Entrepreneurship in Engineering Education

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Abstract - **The recent changes in the world and engineering present both challenges and opportunities to the engineering education. Engineering education is changing to meet these challenges. More and more engineering programs strive to include entrepreneurship and innovation, traditionally American values, in the engineering curriculum. In this paper, we present our view on teaching entrepreneurship to future engineers and describe our experience in introducing entrepreneurship in engineering education through an NSF-sponsored pilot program based on collaboration between Stony Brook University and three other major higher education institutions on Long Island.**

Index Terms – Entrepreneurship, medical sensor systems.

INTRODUCTION

The tremendous recent changes in the world order present both challenges and opportunities to the engineering education. The environment we now face is very different from even a decade ago. The practice of engineering is changing with the globalization of manufacturing, research and development. New interdisciplinary fields have come to life and traditional engineering is increasingly influenced by the information technology. Employment shifts to smaller entrepreneurial firms often located offshore. Engineering education seems poised to follow the jobs. After all what can the US offer that others will find hard to emulate?

We believe one of the most powerful answers is *entrepreneurship*. Not only has this been the traditional American strength, but its very foundation rests on the unique advantages of our society, our openness, mobility, relative absence of corruption, relative freedom from red tape, our extremely well established system of intellectual property protection and widely available venture funding structures. We do not teach all that to our engineers, they learn entrepreneurship on their own, usually well past the university stage of their careers. In our view, this must change, and change rapidly. This change must be reflected in the curricula, but more importantly, in the *attitude* at our academic institutions.

One purpose of this paper is to share our recent experience with a pilot program, called the *Sensor Consortium for Medical and Security System*. The Consortium, led by the University at Stony Brook, was supported by the National Science Foundation (NSF). Another purpose is to articulate our views on the future engineering entrepreneurial programs at Stony Brook.

This paper is organized as follows: In the next Section, we present a short review of entrepreneurship education in the engineering curricula. Section 3 describes in more details our Sensor Consortium, including its position at Stony Brook University, its structure, and components. Section 4 is a discussion of our experience in teaching entrepreneurship while Section 5 presents our vision of future entrepreneurship programs.

ENTREPRENEURSHIP IN THE ENGINEERING CURRICULA

Traditionally, courses on entrepreneurship originated in business or management schools. This began to change during the last decade when many educational institutions began to introduce entrepreneurial education in the engineering curriculum. By now, more than 400 engineering schools offer some entrepreneurial and business courses. Among several existing models for entrepreneurial education [1], we shall consider two well known exemplary programs, those of MIT and Stanford. The MIT program, though open for engineering and science students, is centered at the Sloan School of Management, while the Stanford program belongs to the School of Engineering. The Sloan School offers a wide range of courses in launching, managing, and growing technology-based businesses available to engineering and science students. The courses use a variety of teaching methods: case studies, internships, guest lectures, external reviews of student assignments by venture capitalists, and student projects. All courses involve teamwork and focus on presentation skills. As a part of the MIT program, the MIT Entrepreneurship Center was instituted in 1996 to help MIT students, alumni, and faculty to start and sustain entrepreneurial activity. It provides an array of educational programs, networking opportunities, technologies, and resources. The Center also conducts the renowned *MIT $50K Entrepreneurship Competition* [2] that is designed to encourage MIT students and researchers to act on their talent and ideas. The Competition awards money and business startup services to outstanding teams of student

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entrepreneurs. The Competition is open to all undergraduate and graduate students.

The Stanford Technology Ventures Program (STVP) [3] is hosted by the department of Management Science and Engineering within Stanford University's School of Engineering. It has a strong outreach effort that includes hosting international conferences on teaching entrepreneurship. Stanford's STVP is mainly an educational program for individual students founded on the premise that in addition to technical skills, students need to know how to identify market opportunities and to take leadership roles in business. To meet this goal, the program offers both introductory and advanced courses in the field of entrepreneurial marketing, finance, strategy, and innovation. The courses range from standard academic courses for undergraduate and graduate students to large public lecture series such as the Entrepreneurial Thought Leaders, to intensive, year-long programs such as the Mayfield Fellows Program.

