

Incorporating Global Entrepreneurship Courses Into an Engineering Curriculum

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Abstract

It is widely recognized that engineering students need to know more about business practices, entrepreneurship, and the global economy. Unfortunately, engineering curricula cannot easily accommodate such classes due to engineering accreditation and university core requirements. A new, two-course sequence is being developed at Baylor that will integrate engineering economics and business communications with entrepreneurship, replacing traditional courses in engineering economics and technical writing. The first course will integrate technical writing, professional speaking, and engineering economics to provide a rich, synergistic learning experience. The principles learned in the first class are further developed in the sequel course on technical entrepreneurship. The technical entrepreneurship class will develop principles of entrepreneurship in a global economy and will include developing technology-based business plans for industrial firms, allowing students to apply in a real-world situation what they have previously learned about communications and engineering economics.

Introduction

Engineers usually work in a business environment. Many new business ventures within companies or new business formations are based on technology, making it essential that engineering students are introduced to the relevant principles, processes, and practices of technical entrepreneurship. Furthermore, the pervasive globalization of the economy has dramatically changed the environment in which engineers practice today. Engineering education needs to prepare students for this new world of opportunity and challenge.

Unfortunately, the rigorous demands of engineering students' technical training, as mandated by engineering accreditation and the fundamentals of engineering examination required for licensing, and the usual university core requirements that apply to all students, leave little opportunity in engineering curricula to prepare engineering students to function effectively in this global, entrepreneurial environment. A joint initiative between the Hankamer School of Business and the School of Engineering and Computer Science at Baylor seeks to remedy this situation by replacing the customary, stand-alone courses in engineering economics and technical writing with a carefully designed two-course sequence that fully integrates the teaching of engineering economics, technical/professional communication, and global entrepreneurship to maximize the synergism and provide more realistic learning experiences that mimic entrepreneurial business practices in technical companies or startups.

Literature Review

During the past five years, there has been a rapid growth in the inclusion of entrepreneurship in engineering education with strong support from the professional societies. For example, the American Society of Mechanical Engineers' Center for Engineering Entrepreneurship & Innovation held a competition in 2007, with the finalist presenting at the ASME Annual Meeting November 9, 2007. Entrepreneurship activities in other engineering societies are also increasing rapidly. Engineering programs around the country are now introducing entrepreneurship to their students in a variety of ways.

Steve Nichols¹ has championed the development of engineering entrepreneurship classes, developing pedagogical justification for including entrepreneurship in engineering education and defining what a course in engineering education might include. His work has been based on a pilot course at the University of Texas (Austin) and documents from the National Science Foundation, the American Society for Mechanical Engineers², the ABET accreditation board, and pilot courses being developed at California Institute of Technology,

Massachusetts Institute of Technology, Stanford, and the Universities of Wisconsin (Madison), Illinois (Urbana), and Maryland (College Park).

Some schools have incorporated engineering entrepreneurship into their curriculum using a product development approach. One approach is to have an interdisciplinary course where business students and engineering students work together on teams, with the course being team-taught by professors from business and engineering. Deliverables include an intellectual property search, a project proposal, a market analysis, a product requirement specification, an engineering design, a financial plan, and a marketing plan.³ Others have used the Formula SAE car competition by combining the engineering project with the development of business plans written by business students around the new technology developed for the Formula SAE car.⁴ While giving the engineering students the experience of working with business students, it unfortunately did not have them as directly involved in the business creation aspects of the project. Lehigh University also uses product development to introduce interdisciplinary teams to entrepreneurship.⁵ This has resulted in new courses as well as new, integrated degree programs such as a joint MBA and Engineering degree at Lehigh. The Mechanical Engineering Department at Yuan Ze University in China teaches international business and entrepreneurship around fuel cell technologies they are trying to develop.⁶ The University of Puerto Rico has used product development as a platform on which to teach a new course entitled “Technology Based Entrepreneurship.”⁷ Students in the EPICS track at Purdue University can take courses to learn about entrepreneurship and management of intellectual property and may obtain further assistance from the Krannert School of Management if they want to try to commercialize a new product.⁸ The University of Nevada has developed a capstone class for seniors in electrical and mechanical engineering with seniors in Business. The class focuses on the fundamental principles of invention, innovation, and entrepreneurship.⁹

