

Opportunities in Education at the Confluence of Technology and Management

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Abstract

Due to the increasing need for an understanding of technology and engineering for individuals in management positions, a familiarity with both business and engineering principles, as well as their interdependence, is required. This paper is a study of the academic opportunities offered by selected colleges and universities to prepare students to become business leaders in fields that require the systematic and efficient solution of technological problems. It first describes the categories of programs offered, along with descriptive examples, and then focuses on a unique program offered at Bucknell University. The strengths of these programs are highlighted and suggestions for improvement are given for developing the most effective program.

1.0 Introduction

The business world has become increasingly technology-dependent, and with that has come new expectations for college graduates. Employers look for graduates with strong leadership and communication skills and experience in both engineering/technology and business management. In order to obtain and excel in managerial positions, graduates must have a firm understanding of the interactions between technology and management. The *Engineers Leadership Foundation* and the *Foundation for Professional Practice* conducted a survey of almost two hundred senior engineering managers and leaders, in which they concluded that engineering knowledge is essential, but that leadership positions can be attained earlier if engineering students are exposed to management, public speaking, and other non-engineering coursework. The most highly recommended courses included business management, public speaking, and marketing. In addition to taking courses, the professionals surveyed suggested involvement in activities like sports, internships, volunteering, and clubs to improve interpersonal skills. Engineering and technology-related careers involve life-long learning of not only technical skills, but also people skills, written and oral communication skills, and teambuilding skills.⁶

Institutions of higher learning have responded to the new demand with a variety of degree programs and special centers at both the undergraduate and graduate levels. These educational opportunities can be classified into several categories: engineering management, systems engineering, engineering entrepreneurship, and leadership, internship, and other multi-disciplinary programs. Most of these programs are designed to introduce engineers to the business world through courses, project teams, and interaction with business enterprises and business leaders.

The overall purpose of this study is to summarize the approaches taken to combining management and technology education in preparation for employment in a demanding business world. It evaluates the most effective approaches to achieving this goal by examining current

programs offered by colleges and universities. The paper focuses on a specific program offered at Bucknell University, describing the program's strengths and suggesting ways of improving the program and other existing programs.

2.0 Overview of Educational Opportunities

A number of institutions that offer educational opportunities at the confluence of technology and management were investigated through web searches, journal articles, course offerings, and project descriptions. This section describes the categories of educational opportunities: each division begins with a definition of the category and includes descriptive examples of specific programs followed by tables summarizing opportunities offered by various institutions.

Engineering Management

Degree programs in engineering management (EM) focus on the relationship between engineering and management tasks. The programs generally involve business and management courses in addition to a strong core of engineering courses. Many programs also offer opportunities for coops, internships, and undergraduate research. Two such degree programs are offered at the United States Military Academy and at Stanford University.

The USMA offers an undergraduate engineering management major that is available in different engineering disciplines, such as an EM major with a civil engineering concentration. Beyond the engineering curriculum, the program offers courses like *Leadership Theory and Development*, *Human Resource Management*, *Financial Accounting*, and *Decision Analysis*. Also, an optional summer internship program called Advanced Individual Academic Development (AIAD) gives cadets the opportunity to work on projects for real army clients.³

Stanford University offers Bachelor of Science, undergraduate minor, Master of Science, and doctor of philosophy degrees in the department of Management Science and Engineering. Within the undergraduate degree program, students take core department courses (including computer science, finance, and organization theory) and explore one of six concentrations: Financial and Decision Engineering, Industrial Engineering, Operations Management, Operations Research, Technology and Policy, or Technology and Organizations.⁹

Table 1 summarizes prominent programs offered in engineering management at several institutions.

Systems Engineering

Systems engineering is similar to engineering management, but focuses more on the application of engineering principles and problem-solving approaches to analyzing technical problems and less on management. Steven's Institute of Technology and the University of Virginia both offer systems engineering programs, although Steven's Institute offers it at the graduate level while UVA offers it at both the undergraduate and graduate levels.