At MIT and Stanford, as in hundreds other college programs, the entrepreneurial education is part of formal curricula, and the entrepreneurial activity is funded by the respective schools or colleges. The case is very different for the Sensor Consortium at Stony Brook. Our course in entrepreneurship was specially developed for the Consortium students (Section 3.3.II.) and is not a part of the Stony Brook academic curriculum. The support for the Consortium activities was provided not by the participating academic institutions but by a two-year federal grant from the NSF under its Partnership for Innovation (PFI) program that promotes innovations by bringing together colleges and universities, state and local governments, private sector firms, and nonprofit organizations.

Out of approximately a hundred NSF PFI funded projects [4], most promote entrepreneurship, directly or indirectly. For comparison, we briefly review two PFI projects that are most similar in spirit to the Sensor Consortium. They are: *New Paradigm for Entrepreneurial Discovery and Business Development* (University of Louisville) and *ACTiVATE Program* (University of Maryland, Baltimore County).

The primary objective of the project *A New Paradigm for Entrepreneurial Discovery and Business Development* at the University of Louisville is to establish a sustainable program for the discovery and commercialization of cardiovascular devices to help improve quality of life for patients and to stimulate regional economic development. It is run with the Cardiovascular Innovation Institute in Louisville and provides the participants with the Innovation Training Program and Innovation Discovery Grants. The difference with the Sensor Consortium is that this program is aimed towards researchers and PhD students.

The aim of the *ACTiVATE Program* at University of Maryland is to strengthen the commercialization of technology innovations from universities by training women entrepreneurs to create technology-based start-up companies. Though entrepreneurial in its nature, this program embraces only female researchers.

While the Sensor Consortium has a common goal of promoting entrepreneurship and shares some common features with the above programs, it is a unique organization in that it embraces a very diverse, racially and socially, cross-section of Long Island population. It includes both undergraduate and graduate students and faculty; it involves four different educational institutions ranging from a private college to a research-oriented university to local two-year community college. It differs from all entrepreneurial college programs in that the entrepreneurial activities are not a part of the college academic and the funding is provided by a federal grant from the NSF PFI program. The Sensor Consortium has been conceived as a pilot program to build a foundation for the future engineering entrepreneurial education programs. In the following sections we shall describe our experience of two years of the Consortium operation. We shall assess the role of the Sensor Consortium in the process of developing entrepreneurial skill among engineering students and fermenting future development of the entrepreneurial programs.

SENSOR CONSORTIUM FOR MEDICAL SECURITY SYSTEMS AND ITS SCOPE OF ACTIVITY

The Sensor Consortium is centered at the Electrical and Computer Engineering Department of the College of Engineering and Applied Sciences at Stony Brook University. Many of the faculty members and staff of the Electrical and Computer Engineering Department are experts in the sensor systems for medical and security technologies. Not surprisingly, this expertise gave rise to the technical orientation of this entrepreneurial project.

Long Island, with its defense industry past and large number of higher-education institutions, is a fertile ground for high-tech industries. It has many centers funded by the state and local governments. A tremendous amount of effort is aimed at promoting entrepreneurial and technology transfer activities mainly for businesses. Not much has been done to educate engineering students in entrepreneurship.

The Sensor Consortium was inaugurated in June 2004. The main objective of the Consortium is to provide engineering and technical students of Long Island with entrepreneurial skills, with a focus on medical and security sensor systems.

A rather unique feature of the Sensor Consortium is its *inter-university* nature. For the first time, four of Long Island's campuses join forces to educate their students in engineering and technology entrepreneurship. The Sensor Consortium's Education Partners include Stony Brook University, Hofstra University, Farmingdale State College of Technology, and Suffolk Community College. By forming this partnership, the four education partners bring together a large and diverse student pool that reflects the demographics of Long Island.

