How to Assess the Effectiveness of Engineering Programs in Invention, Innovation and Entrepreneurship

E. L. Wang, J. A. Kleppe
University of Nevada, Reno

Abstract

A special capstone course for senior electrical and mechanical engineering students has been developed at the University of Nevada, Reno. The class also includes MBA students from the College of Business Administration. All phases of new product development including innovation, patent law, product liability, business, sales, marketing and venture capital are covered. This paper presents some techniques for assessment of this multidisciplinary class that have been developed over the past several years. It has been concluded that it is extremely difficult for a student or group of students to form and/or operate a business successfully without strong, dedicated, long-term support of a mentor. The graduates of this program do, however, quickly become key elements in the companies that they join. They bring to the table learned entrepreneurial skills that can be applied to most any business, company, or product development team.

I. Introduction

The Mechanical and Electrical Engineering Departments at the University of Nevada, Reno are participating in a program on entrepreneurship education. As part of this program, a multi-disciplinary senior-level capstone undergraduate course (MECH 452/EE491) is taken by all mechanical and electrical engineering undergraduates.

Both EE 491 and MECH 452 are offered once per year during the spring semester and traditionally have enrollments of approximately 30-40 students each. While innovation and entrepreneurship has been part of EE 491 since the early 1980's [1, 2], they were introduced in MECH 452 only as recently as 1996. The two courses shared lectures in 1997 and have been completely integrated since 1998 [3].

In addition to the engineering students, MBA students enrolled in an independent study course (BADM 793) also participate in EE 491/MECH 452. The MBA students assume the role of business mentors and provide aid in the development of marketing studies. Each MBA student selects one E-Team to focus on to develop a full-fledged business plan for. The selection process is treated like a venture capital screening process whereby the MBA students read each E-Team's reports and proposals and selects one based on merit of the proposal and perceived potential for success.

While the instructional material focuses on innovation and entrepreneurship, the goal of the course is not necessarily to produce entrepreneurs, but rather engineers better prepared to enter

the workforce. To achieve this goal, students form companies known as E-Teams ("E" denotes both Excellence and Entrepreneurship). The E-Teams are charged with the responsibility of generating product ideas, evaluating and selecting one of the ideas, developing a working prototype, and performing market and financial analyses to determine if the product could sustain an actual business.

By providing engineering students with exposure to the business world prior to graduation, they are better prepared for both engineering and management positions. They gain a better understanding of the process required to develop marketable products; become engineers capable of working on multi-disciplinary teams; they understand product development, marketing, and finance as well as the technology; and they gain the ability to communicate effectively to their peers, suppliers, and customers.

This paper presents a brief description of this unique capstone course and discusses the observations concerning assessment made during the past few offerings.

II. Course Description

Entrepreneurship is a difficult subject to teach. There are no roadmaps to success. Thus, rather than having the faculty give lectures *defining* what entrepreneurship is and what it takes to succeed, a more inductive teaching method is used[4]. The course utilizes a series of two-dozen special lectures on business, innovation, and entrepreneurship provided by experts in their respective fields. Topics, lecture formats, and specificity of material vary widely depending on the guest lecturer. The lectures cover areas including: patent law, financial records, venture capital, SBIR, product liability, ethics, product development, creative thinking, invention, and starting your own company. Perhaps the best known of all the guest speakers is Dr. Paul MacCready from Aerovironment, developer of the human powered Gossamer Albatross[5]. By providing students with a broad experience of relevant lectures, it is hoped that the students will infer what innovation and entrepreneurship is all about.

Like many capstone courses, the lectures are supplemented with a large-scale project-based learning activity. In the span of 90 days each E-Team must go from concept generation to working prototype. Along the way they work within a budget, order supplies, consult with industry sources, prepare a marketing plan, conduct patent searches, and learn to communicate on a professional level with other engineers and business representatives. Teams must organize themselves quickly, select officers, assign duties, and develop teamwork skills. Needless to say, students find the course both extremely time consuming and extremely rewarding.

The grading of the course is also quite innovative. The E-Teams are awarded "points" for their oral and written reports. These points are treated as currency, which can be traded between teams for services rendered and/or parts. For example, if one team has a particular expertise in writing financial statements, they can "offer" their services to other teams for "points." Each student on a the team receives the same number of grade points, with a peer evaluation determining whether or not a particular student did not perform up to the expectations of the team. Because of the unique nature of the guest lecture series, attendance constitutes approximately 30% of the grade points. When one team member misses a lecture, the entire team is penalized. It is up to the team to inform the member who missed the lecture as to the content and main points made by the

guest lecturer. The faculty provide oral examinations for students who missed lectures as a chance to earn back team attendance points.