School	Program type	Level	Description/Features
University of Missouri-Rolla	Degree	Undergraduate and Graduate	Technical and business courses, coops, internships, undergraduate research
Steven's Institute of Technology	Degree	Undergraduate and Graduate	Engineering core with business electives
USMA	Degree	Undergraduate	Available in various engineering disciplines, AIADs internship program
Stanford University	Degree	Undergraduate	Offers five concentrations
University of Maryland	Courses	Undergraduate	Individual courses offered within different disciplines
Rowan University	Engineering Clinics	Undergraduate	Project-based learning

Table 1. Programs in Engineering Management

The undergraduate SE (major in Systems Engineering) curriculum at UVA includes engineering courses, general education electives (commerce, economics, etc.), applications electives, and technical electives. The program concludes with a senior-year capstone design project that assigns small teams of students to work with a client on solving an open-ended design problem. It is designed to prepare students for graduate work in a variety of areas including business, law, social sciences, and engineering and technology management.⁴ The SE graduate program at Steven's Institute focuses on considering both the business and technical needs of customers in order to produce a high quality, technically sophisticated product at a profit. Graduate students benefit from the program's strong industrial partnerships and numerous offerings of research projects or university service.¹²

Table 2 describes systems engineering programs at four institutions, two at the graduate and two at the undergraduate level.

Engineering Entrepreneurship

Another educational opportunity available is the growing field of engineering entrepreneurship. Programs in this field encourage students to develop new technology-based companies to meet the needs of their communities, but mostly exist as minors. Strong programs in this area are offered at the University of Texas at Austin and Pennsylvania State University.

Engineering entrepreneurship opportunities at UT-Austin are in the form of a special center and a student-run organization that provide multidisciplinary programs to students. The Center for Technology Entrepreneurship was formed in conjunction with the Ford Center of Excellence in the College of Engineering (supported by Ford Motor Company) to provide resources in education, research, and public service programs at UT. In the spring of 2001, the Center offered

School	Program type	Level	Description/Features
Cornell University	Degree	Graduate	Offered as a major or minor; in close contact with industry through advisory group
Steven's Institute of Technology	Degree	Graduate	Consists of courses, research, university service, etc.
USMA	Degree	Undergraduate	Available as major and field of study; includes AIADs internship program
University of Virginia	Degree	Undergraduate	Prepares students for graduate work; concludes with capstone design project

Table 2. Programs in Systems Engineering

a new graduate course in Technology Entrepreneurship. The Center also offers a series of lectures by leaders in the entrepreneurship field called the *Thought Leaders Lecture Series* as well as competitions in technology entrepreneurship and an introduction to business for engineering majors. The student-run Engineering Entrepreneurship Society (EES) was founded in 2000 to better introduce engineering and computer science majors to entrepreneurship. EES sponsors programs like *The Idea Generation Conference*, the *Thought Leaders Lecture Series*, and *The Idea To Product Competition* to stimulate entrepreneurial thought in students of all majors.²

Pennsylvania State University offers an engineering entrepreneurship minor in addition to a student-run organization (The Entrepreneur's Network) and special centers. Students wishing to earn this minor must complete four required courses (*Entrepreneurial Leadership, Entrepreneurship Business Basics, Technology-based Entrepreneurship, Entrepreneurship and New Product Development*) and six credits from a list of approved courses, such as *Critical Issues in Science, Technology and Society* or *Contemporary American Marketing*. The courses are structured around minimal lecture time and extensive teamwork exercises that integrate business and engineering problems. Additional entrepreneurship courses are offered outside of the minor to students in all majors.⁵

Engineering entrepreneurship programs appear in many different formats, and several examples are provided in Table 3.

Miscellaneous Programs

In addition to programs specifically designed to introduce engineers to business, many schools offer programs in the related areas of leadership development, teamwork, and internship experiences at the confluence of engineering and management. These programs are designed to help students develop the interpersonal skills that are necessary to succeed in managerial positions. Programs in these areas are offered at both the undergraduate and graduate level.

School	Program	Level	Description/Features
University of Maryland	Hinman Campus Entrepreneurship Opportunities (CEO) program	Undergraduate	Students of any major desiring to be business leaders housed in a dorm and offered mentorship sessions by lawyers and entrepreneurs; encouraged to start businesses, some even raise revenue; almost fifty percent engineering students
University of Texas at Austin	Center for Technology Entrepreneurship and student- run society	Undergraduate	Offer multidisciplinary support of entrepreneurship
Cornell University	Entrepreneurship and Personal Enterprise	Undergraduate and Graduate	Courses, lectures, internship program, and other activities to encourage entrepreneurship
Rensselaer Polytechnic Institute	Lally School of Management and Technology	Undergraduate	Offers concentrations and minors in technological entrepreneurship
	Severino Center for Technological Entrepreneurship	Undergraduate and Graduate	Offers programs that inform students, faculty, and staff of opportunities in entrepreneurship
Pennsylvania State University	Degree	Undergraduate	Minor, supported by student-run organization and special centers
Harvard University	Technology and Entrepreneurship Center	Undergraduate	Within College of Engineering and Applied Sciences; offers courses, study groups, mentorship, special events
Rowan University	Engineering Clinics and Venture Capital Fund	Undergraduate	Funded opportunity to develop a unique product for junior/senior design project
Stanford University	Technology Ventures Program	Undergraduate	Center within school of engineering; offers courses, conferences, internships, etc.