Each of the education partners has a unique student body. Stony Brook University, as a major research university, has a student body that tends to have more research experience even at the undergraduate level. Stony Brook University was

chosen by the NSF as one of the top ten national universities with outstanding programs for undergraduate research. Hofstra University is a major private university on Long Island. Its main assets are the business and law programs, complemented well by a strong liberal arts school. Hofstra has already taken an active role in emphasizing and enhancing the entrepreneurial skills of its student body. Farmingdale State's curriculum emphasizes practical and hands-on activities. Its student body, therefore, tends to possess more practical and technology oriented skills. Suffolk Community College has a large proportion of students beyond the conventional age cohort, mature individuals with a strong drive and more work experience.

I. Position of the Sensor Consortium within Stony Brook University

Stony Brook University is a fertile ground for the Sensor Consortium. In addition to being a top research university, it hosts the New York State Center for Advanced Technology in Sensor Systems (the "Sensor CAT"). The mission of Sensor CAT is to provide an organizational framework and intellectual and material resources for the development of sensor-related technologies by facilitating partnership between NYS industry and university research. The Sensor CAT currently works with more than 40 companies, from large international corporations to small high-tech start-ups. Over 30 faculty members from various departments work on the CAT projects. Research and development at the Sensor CAT is based on the resources of the University at Stony Brook and is supported by $1M annual state grant and over $2M annually in industrial contracts. The Sensor CAT has been instrumental in developing a number of breakthrough technologies, including novel DNA sequencing instrumentation with ultra-high sensitivity, ultra-high speed superconducting electronic circuits, magnetic sensors, and infrared laser and imaging technologies. In its activities, the Sensor Consortium builds upon the Sensor CAT success and close-relations with the sensor technologies and its experience in creation of start-up companies to commercialize new technologies.

Another auspicious factor is the presence on the Stony Brook campus of the Small Business Development Center (SBDC), one of twenty-three regional SBDCs in New York State. The Stony Brook SBDC brings together the resources of the University, the private sector and government at all levels to assist entrepreneurs, business and industry in the solution of their problems. Technical assistance is provided by the College of Engineering and Applied Sciences. Management theory is updated by the College of Business. This establishes the Stony Brook SBDC as an agency with the latest information on small business development.

II. Structure of the Sensor Consortium

The Sensor Consortium activities can be separated into three components, *Education, Research and Technology Transfer,* and *Outreach and Dissemination*. All three components are interlinked together to provide an infrastructure and a community to support each other.

The *Educational Component* plays a key role in the Sensor Consortium activities. The basic activity in the Education Component is the Technology Entrepreneurial Team (E-Team) Program in which several teams of students compete in projects involving entrepreneurial development and commercialization of technical innovations. Each team consisting of four undergraduate students (one from each of the Education Partners), is led by a graduate student and supervised by faculty project advisors both selected from the Electrical and Computer Engineering Department at Stony Brook. The E-Team concept has been widely accepted in the literature as an effective means of engaging students in entrepreneurial activities [5-10]. Our unique approach is that each team consists of one undergraduate student from each of our four Education Partners. This mixture of students creates unique dynamic for the teams and allow the students to practice teamwork in a life-like interdisciplinary environment. The advisors suggest project topics and select graduate students to lead E-Teams. The other three Educational Partners provide from their ranks the project coordinators whose function is to select best students for E-Teams, coordinate their coursework at the Sensor Consortium, and with their project advisors evaluate their project performance. All four colleges agreed to credit the participation in the Sensor Consortium program as a full senior design course.

The partners of the Sensor Consortium *Research and Technology Transfer* components are: Brookhaven National Laboratory (BNL), Stony Brook's Sensor CAT and its affiliated industrial sponsor; and Stony Brook Office of Technology Licensing and Industry Relations (OTLIR). The scientific staff of BNL, along with the faculty of Stony Brook, forms the research backbone of the Sensor Consortium. It provides a large pool of scientists and experts to give technical guidance to the E-Teams.

Sensor CAT and the OTLIR are critical partners of the Technology Transfer component. Sensor CAT with its large number of industrial clients acts as a liaison between the Sensor Consortium and the industrial community. The Sensor Consortium works with the OTLIR to promote and assist technology transfer to the commercial sectors. The annual Sensor Consortium Competition is co-sponsored by the Sensor CAT, Sensor Consortium and the OTLIR.