III. E-Team Projects

The projects are obviously the main component of the course. The major requirement for each project is that each company (E-Team) must design and construct an electro-mechanical product (prototype). Project concepts generated by faculty, industry, previous E-Teams, and students are all welcome. During the first week of class, a list of the faculty, industry, and previous E-team generated projects is discussed and "project folders" are made available for review. Each project folder contains as much background information as possible, which helps the E-Team decide which project to work on. The folders also tend to jumpstart teams by providing substantial amounts of background information. Student generated projects can either be presented to the entire class or to individual E-Teams.

After all the potential projects have been described, each team selects a project to work on. The students must then provide both an oral presentation and a written proposal whose format is based on both government and industrial formats. The proposal is evaluated based on seven topics, including: technical background/significance of the problem, specific project objectives, research or product development plan, related research, personnel, facilities, and budget[2]. If the proposal is rejected, the E-Team must either resubmit a revised proposal that addresses the deficiencies or select another project and submit a new proposal. Due to the obvious time constraints imposed by the course, the rejection of a proposal places additional pressure on an E-Team.

Once their project has been approved, each E-Team sets out to solve the problem/project. During the course of the semester, each team presents three oral and three written progress reports. These reports update the faculty and fellow students as to the progress in both the engineering and business aspects of the project. Like a design review, constructive criticism is the main emphasis of the progress reports. Understandably, the major difficulties encountered are usually business related, such as market projections. The E-Teams tend to concentrate on the engineering aspects of a problem and lose sight of the overall goal (deliver a marketable product on time). Another common mistake students make is that they try to justify employing every team member in their business plans without realizing that the company will support the only staff that makes it profitable based on realistic market projections.

Project failure is treated in a very unique manner. If a team cannot complete the project selected, due either to engineering, business, or personality problems, the E-Team can declare bankruptcy. In the event of a bankruptcy, all points earned by the E-Team are lost and each individual member of the E-Team is faced with the choice of either "interviewing" with other E-Teams or retaking the course next year.

E-Teams can also choose to fire a team member for unsatisfactory performance or behavior. As in the case of a bankruptcy, a student who has been fired must either interview with other E-Teams or retake the course next year. Of course, most personality conflicts are resolved before it comes to the ejection of team member from the E-Team. Additionally, the course faculty always

mediate any bankruptcy or personality/performance conflicts before any action is taken, which usually results in an amicable agreement being reached.

Working on a failing project or being fired is rarely treated as a negative outcome. It is emphasized to students that *products fail, not engineers*. Oftentimes products and/or projects fail due in no part to the engineering. As a case in point, during the 1998 offering one E-Team was faced with going bankrupt. After spending approximately 10 weeks researching and developing a prototype air filtration system that utilized water as the filtering media, the team found that the concept could not compete on a price/performance level with existing electrostatic filters. Faced with certain bankruptcy, the team exercised some innovative thinking and managed to apply the same filtration technology to develop a system for automatically removing lint from clothes dryers. Due to the water-based filtration, the system also provided a means of suppressing clothes dryer fires caused by lint. Their engineering skills were not to blame for the original product failing. The fact that the team was able to successfully apply the same engineering skills to produce an alternative product was an indication of their excellent engineering capabilities.

The course culminates with a final written report and presentation. All teams must produce a working prototype by the end of the semester. The written report must include a description of both of the engineering and the business research that went into the development of the prototype product. The final presentation is a major event attended by faculty; university, business, and government representatives; local and national media; and others interested in innovation and entrepreneurship.

IV. Assessment

In general, assessment can be broken down into three categories:

1) Assessment of student work (e.g.. grading)
2) Assessment of course logistics (e.g. continual improvement of course) and,
3) Assessment of learning outcomes (e.g. were the learning objectives met?).

Student work is assessed during the semester in three ways: student peer assessment, faculty assessment, and industrial assessment. The assessment of student work in a projects-based course is never simple. The approach taken in this course is to assign the team an "average" grade based on the work submitted as a team. Each presentation and report is graded by at least 2 faculty members. Evaluating teams relative to one another is difficult because each project is different and, more often than not, the place within the development cycle is different among teams. Thus, the grading criteria is largely performance based, with the team's own project proposal serving as the benchmark.

