Entrepreneurial Skills for Engineers - An Interdisciplinary, Team Project Approach

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KEYWORDS: *Entrepreneurial, interdisciplinary, commercialization, business, wireless*

ABSTRACT: *We report on our experience with a course where engineering students learn to create a commercialization plan for a technological innovation. Student teams consisting of both business/economics masters students and research engineers design an entrepreneurial strategy for bringing the technology out of the doctoral students' labs and into practical use. Engineering students develop written and oral communications skills as well as experience in a multidisciplinary team environment as a by-product of the course structure. The innovative team-taught course focuses on commercializing a wireless or networking technology with the goal of establishing more entrepreneurial business skills in engineering students. We discuss our approach to the interdisciplinary course, the course structure, and the goals for the course. We address the lessons learned, the advantages and challenges, and the implications for future coursework designed to imbue engineers with business skills. Based on our experience in this and prior courses, multidisciplinary education is more likely to be successful with our team-oriented and project-focused structure.*

1 INTRODUCTION

Some of the most pressing needs in engineering education were recently addressed by the President of the U.S. National Academy of Engineering William Wulf, and the Chair of the National Academy of Engineering Council, George M.C. Fisher [Wulf and Fisher 2002]. They argue that there is an urgent need to remedy the fact that engineers today are "ill-equipped for complex interactions across many disciplines" and that "knowledge of the global … business contexts for design are now important parts of an engineer's repertoire" but are not part of the engineering students' education. In addition, the Accreditation Board for Engineering and Technology argues "it is essential to include a variety of realistic constraints, such as economic factors" in engineering designs [Eagan, et al 2002]. Dr. Eli Fromm, recipient of the National Academy of Engineering's 2002 Bernard M. Gordon Prize, notes in his acceptance speech entitled "The Changing Engineering Educational Paradigm" there is a crucial need for "a more rounded graduate with the ability to function in the socially interactive, communicative, and business climate of modern industry" [Fromm 2002].

We report on our experience offering a course where engineers work closely with business students on an exercise of direct relevance to the graduate engineer -- their thesis project. Course material is tightly focused on learning skills needed in designing a plan to move their research innovation to market rather than merely covering standard business topics. In completing their term projects, students are expected to incorporate strategic industry analysis and a detailed financial plan into a presentation that will convince potential real-world industry partners that their product will be a business success. Engineering students develop written and oral communications skills as well as experience working in a multidisciplinary environment as a by-product of the course structure.

In this paper, we discuss our approach to this interdisciplinary course, the course structure, and the goals for the course. Designing the project orientation of the course is crucial for achieving the pedagogic goals. We address the lessons learned, the advantages and challenges, and the implications for courses designed to imbue engineers with business skills.

2 COURSE STRUCTURE AND DESIGN

The course focuses on developing a commercialization plan for a wireless or networking technology with the goal of increasing the entrepreneurial business skills of engineering graduate students. The course is required of second-year doctoral students in a research program in advanced networking. The program was created and funded by the National Science Foundation to improve the background and preparation of doctoral students as they progress toward either an academic or industry career. The concept for the course is based on an earlier experience with a successful interdisciplinary course taught to undergraduate and masters students in engineering, geography, economics, and business [Bostian, Carstensen and Morgan 2001].

Teams contain both business/economics graduate and research engineering students. The team designs an entrepreneurial plan for bringing the technology out of the doctoral students' labs and into practical use. Using a technology on which a researcher is currently working has the advantage of providing a real research issue that directly connects with the research engineers' interests rather than an abstract or hypothetical engineering topic. It also introduces different challenges for the instructors, as discussed below.

At the start of the semester, PhD. engineering students (the Fellows in the Integrative Research and Education in Advanced Networking Program, “IREAN”) present to the class a description of technologies and innovative ideas that they have for their theses.. Then business students are given the opportunity privately to express their preferences on which technology project they wish to work. The instructors tried to meet as many of the preferences as possible in creating the teams of both business and engineering students. In this way, the engineers were linked with business students for the remainder of the term.

