves, the skills that they learned are valuable in the larger companies in which they work. Industry sponsors, such as IBM, have organized into units where the entrepreneurial spirit is encouraged and the teamwork and leadership skills learned in the Program are valuable. The dynamics of small companies are something that students learned about both through experience on their teams and through the seminar series. Eighty-seven percent of the students found the seminars interesting and 88% found them important.

Conclusions

The model of the Entrepreneurs Program is one that we feel can be implemented in any engineering program. It lends itself well to multidisciplinary teams, although those have not yet been implemented at NC State. The Program has been successful at promoting retention in engineering and in developing teamwork and leadership skills among the participants. Students who participate for multiple semesters seem to get the most benefit. They learn teamwork skills and leadership skills and have the opportunity to continuously apply them as they develop more technical skills.

For more information about the Engineering Entrepreneurs Program, including a detailed description of the course philosophy and operations, published articles about the program, student project examples, as well as the full evaluation report, please visit our web site at http://www3.ncsu.edu/dox/ep. Seminar series and student presentations are available on videotape for the cost of reproduction.

Reference

[1] Accreditation Board for Engineering and Technology, Criteria for Accrediting Programs in Engineering in the United States. Available on the world wide web at http://www.abet.ba.md.us/EAC/eac2000.html. 1995.