Table 3. Programs in Engineering Entrepreneurship

Within Cornell University's Johnson Graduate School of Management is the Center for Leadership in Dynamic Organizations, which does not offer opportunities for undergraduates but does offer a variety of resources for MBA and PhD students interested in improving their leadership skills. In addition to offering courses and workshops, the Center sponsors the Park Leadership Fellows Program, which is an opportunity for approximately thirty students each year to further develop and demonstrate leadership. The program puts participants in contact with

leaders of the business world through speakers and a mentor program, and stresses life-long development in the areas of leadership and service. In addition to earning an MBA, the students must complete a project that improves either the Johnson School or the surrounding Ithaca community.¹

Rowan University offers a unique opportunity for undergraduate engineering students with the eight-semester long Engineering Clinics. In the first year, students learn the basic components of various engineering disciplines and delve into the engineering design process. Sophomore students acquire writing, speaking, and organizational skills by creating mock corporations that apply engineering tools to developing products. The junior and senior years consist of year-long, faculty-sponsored or original projects that emphasize teamwork to resolve a technical issue or enhance a product.¹⁰

Stanford University's Mayfield Fellows Program is described as a nine-month work/study program that involves undergraduate and co-terminal students in the development of an emerging technology company. The program includes courses, internship experience, and networking/mentoring opportunities during sessions running from April through December. During the spring session, fellows take a course called *Management of Technology Ventures* and begin interviewing with start-up companies for internships. The summer session requires students to complete the second part of the spring course, participate in a paid internship, and keep a journal of their internship experience. Finally, the fall session consists of a "debriefing course" in which participants talk with other fellows, faculty, employers, and venture capitalists about their experiences and the relevance of the course to the internship. The last requirement is the development of a case study and project report.¹¹

Table 4 summarizes the programs described above and offers other examples of multidisciplinary programs that strive to prepare students for managerial positions in the work force.

3.0 Bucknell University's Institute for Leadership in Technology and Management

A particular program that combines many of the opportunities of other institutions is offered at Bucknell University. Bucknell's Institute for Leadership in Management and Technology (ILTM) gives participants a comprehensive overview of the technology based corporate world and encourages the development of the skills and experience for students to become leaders in that world. The program was founded in 1991 with a donation from a former Bucknell student and retired industry executive. Its goal was, and continues to be, the integration of engineering and management education theory with experience in the engineering and management professions.⁸ Although much of the information presented in this section is available at the ILTM website, it is repeated here for the convenience of the reader and to draw attention to the strengths of the ILTM program that others may wish to consider for inclusion in their own technology and management programs. ILTM offers an intensive two-summer program for twenty students from either an engineering or management/accounting major that combines theory and real-life experience – it is not just a management course for engineers. The program also emphasizes personal development of leadership skills, communication skills, and working effectively in a team.

School	Program type	Level	Description/Features
Babson College	Coaching for Leadership and Teamwork Program	Undergraduate	Mentorship program with trained alumni or MBA students; helps build leadership, teamwork, and decision-making, listening, and communication skills
Cornell University	Center for Leadership in Dynamic Organizations	Graduate and PhD	Resources to improve leadership skills
	Park Leadership Fellows Program	Graduate	Earn degree and provide service project to community
University of Virginia	Courses	Undergraduate and Professional	Offers courses in technology leadership; Professionals can earn a Certificate in Technology Leadership
Pennsylvania State University	Engineering Leadership Development Minor	Undergraduate	Must complete five courses (<i>Technology-Based Entrepreneurship, Leadership in Organizations, etc.</i>) plus six additional credits
Stanford University	Mayfield Fellows Program	Undergraduate	Work/study program
Rowan University	Engineering Clinics	Undergraduate	Project-based learning

Table 4. Other Relevant Programs

Overview of ILTM

The first portion of the program is a six-week on-campus session during the summer after students complete the sophomore year. During this session, students are introduced to issues such as globalization, ethics, communication skills, critical thinking, teamwork, and leadership through in-classroom case studies and discussions, field trips, and a group project. Evidence of sessions that address these topics is given in the schedule that is posted on the ILTM website.⁸ Table 5 provides an example of a typical weekly schedule for the on-campus program.