Outreach and Dissemination component of the Sensor Consortium activities is aimed to instill the understanding of importance of engineering entrepreneurial education and propagate information about the Sensor Consortium among Long Island business, technical and educational communities. The Sensor Consortium web site is an effective tool for (http://www.ece.sunysb.edu/~sensorconsortium)
dissemination of the information about the Consortium and its goals and objectives in the community. It is linked to the NSF PFI home page and contains links to other relevant sites. The Consortium seminars feature entrepreneurs, venture capitalists and other industry professionals as guest speakers. The Consortium Newsletters, also a part of the Consortium

outreach and dissemination efforts, has been published every three months. Each issue covers all Consortium events and happenings during the trimester.

Since this paper is concerned with entrepreneurial education in engineering, the discussion in this paper will focus on the educational component.

III. Entrepreneurial Education at the Sensor Consortium

1) E-Team Formation

a) Recruiting and selecting students for E-Teams. The Consortium began its activity in June 2004. The project coordinators in the Educational Partners colleges advertised the Sensor Consortium program among their students. The advertisement effort was not limited to engineering students (about 40% of participants came from fields of studies other than engineering, such as biology, mathematics, communications, architecture, business, industrial art etc.). The information was disseminated via fliers, internet site and application forms. In the first week of the fall semester the coordinators gathered all applications. Since the program offers attractive incentives (the prestige of the NSF-sponsored project, stipend, course credit) a large number of students from all four campuses expressed their desire to participate. After preliminary filtering of the submitted applications we had a pool of about 40 students, 10 students from each school. At the last stage of the selection process, the Stony Brook faculty project advisors selected each four undergraduate students (one from each college) for their E-Teams. Each year about half majored in electrical or computer engineering while the other half were from security systems, architecture and visual communication majors.

b) Selection of projects. E-Teams projects were selected by the faculty project advisors on the merit of its technical, entrepreneurial/commercial potentials and social potentials:

- To satisfy the technical merit requirements, the E-Team projects should produce at the end a ready-to-use prototype that constitutes a complete system including mechanical, electrical, optical and software components. Such system approach to engineering research is an essential part of the engineering entrepreneurial culture
- Entrepreneurial merit criterion requires that each project should contain an original patentable idea as a basis for a startup technology company.
- To satisfy the social merit requirements, the E-Team should aim to nurture social consciousness in the student body coming from very different backgrounds and have a potential to improve the quality of life for large groups of people.

We estimated that the NSF funding was sufficient to support four such projects annually, each developed by one E-Team. Below we give a short synopsis of each project:

The "*Wireless Health Monitoring System*" project. was designed for monitoring vital signs of users and sending e-mail and/or phone notification to families and medical personnel in case of emergencies. It can be used by individuals living alone; assisted living communities; and patients in hospitals and emergency rooms.

The "*Wireless Biopotential Recording for the Treatment of Sleep Apnea Disorders*" project, designed for monitoring the body's biopotentials without the patient being tethered to bulky equipment, could improve the quality of life of more than twelve millions Americans who suffer from sleep apnea disorders.

The main goal of "*Embedded Navigation System*" project is to help orientation of visually challenged people as well as easing their moving in new environments. A prototype of the system can also be adapted for aiding elderly people, including people with difficulties in moving or those with memory affecting illnesses, like Alzheimer.

The aim of "*RFID Sensor Networks*" project is to explore the feasibility of a radio frequency identification **(**RFID) sensor network for use in hospitals. Such a system can be used for tracking patient's location, real-time tracking of doctors and nurses, tracking of expensive and critical instruments and equipment, use of the patient's RFID tag to access patient information for review and update through hand-held computer (PDA), and drug tracking.

At the end of the academic year, all projects were brought to the working prototype stage.