A second approach being taken to introduce engineering students to entrepreneurship is to work with companies doing technical development or assessment of new product ideas suggested by a company, including a feasibility study of the technical and economic viability of the potential product. A full business plan is produced when the feasibility study looks promising. For example, Brown University has a two-semester course where teams of engineering students work closely with companies to explore commercialization.¹⁰ Cooper Union, working closely with their engineering alumni, friends, and extended family, is delivering authentic opportunities for engineering students in teams of about four students to develop a business plan for a product or service of their choice.¹¹ Case studies, guest lectures, and off campus visits are used to provide students with the necessary tools and motivation. The College of Engineering at Penn State University, with support from GE’s Learning Excellence Fund, is developing undergraduate engineering courses that integrate product conceptualization, design, technical, and economic feasibility in the context of industry-sponsored engineering design projects.¹² Business, Engineering, and Information Science and Technology students work together on interdisciplinary teams. The University of Pennsylvania has developed two Engineering Entrepreneurship courses that receive the highest student ratings of all the courses offered in the School of Engineering.¹³ The premise of these courses is that “engineers create and lead great technology companies, hiring managers where needed to execute their vision.”

The two-course sequence being developed at Baylor University to introduce engineering students to technical entrepreneurship will follow the second approach described in the literature search above; namely, using interdisciplinary teams of engineering and business students to do feasibility studies and business plans for companies who propose project or product ideas.

The New Two-Course Sequence at Baylor University

Course Assumption and Design

The proposed two-course sequence must achieve a similar mastery of engineering economics and technical writing to current courses while also introducing students more broadly to principles of professional speaking, technical entrepreneurship, and the global economy. How is this possible?

The design of the sequence is based on two reasonable assumptions: first, engineering students can achieve a high level of proficiency in engineering economics in less time than the forty-five hours of classroom instruction currently required in the stand-alone course; and second, that teaching technical writing, professional speaking, engineering economics, and technical entrepreneurship could be done with a great deal of synergism and realism if done in

a fully integrated two-course sequence. For example, a team of engineering students could do a feasibility study of some emerging technology that might be used for a new venture using their engineering training and engineering economic analysis, then prepare a written report describing the technology and the project's potential economic viability and make a professional presentation of the feasibility study. If the technical venture appears promising, the students prepare a business plan for the startup, working on a team that includes engineering and business students. The learning process concludes with a professional presentation of this proposed project (ideally to venture capitalists). This learning experience is much richer and more realistic than these same topics taught in stand-alone classes.

It is worth noting that teaching these topics together is also much more efficient than teaching them separately. Technical writing classes, professional speaking classes, engineering economics classes, and entrepreneurship classes each spend significant time doing the necessary digging to have something to write about, speak about, analyze economically, or prepare business plans around. If projects can be carefully selected to allow the usual goals of a technical writing class, professional speaking class, engineering economics class, and entrepreneurship class to be achieved using the same project and associated information, then the total learning experience can be achieved by practicing the various disciplines using the same project details. How are these learning objectives and experiences divided between the two classes?

First Course: Engineering Economic Analysis and Professional Communications

Designing the course itself is an exercise in cross-disciplinary collaboration, with faculty from engineering, liberal arts (English), and business participating. The goal is to fully integrate the learning experience for the three disciplines. The key is to keep the focus on what each student needs to learn and how to integrate the learning experiences in the three areas using a few carefully designed projects. Secondly, keeping the desired outcome in mind is crucial: participating students will combine principles and skills developed in the first course with their engineering expertise in the sequel course in Technology Entrepreneurship. The learning experiences in the second course must combine understanding principles, applying them in an industry-sponsored project, and receiving constant mentoring as they go through the process for the first time.

In this first course of the two-course sequence, the course objectives focus on achieving proficiency in doing economic evaluation of engineering projects using time-value of money principles, writing formal reports to both technical and non-technical audiences, and making professional presentations to technical and non-technical audiences. Most of the writing projects and presentations include results from engineering economic analysis, enabling students and teachers to focus on developing, expanding, and integrating skills and knowledge from the three subject areas.

The major project for this semester involves three teams of four students each doing feasibility studies of various renewable energy options for a hypothetical oil company, West Texas Crude, whose oil wells are gradually playing out. The company has done well over the years and wants to reinvest some of its accumulated capital in alternative energy as it seeks to diversify its energy business. One team is doing a feasibility study of wind power, a second team is considering solar power, and a third team is evaluating bio-fuels, including ethanol and bio-diesel. Their written report will mimic what is typically done in a technical writing class as the major writing project. The reports will require engineering economic analysis to determine what return on investment each of these technologies might provide and what scale of investment is required to be efficient and economical. The students will each do their own economic analysis and write their own reports based on the pooled information they collect as a team, to save some time in researching the topic. They will then prepare a PowerPoint presentation as a team to communicate their recommendations.