In the week shown, ethics was stressed in the cases discussed by Professor Gruver. *Developing Team Presentations* emphasized communication skills as well as teamwork, a topic that was also developed in *Managing Human Resources*. Critical thinking was an essential part of the *Engineering Concepts* discussion and of the integrated project, which is described later in this paper. Leadership was presented in a variety of ways during the week. Besides being a focus of Professor Gruver's case studies, it was also discussed by executive-in-residence William R Gruver, executives at IBM, and Mark Ronald, the CEO of BAE Systems' North American division.

WEEK 2

Time	Monday June 24, 2002	Tuesday June 25, 2002	Wednesday June 26, 2002	Thursday June 27, 2002	Friday June 28, 2002
9:00am	(8:00am) Eng. Concepts Prof. Buffinton OR (9:00am) Account./Finance Prof. Needham	(9:30am) Two Cases in Leadership Prof. Gruver	(6:00am Departure!!!) Field Trip IBM East Fishkill, NY	Integrated Project Preparation	(6:45am Departure!!!) Field Trip BAE SYSTEMS Lansdale, PA
1:00pm	Managing Human Resources Prof. Pagana	(noon) Executive-in-Residence William R. Gruver General Partner (retired) Goldman, Sachs & Co.	Field Trip IBM East Fishkill, NY	Developing Team Presentations Prof. Zappe	Field Trip BAE SYSTEMS Lansdale, PA
7:00pm					

Table 5. Sample Schedule, Summer 2002

Field trips are an essential and enjoyable aspect of the first summer with the purpose of reinforcing and strengthening the ideas introduced in the classroom. Field trips are day-long visits to a variety of organizations of different sizes and types. High-level executives familiarize ILTM students with all areas of the organization's operations through a plant tour of production and manufacturing facilities as well as presentations.⁷ During the Summer 2002 session, students and faculty took field trips to IBM in East Fishkill, BAE SYSTEMS in Lansdale, Pennsylvania, NBC studios in New York, Playworld Systems in Lewisburg, Pennsylvania, and the New York Stock Exchange.

All ILTM students are required to participate in a case project designed to tie together all of the concepts and experiences acquired during the six-week session by providing an opportunity for students to work on interdisciplinary teams in order to resolve a real world problem. Students are divided into four teams of five students, with at least two management and two engineering students in each group, in order to best balance the skills available to each group. Each team is assigned a project created by a host organization that asks the students to solve a problem being faced by the organization. The problem is structured so as to require both business and engineering skills. The majority of the project work is completed in the late afternoons or evenings after classes and on weekends. Each team is assigned two mentors: one is a member of the ILTM faculty and the other is a member of the host organization. The faculty mentor is there to monitor the team's progress and help them avoid disaster, but not to interfere in the problem-solving process. The company mentor introduces the team to the host organization and provides them with initial sources of information. At the conclusion of the project, teams submit lengthy reports and deliver sixty-minute oral presentations of their solutions to the faculty and the host organization.⁷

One of the project teams for the 2002 session participated in a Diminished Material Supply (DMS) Study for BAE SYSTEMS. The problem addressed how to predict and accommodate

hardware obsolescence without significantly driving up costs to the company. The students had several tasks to complete, including summarizing how other companies handle DMS, assessing the costs involved in different methods of addressing obsolescence, and recommending a process for handling DMS analysis. The project required the integration of skills learned during ILTM, knowledge acquired in previous major-related courses, and efficient teamwork.

For successfully completing the six-week on-campus session, students receive academic credit and are able to advance to the second portion of the program, which occurs during the summer following the junior year.