2) Entrepreneurship Course. The entrepreneurial course was taught by Prof. Gerrit Wolf of the Harriman School of Management and Policy at Stony Brook. This course met at a Stony Brook location each Saturday with the entire body of all four E-teams present. The course was developed during the first year of the Consortium existence, specifically for the E-team projects. During first weeks of projects' selection and definition, the course topics were honed to specific problems of the enabling industry. In the beginning of the second year, the topics were further adjusted to project changes.

The goal of the course is to provide E-Teams with tools to build a business plan. The course is built on the engineering-business duality of the engineering entrepreneurial process. The engineering track defines the product and develops prototypes; it requires students to write a technical proposals and reports and present them to a customer. The business track deals with team issues, market opportunities; it requires students to write a business plan and to present it to client.

During the first year, the course was taught only in the fall semester. For the second year, the course was extended to the spring semester. General topics such as creativity, project management, opportunities, intellectual property are taught in the fall semester; business oriented topics such as developing a business plan and planning, financing and launching a venture are taught in the spring. Each E-Team is assigned an MBA graduate student who helps the teams to define the key problems in their projects. In the spring semester, under the guidance of Prof. Wolf and his MBA students the teams develops the business plans. A month before the Competition, the plans are submitted for review to the Stony Brook Development Center, and corrected and improved if needed.

3) Project competition. The Sensor Consortium Project Competition is the most significant event in the Educational

component. This is the time when the work of each E-Team is evaluated and compared with that of other teams. Students present their projects from both technical and entrepreneurial sides. We instituted the Consortium policy that the project should be presented at the Competition as a working prototype. The students must carry out the presentation themselves.

Four projects from four E-Teams compete for the first prize each year. During the first year, we recruited a panel of five judges to evaluate technological innovation and business plans of the competing projects. The panel of five consists of experienced entrepreneurs, professional service providers and investors, including a past winner of the MIT $50K [2], the oldest and most prestigious student entrepreneurship competition.

The first Competition event (May 2005) gathered about 100 people. Each E-Team fractioned their allotted time to let each student talk about their part in the project. The judges selected the "*RFID Sensor Networks"* as a winner. Also, the Competition proved to be a great public relation success. However, there were some snags, mainly due to lack of coordination between different E-Teams. Since each team worked separately, the formats of presentations were very different (different media: videos, photos, viewgraphs, advertisements etc., different order and time allocation on technical and business presentations). Some of the prototypes failed to work from the first attempts, thus crumpling the schedule.

In the second year, we developed a common format for the presentation. The presentation was broken into two parts: The first part is a technical industry-fair style presentation in the lobby, with four exhibition stands for the prototypes. At each stand, the teams present their project to the judges and audience. In the second part the business plans are presented to the audience, with the teams having an opportunity to tell the judges about patent issues, potential customers, financial arrangements, etc.

DISCUSSION

I) Our observations:

1) Finding her/his role, learning from each other. While working on their projects the E-Team students from different colleges and backgrounds learned to work together. Very soon in the course of the project the members instinctively developed their work roles. While technically oriented students played roles familiar to them, the other students adapted to their new roles of business entrepreneurs amazingly smoothly and very soon began developing marketing strategy, search for the customers, and writing business plans. Technically oriented students learned from their entrepreneurial teammates how marketing strategies are developed; how customers are identified and approached; how a successful business plan is established. On the other hand, the students with business roles learned how to develop a business plan and marketing strategies based on real technical constraints and how to translate customers' needs to engineering specifications.

Many of the young people who came to the Consortium from the partner colleges are business savvy; many come from the families with small businesses, some have already formed their own small companies (construction, software, landscaping).

2) Balancing dual participation, changing mentality. During the project development, the advisors had to maintain the balance between the technical and entrepreneurial activities and to prevent natural tendencies from dominating the students' participation in the project. For example, scientifically and technically advanced students immediately fell into familiar routes of technical development and dismissed the entrepreneurial side of the project, while their business counterparts tried to avoid delving into technical matters thus further aggravating the gap between the technical and entrepreneurial sides. To counteract this tendency, the program required all E-Team members participate in both activities.