Smaller writing projects also incorporate engineering economics and professional presentations, making each project as synergistic as possible. For example, the assignment preceding the major project challenged students to use a dataset from an already completed lab experiment they did as freshmen engineering students and write a report that recommended a course of action. Students use analytical skills being discussed in engineering economics, use ASME guidelines for their reports, and they gain experience with drafting, revising, and editing. During the drafting process, writers consult with engineering faculty and with the English faculty member for

assistance with problematic aspects of the assignment. This process prepared them for the more complex major project.

The class time is divided about 60% engineering economics, 25% professional presentations, and 15% technical/professional writing. The engineering economics portion is taught by an engineering school professor; the professional presentations portion of the class is taught by a business school professor; and the technical/professional writing is taught by a professor from the English Department.

Engineering Economic Analysis—The classroom time for engineering economics is primarily used for lectures that cover the usual topics in engineering economics such as the time-value of money and the rate of return analysis, with ample illustrations of how these principles can be applied to evaluate engineering projects. Traditional homework problems and in-class exams are used for learning experiences and assessment. This portion of the course mimics a typical engineering economic analysis except that the principles are used in the writing projects in the first and second courses in a two-course sequence, giving the students the opportunity to do a more complete economic analysis in a real business situation rather than doing exclusively smaller, hypothetical problems from a textbook.

Professional Presentations—The professional presentation time in class is used for lectures on principles of professional presentations and for actual presentations to practice implementing these principles. Classroom presentations are videotaped, reviewed immediately in class with critique, and then repeated during the same class period. Preparation and practice of presentations is done outside of class. The oral communication component complements the written communication component in the course, and also prepares the students for the professional presentations they will make at the end of the second course in the sequence.

Three subsequent lectures cover communication principles, barriers, solutions, skills, and strategies, including time to practice the new skills to ensure understanding. Each team receives a different PPT presentation slide set on a single classic business case. Over the next two weeks, each team practices using its new individual and team presentation skills. Since the content is provided, each team focuses on delivery only. In class, the teams give their presentations, and all are videotaped. Faculty provides critique and non-presenting teams provides peer feedback. Then all teams watch the video recording. Finally, all teams repeat their presentations as time allows. The lead faculty for professional speaking supplies the final form of feedback, which is written, to provide team and individual feedback in addition to the team grade.

One week later, each student team prepares a second presentation, this one based on course content coordinated with the writing assignment just completed. Three more presentations, all content-based, will follow. Each one will be videotaped, critiqued, and repeated in the same session, following the same rigorous pattern established in the first prepared presentation.

Stand-alone oral communication courses provide many opportunities for students to present and receive feedback on a wide variety of topics. Students in this course will give five presentations. Repeating each one a second time following faculty, peer, and video feedback will intensify the process. Coordinating the topics with content from the course themes will ensure maximum effectiveness as well as efficiency. Students understand that both content and delivery of the course presentations will prepare them for collaborating with business students on real-world projects involving innovative technology in Technology Entrepreneurship, the second course in the sequence. At the end of this course, cross-disciplinary student teams will present their findings in extensive written reports and business presentations to company executives or venture capitalists. Knowing this is their ultimate goal provides the students with a practical focus that helps them coordinate and value their efforts in the first course.

Technical Writing—Less than 20% of the classroom time is used for writing instruction. Instead, writing instruction is provided in one-on-one tutorials that focus on student work-in-progress, enabling the English professor to tailor instruction and feedback to the particular needs of each student. Considerable research in writing instruction suggests that this is an optimal situation for learning, especially for learning to write in specific disciplines. Students are required to meet with the English faculty member to discuss revision options for first and subsequent drafts. These one-on-one conferences focus on instruction (formative assessment) rather than summative assessment. Most

speaking and writing projects for the course are suggested by the engineering professor in consultation with the other professors and are also used for doing engineering economic analysis.

Grading of the first course (Engineering Economic Analysis and Business Communications) is weighted 40% engineering economics, 30% professional presentations, and 30% technical/professional writing.

This course is a prerequisite for the second course, Technical Entrepreneurship, where students will have multiple opportunities to further hone their skills in engineering economic analysis, technical/professional writing, and professional presentations.