The second portion of the program is an off-campus, minimum ten week, paid internship. The internship program was created in response to companies' desires to hire graduates with actual exposure to industry practices. The experience gives students exposure to everyday planning and problem-solving activities in the organization and puts them in contact with managerial staff in the organization. Internships come in three forms, project-oriented, shadow-to-an-executive, or executive assistance, with the last two being the preferred types. An effective internship challenges the student to apply the skills learned during the previous summer in order to make a significant contribution to the company. In order to successfully complete the internship program and receive academic credit, students must submit a minimum ten- to twenty-page report on their experiences and the relevance of ILTM to the completion of their tasks, along with a journal describing their daily activities. The internship is also evaluated by the host company via a one-page questionnaire at the end of the internship.⁷

During the summer of 2002, ILTM students entering their senior year at Bucknell participated in a variety of internships. Fourteen of the twenty students held internships that qualified for ILTM internship credit; the internships were offered at Merck, GE Industrial Systems, Lockheed Martin, eMarket Capital, JP Morgan Chase, and Johnson & Johnson, among others. The remaining six students who had completed the previous summer's on-campus program did not participate in these internships for various reasons, including taking an internship that did not qualify for ILTM credit and studying abroad.

In addition to the summer sessions, various seminars and programs are offered to ILTM students throughout the academic year, including resume writing workshops and a special dinner with representatives from leading companies.

Effectiveness of ILTM

The business world demands graduates who are prepared to be leaders in a technology-infused atmosphere, requiring adeptness in the fields of both engineering and management. ILTM approaches this challenge by bringing together both engineering and management students for an intense learning experience. The material covered goes beyond the more traditional engineering/management programs by including ethics, critical thinking, presentation skills, and teambuilding exercises. The format of the program also allows participants to combine theoretical knowledge with practical experience, and challenges them to think holistically about problems rather than one-dimensionally.

Upon completing the on-campus summer session, one participant described the experience as an important lesson in the real world. “We had the opportunity to hear and interact with different professors, CEO’s of different companies, and others in the executive levels of companies. The things I learned are that life will not always turn out as you planned; one must keep on learning after school and be adaptable to different situations. In the real world, engineering and management issues overlap. Thus, you need to know about both subjects to deal with those issues.”

The benefits of the broad scope of the program were recognized by an ILTM alumnus from Bucknell’s class of 1996: “Through the program, I became aware of the potential to leverage the technical skills I was gaining in my engineering studies to become an effective manager...I also began to recognize and develop the communication and teaming skills required to succeed...These skills, along with the ‘big picture’ view of business I began developing at ILTM, allowed me to enter the professional world better prepared, and have continued to afford me flexibility within my career.”

ILTM also provides beneficial networking opportunities and interviewing experience through constant contact with business executives. During the first summer session, executives-in-residence give presentations on their experiences as business leaders; ILTM students also interact with prominent businesses while working on the integrated projects. Obtaining an internship to complete the program is comparative to a job search – students compose resumes and undergo intensive interviewing – and some internships result in job offers for the participants upon graduation. An ILTM participant from the class of 2004 said “the on campus portion of ILTM exposed me to many aspects of the business world that I was not aware of. It also gave me many wonderful experiences to talk about in my job interviews. I don't think that I would have gotten the job I have now without the ILTM background.”

The internships provide valuable work experience and often have an impact on the career path chosen by students. A member of Bucknell’s class of 2003 who completed an ILTM-approved internship with Merck attested to that: “I originally came to Bucknell with the intent to pursue a career in research and development within chemical engineering. My position in the manufacturing division was far from the research arm of Merck. However, I found that this position offered me the opportunity to work with a diverse group of people, as well as the ratio of in-factory to in-office time that was a good fit for me. Since the end of my internship, I have taken an offer for permanent employment with Merck within the manufacturing division.”

Developing a Stronger Program

ILTM fulfills its founders’ goal of integrating engineering and management education to prepare students for managerial positions in business. However, the format of the program limits the benefits to only twenty students each year. An obvious improvement would be to include more students in the program – this could be accomplished with the development of an ILTM minor that would allow students to take ILTM courses during the academic year. The components of the on-campus summer session would then be distributed throughout several months, allowing more time to develop subjects and work on projects, as well as offering the experience to more students.

ILTM could also be improved without developing a formal degree program by providing more continuity during the year between summer sessions. More programs could be offered to participants such as leadership training, a series of speakers (executives, engineers with managerial positions, ILTM graduates, etc.), or informal meetings to simply keep in contact with other participants.

4.0 Conclusions

Colleges and universities have recognized the demand for graduates with adeptness in both technical and managerial areas and are answering with a variety of degree programs and other multidisciplinary programs. The most effective programs infuse technology and management education with the development of interpersonal and leadership skills, which are necessary for graduates to reach high level positions in any business. Participants in these programs acquire the necessary skills to be leaders in their companies – to work effectively with co-workers and be active problem-solvers.

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