The instructors presented an overview of the wireless industry both on the technical and business issues. While business students found much of the technical material new, even the PhD. engineers recognized the benefit of a broader overview of their industry since they seldom have time to focus beyond their research area.

Throughout the semester, lectures and guest speakers built the knowledge base "just in time" for achieving milestones leading to the final product. Lectures featured economic and financial building blocks such as:

- Porter’s Five Forces of Competitive Advantage
- Financial statement analysis and analysis of profitability
- Capital budgeting for wireless projects
- Game theory principles and applications

Industry speakers and our colleagues in other departments augmented the instructors’ lectures with content blocks interwoven on topics such as:

- Market research and high tech products
- Venture capital
- Investment banking
- Corporate research parks and startups
- International developments in wireless regulation
- Government policy and 3G
- Intellectual property protection

There were significant advantages as well as disadvantages to relying so heavily on guest speakers to deliver course content. On the plus side, we are not experts on all of the topics that needed to be covered in this course, so the only way to deliver a well-rounded approach was to call on other peoples’ talents. Having industry experts come to class added credibility to the course, especially when the lessons contradicted the students’ intuition. We think that most of the difficulties can be prevented as discussed below.

In future courses student teams will meet with invited speakers. Students and speakers would have welcomed more than the brief question and answer sessions that were included in the class periods. The wealth of knowledge and expertise of the speakers was not fully exploited for the benefit of the students.

We chose to give speakers only minimal guidelines for the presentation they made to the class. In retrospect we realize that they need to cover specific topics in enough detail that students can make direct use of their lectures. Sometime speakers successfully achieved our unstated goals, while others did not. We now have the experience to give students better guidelines about what they need to learn from speakers as well as more information about the students' present level of knowledge.

Students who were not familiar with a lecture topic occasionally misinterpreted a speaker (or instructor) when statements are taken out of context. For example, when investment bankers say that in the final analysis "business plans are not important" to getting funding, they mean that the final decision often is determined by more intangible factors. This is only true in the context that anyone who has made it to the final stage must have a solid business and financial plan. Thus at this stage the business plan is not the discriminating factor. Instructors must make an extra effort to counteract unexpected effects that a speaker can have on students from other disciplines.

Alternating different topic areas, instructors, and speakers is intended to enhance student understanding and to reduce the monotony. For students who are already exposed to the material, this avoids having them miss class or "tune out" for long periods during the course. However, it also means the subjects are broken up with less continuity. Students indicate that they thought the material was disorganized, that the material lurched from one topic to another and was choppy. This is a valuable realization. The tradeoff between monotony and continuity versus dynamic flexibility went too far toward the dynamic end.

3 COURSE OBJECTIVES

This section is organized according to the objectives we had for the course. For each objective we discuss how the objective is achieved and what challenges are encountered.

3.1 Develop a professional commercialization plan

Our experience with integrative teaching in this and other classes points to the importance of project work as a unifying element that forces collaborative work across disciplines. We believe that this combats the reported malaise felt by engineers who feel disconnected from the practice of engineering [Begley 2002]. The projects need to have strong interdisciplinary content so that each team member can make a contribution and a contribution that will be recognized by their teammates as valuable. Because the course grade is heavily dependent on the project output, students tend to take the exercise seriously. They focus on the end product. Because there is a heavy workload to accomplish their objectives of getting a good grade, they realize that they must rely on their team mates to shoulder the portions of the project for which that team member can provide the most value. This interdependence helps students recognize the contributions of various disciplines to the commercialization plan.

The strengths of this approach are that students focus on the end product (the commercialization plan) and they see practical application of the concepts and the role for other disciplines that in some cases allows the division of labor and allows engineers to focus on their strengths. Students bring to the course research topics to which they are already committed. Usually they want to see a successful implementation.

The disadvantage of our approach is that the students are exposed to topics with less depth than in a traditional course. The course quickly moves from one topic to another in order to get enough material covered so that the projects can be accomplished on time. Students struggle more with each aspect of the plan than they would if more time is spent on each. However, this aspect of the course also reflects practical circumstances where there is not enough time to acquire enough data for an in-depth review.