Second Course: Technical Entrepreneurship

Technology Entrepreneurship is a capstone, experiential learning course that is deliberately cross-disciplinary and project-oriented. Its learning objectives overall are centered in the preparation of both business and engineering students (undergraduate as well as graduate) for strong participation in and leadership of technology commercialization projects and processes, regardless of setting (e.g., corporate or startup ventures). The design employed to achieve these objectives has two platforms: learning the keys to success for high-tech business ventures and demonstrating that learning by applying all the keys to a real-world project for a company or inventor who needs their insights. This design readily incorporates the application and assessment of the engineering students' skills in economic analysis and professional communications.

The most direct and comprehensive assessments are made directly from the quality of what is in effect a junior consultancy engagement at the end of the semester. In each case a business decision will be significantly influenced by the results of the student's work, and thus it is always a requirement that sound engineering and market economic analysis is completed, that the implications of the findings are communicated, and the recommendations to the sponsor are effectively defended. Another critical skill embedded into this learning journey is the ability to deal with incomplete and often contradictory data while still being forced to make a judgment that can be defended. Especially for engineering students, this is new ground, and the role of one-on-one coaching of the project teams by faculty and sponsor throughout the semester is essential. It is typical for each team to meet weekly with the professor, and to hold a weekly conference call with their sponsor. The maturity and professionalism they achieve in this arena is best observed in the Q&A time they spend with the sponsors at the close of their final presentations. When the team can articulate why they have come to firm conclusions about these often imprecise findings, it is clear that they have achieved the preparation we are seeking to instill.

We have found, however, that since many projects do not directly force deep involvement with all the core material in the course (the four modules cover Opportunity Recognition and Validation, Protection of Intellectual Property, Financing the Venture, and Moving into Operations), additional analysis and writing requirements are needed beyond the project report itself. Each team is required to learn about the practices that the company they are working with has in place related to each of the four modules, assess how best practices should apply to the company now or in the future, and write a set of recommendations based on those assessments. As a result the students not only have more practice in professional analysis and communication skills, but gain a richer understanding of how "what's in the book" translates into practice for real companies much like the ones they will soon join.

The global flavor of this course is brought in via two mechanisms. First, many of the projects have a global scope—technology being commercialized includes pieces from outside the US, the target market is global/multi-national, or in some cases the sponsor's location is an international one. Examples of this include a global market feasibility assessment performed for a drug research firm in Belo Horizonte, Brazil and a new-product value equation analysis for a semiconductor process chemicals supplier based in both Indiana and Suzhou China. Conference calls at strange hours become part of the routine, in the same way they do for engineers at work all over the world today. Secondly a summer study-abroad version of Technology Entrepreneurship was launched in 2007 in which all the same practices are followed and objectives are accomplished, but with teams that are culturally mixed and the projects that are for China-based enterprises and executed by the students while living in China.

To summarize the opportunities for application and assessment of engineering economics, technical/professional writing, and professional speaking that occur in Technology Entrepreneurship, the second of the two-course sequence: the students research, compile data, and perform analyses related to the value of a given technology-based business opportunity as specified by their project sponsor. In addition they write four formal assessments of current vs. best practice with recommendations, prepare and discuss a mid-term interim findings report, and at end of term deliver a comprehensive report along with an extensive presentation with Q&A.

Assessment of New Two-Course Sequence and Comparison to Currently Required Courses in Engineering Economics Analysis and Technical Writing

Writing Assessment—Assessment of student gains in writing will use qualitative and quantitative methods. For example, for the first assignment of the semester, students assembled examples of writing they had done before the course and wrote an explanation of their writing and research experiences. The examples they submitted will be used as a baseline corpus that can be compared to writing they are doing during the semester, and most importantly, the work they submit at the end of the semester. Writing will be examined using primary trait analysis (identifying traits that are important for professional engineering writing). Students will submit a semester-end portfolio, which will be assessed holistically and qualitatively, using readers from engineering to determine gains in student writing over the semester. Because students in this course are at advanced stages of their degree work, many of them are enrolled in other engineering courses that require writing. When possible, their writing from other courses will be compared with writing done in the Engineering Economics and Business Communications course to assess transfer of skills. Students will also be interviewed at semester-end to gather information on their perception of their learning as writers in the discipline.

For the second course in the sequence, students will be preparing a professional report for an actual client. One important form of assessment will be the client's evaluation. However, while students are engaging the semester-long preparation of the report, their work will be assessed to determine how skills and knowledge from the first course transfer to their work in the second course. Because the writing process will be similar to that used in the first course, the English professor will be meeting regularly with students to discuss their work in progress and provide feedback for revisions. In the course of those interactions, data will be gathered for the assessment of learning transfer and expansion.