As a part of the team grade, all student projects are judged by a panel of practicing engineers. Just prior to the final presentations to invited guests, a "practice" presentation is given to 4-5 representatives of ASME and IEEE, the relevant engineering professional societies. The student projects are judged based on both the engineering and business content.

The grade received by each team member can be either higher or lower than the team average depending on individual contribution. The average, however, must always remain the same. The

two major determinants of individual contribution are peer evaluations and class attendance. Several standard peer evaluation forms are made available to all teams (students have had several opportunities to use these forms in previous courses). In addition to affecting the entire team's grade, an individual's attendance record is also used by the faculty a measure of individual contribution.

In addition to formal assessment of student work, informal assessment by the faculty is a critical component to the course. During the process of mentoring a team, which often requires large amounts of contact hours, the faculty perform informal assessment of both the group's work and individual contribution. During the time spent mentoring, the faculty member usually gains a fair understanding of who is doing what within each team.

At the end of each semester the course logistics, which deals with the execution and planning of the course, are also assessed using student evaluations, faculty/TA reflective evaluation, evaluation by industrial representatives, and alumni feedback. Like all classes in the College of Engineering, students complete an end-of-term course evaluation. However, since we are not trying to assess how much students like the course, but rather how to improve the mechanics of the course from an instructional point of view, these evaluations are of little utility to us. Instead, informal feedback, from students, faculty, and industrial representatives is used to drive the changes for the next year. Innovation followed by continual improvement is a design model we stress to the students and is the same model that has been applied to the development of this course.

The last issue to be addressed is the assessment of student learning, which is the hardest entity to assess. Thus far student learning has only been assessed qualitatively using anecdotal evidence. Alumni of the course often find themselves in key positions in their workplace due to the additional knowledge they gained from the course. Several course alumni have returned as guest speakers to testify as to the importance of what is learned. Likewise, alumni of the College that did not have the course overwhelmingly support the course because they wish they had been as well prepared as our current graduates are.

Towards the Future

To better quantify the learning outcomes assessment, we have begun surveying the alumni of the course. Of primary interest is how useful the course has been in their professional careers. Would they recommend this course to a friend? Additionally, pre- and post-tests will be compared to assess what the students felt they learned in terms of both engineering and teamwork skills[6].

Conclusions

Based on the experience of the past two offerings of this multi-disciplinary course, the following conclusions can be drawn:

1. It is extremely difficult for a student group to form and/or operate a business successfully without the long-term support of a mentor with extensive business experience

2. Engineering students are more than capable of tackling the engineering aspects of the projects, but do not have the expertise to develop a business plan. In this sense, a mentor is an essential component of the E-Team.

3. The vast majority of E-teams will not go on to create new businesses.

4. Given #3, the E-Team experience is still worthwhile since students bring to the companies they work for an entrepreneurial skill set that greatly benefits most companies.

5. Students like to work on their own ideas, but the scope of the project and stage of development usually limit the project potential.

6. Most E-Team projects cannot realistically be completed in a single semester. Projects that have been jumpstarted in one way or another have much higher chances of completion.

7. Entrepreneurship courses/projects are often not seen as "real" projects within engineering.

8. Assessing the learning outcomes will take long term tracking of alumni.

Acknowledgments

Funding for this project was provided by several grants from the Lemelson Foundation and the National Collegiate Inventors and Innovators Alliance (NCIIA).

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Eric L. Wang
Eric Wang is an Assistant Professor of Mechanical Engineering and Biomedical Engineering at the University of Nevada, Reno. He joined UNR in 1995 after earning his Ph.D. from the University of California at Davis. Dr. Wang received an MS degree in Mechanical Engineering from the Massachusetts Institute of Technology and a BS degree from UC Berkeley. In addition

to his pedagogical activities, his research focuses on orthopaedic biomechanics and intelligent materials.

John A. Kleppe
John earned his Ph.D. in Electrical Engineering at the University of California, Davis. He has been a professor of electrical engineering at the University of Nevada, Reno since 1969, where he held the position of chairman of the Electrical Engineering/Computer Science Department from 1985-1988. In over thirty years of design and research and development experience, Dr. Kleppe has published over 100 technical papers and one textbook.