- In addition the instructors face several challenges that are not common in traditional class settings, as mentioned below.
- The instructor has little control over research topics that Ph.D. students bring to the class. So the instructor does not know in advance the precise topics that need to be covered. Thus instructors need to be more flexible on coverage of planned material (one might have to spend more or less time based

on previous exposure of students outside the discipline being presented). Advance information about the students' research projects is helpful in planning the semester.

- Projects range from nascent stages to near completion. Therefore, instructors need to be sensitive to the lessened ability to describe and market a nascent idea versus an invention approaching the patent process. In addition, Fellows who are just starting their topic definition have more difficulty explaining the commercial value to the class and to their team mates.
- Instructors must quickly tailor assignments to different projects already in progress when students enroll. An assignment for a market definition maybe useful to a brand-new thesis idea, writing a sales letter to a customer that identifies the strengths of the invention is a better assignment for a team that already is aware of the market.
- There is no textbook so instructors developed additional reading assignments (book chapters, magazine articles, websites) just in time. A study guide handout packet as well as syllabus is ideal, if one has advance knowledge of the topics needing coverage.

3.2 Communicate technology to non-technical individuals

The PhD. students are challenged by the instructors at the start of the semester to bring the other students up to speed on the research topic area and this task continued throughout the term. As the Fellows make progress on their research, team members are updated and in some cases the emphasis in the commercialization plan changes. The initial presentations had varying degrees of success. Some students, steeped in their fields of research, used a lot of jargon and were stopped repeatedly by the instructors and the class members. Especially at the start of the class, students do not want to appear dumb in front of accomplished engineers. Thus the instructors must take an active role as the "dumb layperson" and force presenters to use language and terms that will be understood by the general audience. Although this creates some initial friction, it can be done in a friendly spirit to set the tone early of creative dissonance. It is vital that every student realizes that the objective is not to be mean, instead that other students in the class, like venture capitalists or investors, are not as accomplished at the topic area as the speaker/researcher.

3.3 Work in heterogeneous teams

Success of team projects depends on extensive interaction with team members. The team approach stimulates collaboration with others outside the students' own disciplines providing valuable practical experience.

Some teams can be so heterogeneous as to be dysfunctional. One such team developed in our first course and never realized the importance of integrating the views of all its members nor recognized that this was intended as a serious endeavor. When compared with the work products of other teams, it was apparent that this team was missing the point of the course and was not willing to cooperate among themselves or with the instructors. A weakness of our approach is that it relies on the students being motivated to participate and integrate or to eventually recognize the value in doing so. One team never achieved this realization and integration. Cultural differences could have been a contributing factor. However, the other teams in the class made noticeable progress in integrating a variety of views and skills. The instructors noted increased discussions within groups as the term continued.

Another noticeable change occurred with an increased recognition of the value of business skills. Although marketing is often viewed as inconsequential, by the end of the projects most of the teams expressed concerns that they did not have enough time to obtain more marketing information and to understand the market better. Several engineers made such comments in a surprising turn of events relative to the beginning of the course. In addition, we received several comments about the value of financial plans for the team's ultimate understanding of the strengths and weaknesses of the technology. Although some of the details of the financial modeling are tedious, the comments indicated a perception that building the financial model focused attention on key issues and assumptions about the market and the technology. These comments came from both engineers and from non-financial MBAs.

Based on this course as well as an earlier interdisciplinary course, it may be advisable to provide more time for market research. The semester format may not be long enough for the kind of market investigation that is required. A two semester course is one solution that we are considering.

In a serendipitous circumstance, two students in the class were married to each other prior to the class; one an engineer and the other a business student. With some trepidation, we allowed the two to work on the same team. Another observation on the success of the course is that the couple remained married at the end of the course! They commented that the course helped each of them better understand and appreciate what the other does in their work – something that merely talking to each other about their jobs did not accomplish.