Learning to write in a discipline or profession is not accomplished in one or two courses. It is a lifelong process. However, integrating writing assignments and focused writing instructions in this two-course sequence is an ideal example of how writing instruction in the disciplines should occur. Freestanding technical writing courses cannot provide students with the synergy that this sequence provides.

The most important assessment of writing will be the comparison of the students' report presenting their feasibility study at the conclusion of the first course and again with the report to the client at the completion of the second course to the research paper prepared by students at the completion of their technical writing course. The comparison will be made both by professors in engineering at Baylor and the English professor (Dr. Blalock), who also is the primary teacher of the currently required technical writing class for engineering students. Dr. Blalock is uniquely positioned to make careful comparisons on how well the students do in the experimental classes compared to students in the currently required technical writing class.

Assessment of Engineering Economic Analysis—To evaluate the knowledge of engineering economic analysis students had at the beginning of the semester, they took a pre-test on the subject the first day of the semester and showed essentially no knowledge of engineering economics. The students' knowledge of engineering economic analysis at the end of the semester will be evaluated on the final exam using questions from the Fundamentals of Engineering exam. Typical FE exam questions taken from FE exam review materials will be used on the final exam for Engineering Economic Analysis and Professional Communications and also for the currently required Engineering Economic Analysis course. This will allow students' mastery to be evaluated using the FE exam and also by comparison to the mastery achieved in the currently required course on engineering economics taught in the Department of Economics at Baylor.

Assessment of Professional Presentations—In order to provide a baseline for evaluation of progress, student teams are given a simple conundrum during the first day of class to solve outside of class, plus basic instructions to present their results using a PowerPoint presentation during the second class. Each student then presents at least one slide before passing the presentation to the following teammate. The results are videotaped so students and faculty alike could note baseline performance. Three faculty members participate in the ensuing discussion.

Videotaping of each subsequent presentation will allow assessment of the progress the students have made. Comparison of the baseline to the final presentation in both the first and second courses in the two-course sequence will allow professors in engineering to evaluate the efficacy of the professional presentations portion of the two courses. Since their current courses do not include professional oral communication, it is not possible to compare the efficacy of this course to a current course.

A preliminary assessment will be made in December 2007 and will be presented at the NCIIA conference in March 2008, with a final assessment to be made in May 2008, once the students have completed the two courses.

The assessments in the Engineering Economic Analysis and Professional Communications class one week before the final exam have been encouraging. The mid-term exam on engineering economic analysis for the fall 2007, using primarily questions from the FE exam, resulted in a class median of ninety, which is very encouraging. The writing projects so far in Engineering Economic Analysis and Professional Communications have produced work that is comparable, possibly even superior to that being submitted for the Technical Writing class, which is also being taught by the same professor this semester (Dr. Blalock).

Summary

We plan to combine the Technical Writing course and our Engineering Economics course our students currently take into a single course entitled Engineering Economic Analysis and Professional Communications, and then reinforce these concepts in a second class, entitled Technical Entrepreneurship, that focuses on evaluating the feasibility of market deployment of a new technology and preparation of a business plan for a sponsoring company.

Because engineering students are very analytical, we believe that they can learn the necessary engineering economic analysis principles and practices in nine weeks of class time, rather than the usual fifteen weeks, especially if they are also given at least two major projects subsequently where engineering economic analysis is used to reinforce their classroom lectures and homework practice assignments.

The current technical writing class focuses on a research paper, but this is not very typical of the type of writing they will do in industry. The course being developed will focus on business writing and oral presentations, with an emphasis on preparation and presentation of business plans, including supporting financial statements and business reports.

In the companion/sequel course, engineering students will be teamed with business students to develop business plans for companies that are considering commercializing some technology. They will get an opportunity to evaluate the feasibility of deploying the new technology into the marketplace and prepare a business plan for that deployment. They will also prepare a report with recommendation for the company, since the conclusion with some technologies will be that market deployment is not feasible.

While most students will take this two-course sequence on campus, they will have an option of taking the companion classes in Shanghai, China in a summer study abroad program sponsored by Baylor. This program will cover the same content, but will involve students working on projects for Chinese companies in Shanghai. Each four-person team will include a Chinese business student and engineering student, and a business student and engineering student from Baylor, giving an excellent opportunity for students to work on an interdisciplinary, cross-cultural team.

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