3) Going to the customer. The judges were impressed by the versatility of the E-Team students, by their ability, on one hand, to implement a technical innovation and make it work and, on the other hand, to promote it, with enthusiasm, grace and ease, to potential customers. All four groups made short presentations of their future products for their customers. The students from Wireless Biopotential Recording for the Treatment of Sleep Apnea Disorders project made contacts with the Center for the Study of Sleep and Waking at Stony Brook University Medical School who expressed interest in testing the device. Another group from the Wireless Health Monitoring System project offered this product to several assisted living communities and made arrangement with a local geriatrist for testing it among his patient. E-Team students from project ANGEL: embedded platform for improving on-campus security) found customers at the On-Campus Disability Support Center. The School of Health Technology and Management at Stony Brook is very much interested in the RFID Sensor Networks project.

*4) E-Team as a mirror of real life***.** Because of the inter-college nature of the Sensor Consortium, the student body of E-Teams was different from that of each participating school. While each college attracts students of a certain kind, the mixed group created an atmosphere similar to the real life situation in a small business collective. We believe that this mixture generated an interactive and challenging environment in which students learn from and inspire each other. It also provided the versatility and flexibility in the group approach to problems, the "division of labor" necessary for developing a product from the scratch, and greatly contributed to the success of the projects.

II) Impact of the Sensor Consortium

The effect of exposure to the Sensor Consortium is manifold and subtle. We believe that there will be a change in the attitude of academically oriented students, in the realization that the entrepreneurial talent is at least as important as scientific and engineering prowess.

One third of the young people participating in the E-teams were women. These young women have been initiated into entrepreneurial wisdom and are now better armed for making it in the business world.

For many participating faculties at Stony Brook and partner colleges, the Sensor Consortium experience was eye opening. It is our conviction that he Sensor Consortium has inspired our faculty to pursue entrepreneurial activities. For example, most of our engineering faculty has a strong publication record, but the number of faculty holding patents is still relatively small. We expect that the Sensor Consortium will help increase the number of inventions disclosed and patent applications filed, establishment of new ventures by our faculty and graduates and eventually increase the number of women or minority owned and managed businesses in the Long Island region.

CONCLUSION: WHAT IS TO BE DONE?

The PFI grant for the Sensor Consortium allowed us to establish a permanent infrastructure to promote entrepreneurial skills. As a part of this infrastructure, we created a set of suitable projects and criteria for future project selection. We amalgamated the core personnel of our program into an active entrepreneurial group. We formed well equipped laboratories to work on the projects and an informative web site. We developed a special entrepreneurial course that can be easily adjusted to new projects. Most importantly we formed strong ties with Long Island business community to serve as entrepreneurial promoters, guest speakers, advisors, judges for our Competitions. We also generated interest to our projects among potential customers at Stony Brook University Hospital.

Our long-term goal is to expand this activity to a program for all engineering students, not only to students who are interested in acquiring business skills. Such a program can not be supported by grants, but should become a part of the engineering curricula at Stony Brook. Moreover, we would like to advocate the inclusion of entrepreneurial skills in engineering curricula nation wide. Based on our Sensor Consortium experience, we gravitate to the Stanford model in that we firmly believe that the entrepreneurial engineering programs should originate at the engineering academic entities.

More specifically, the following features should be incorporated in an engineering entrepreneurial curriculum:

- The program should involve hand-on business experience based on innovating engineering projects. The *program should be obligatory for all engineering students.*

- The program should be based on multidisciplinary teamwork projects. In our Consortium experience, mixing people from different colleges and backgrounds added versatility and functionality to the teams and broadened their entrepreneurial experience. Within one college, the heterogeneity can be achieved by mixing students from several departments. All engineering students should participate in developing of both engineering and entrepreneurial aspects of the project.

- The program should encourage the competitive component of the entrepreneurial education emulating the MIT program with the idea of annual competition that encourages the students and researchers to act on their talent and ideas.

In conclusion, our Sensor Consortium experience clearly demonstrated that academically oriented engineering students from Stony Brook would greatly benefit from entrepreneurial education.

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