3.4 Enhance presentation skills

Team members had ample opportunities to practice their oral and written communication skills. They were given periodic assignments as milestones toward their final product, the commercialization plan. The same team member was not permitted to make repeated presentations for the team, no matter how accomplished that individual was at presenting. Each team member was required to participate by making one oral presentation to the class in the presence of guest reviewers. We find that it is important to force students to be responsible for one presentation since there are often team members who would not otherwise get up in front of a class. Furthermore, we stipulated that the PhD. student not be the presenter of the material on the technology after the first presentation. (In prior courses, engineers could not make engineering presentations, MBAs could not make financial or business presentations and geographers could not make geographic presentations.) This "cross-training" exercise is usually very successful. It forces non-technical students to present the technology and forces the researcher to explain the technology sufficiently well to colleagues so that they can deliver a presentation on the technical aspects of the project.

An effective result was that the students received feedback from the audience, made up of class members in other groups. They heard from their peers what modification of their business plans was needed for clearer understanding. The class members functioned as a real-world audience, albeit in the classroom.

Instructors graded the presentations and written assignments and provided feedback to the students. Over the course of the semester we noted marked improvement in descriptions of the technology by several of the teams. The PhD researcher who had the most difficulty at the beginning produced one of the best technology descriptions in the end product.

3.5 Learn how the business world works

One of the major cultural differences between engineers and business managers concerns the sorts of work product they value. Engineers like to solve problems. Business managers like to make money. They often fail to communicate with each other because no matter how neat the engineer's solution to the problem is, if it won't make money the business manager is not going to get excited. A major goal of this course, therefore, was to help the engineers learn to speak the language of business.

Students learn about the process for identifying the business opportunities for technology by brainstorming with teammates. They learn that even the best technology faces important hurdles with the financial and business communities. The focus on how the technology might be implemented is somewhat new to the doctoral students.

Guest speakers emphasized the importance of being able to "sell" your ideas inside your own company. A career engineer highlighted the role that non-technical issues played in decisions about whether a technology is implemented or not. One speaker presented materials intended for decision makers at his company in the following weeks. This demonstrated the process by which decisions are made, the preparation needed to influence decision-makers as well as good presentation skills.

To make some of the issues more concrete, we arranged for a visit to a pilot test site for a new communications technology. The company that was functioning as the value added reseller and service provider provided a lecture from the equipment manufacturer's representative. In addition we visited the "network control center" for the small trial network deployment. Students commented that additional visits to such companies would have been valuable. The tours and discussions give them an additional appreciation of the difficulty of deploying technology to paying customers. More such visits are planned for the future offerings of the course.

Some student teams were concerned about how to protect ideas and inventions embodied in their technology. The greatest interest was in protecting computer software. All the teams quickly determined that their best strategy was to license the software to an established company and collect the license fees rather than building and selling devices that used the software. Although there was much concern about intellectual property, there was a heightened awareness of the issues in financing a startup manufacturing operation and the obstacles posed. The problems of protecting software from piracy, imitators, and competitors did not seem to outweigh the financial issues in student thinking. Nonetheless, students who had not previously thought about protecting intellectual property developed in their research arena gained some understanding of the time and steps that the exhaustive process and legal issues involve. They are now aware that universities have a mandate to ensure that inventions arising from federally funded research are commercialized. In subsequent courses, we will schedule more time on the process and risks of software licensing.

4 SUMMARY AND CONCLUSIONS

The course successfully provides doctoral engineering students with a unique experience working together with business students. They acquire and develop business-like skills marketing their research to their classmates, to guest venture capitalists and viewing the business context for their R&D. In addition to the technical skills including financial budgeting and market research needed for technology commercialization, students learn about the different culture of business. They now appreciate the skills for coping with that culture and the skills that business researchers bring to the various challenges encountered by the entrepreneurial engineer. Educating engineering students, in our experience on this and prior multidisciplinary courses, is more likely to be successful with our team-oriented and project-focused structure. It provides significant value to engineering students whether they intend to stay in academia or to work in industry.

ACKNOWLEDGEMENTS

We express our appreciation to the National Science Foundation (NSF Award #9987586) for their support and to Charles Bostian and Bill Carstensen for their collegial support and assistance. We also appreciate the contributions made by our numerous guest speakers who devoted considerable time helping prepare our students. The authors are responsible for any remaining errors.

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