

AC 2010-666: TECHNOLOGY ENTREPRENEURSHIP PROGRAMS IN U.S. ENGINEERING SCHOOLS: AN ANALYSIS OF PROGRAMS AT THE UNDERGRADUATE LEVEL

Angela Shartrand, National Collegiate Inventors and Innovators Alliance

Angela Shartrand is Research and Evaluation Manager at the National Collegiate Inventors and Innovators Alliance, a non-profit organization that supports technology entrepreneurship in U.S. colleges and universities. Her research focuses on understanding how to develop and sustain ecosystems that support innovation and entrepreneurship in higher education. She holds a Ph.D. in Applied Developmental and Educational Psychology from Boston College, an Ed.M. from Harvard University and a B.A. from Williams College.

Phil Weilerstein, National Collegiate Inventors and Innovators Alliance

Since 1996 Phil Weilerstein has been the Executive Director of the National Collegiate Inventors and Innovators Alliance (NCIIA www.nciia.org) a national program that stimulates and supports the incorporation of innovation and entrepreneurship in higher education curriculum. He directs programs which encourage curricular innovation and student venture creation, provide resources for faculty and student entrepreneurs, and develop conferences and workshops for faculty and students with a focus on encouraging socially beneficial application of technological innovations and the improvement of entrepreneurship and innovation education in higher education. Mr. Weilerstein attended the University of Massachusetts where as a graduate student he was a co-founder of EcoScience Corporation a publicly held biotechnology company developing naturally occurring pest control products. He is a Founder and Past Chair of the ASEE Entrepreneurship Division and recipient of the 2008 Price Foundation Innovative Entrepreneurship Educators Award.

Mary Besterfield-Sacre, University of Pittsburgh

Mary Besterfield-Sacre is Associate Professor and Fulton C. Noss Faculty Fellow in the Department of Industrial Engineering. Dr. Sacre's principal research interests are in engineering education assessment and evaluation methods. Her research in this area has been funded by the NSF, Department of Education, Sloan Foundation, Engineering Information Foundation, and the NCIIA. She has served as an associate editor for the Journal of Engineering Education and is currently associate editor for the Applications in Engineering Education Journal. Additionally, she co-authored the book Total Quality Management, 3rd Edition (Prentice Hall). Prior to joining the faculty, Dr. Sacre worked as an industrial engineer with ALCOA and with the U.S. Army Human Engineering Laboratory. She received her B.S. in Engineering Management from the University of Missouri-Rolla, her M.S. in Industrial Engineering from Purdue University, and a Ph.D. in Industrial Engineering from the University of Pittsburgh.

Katharine Golding, National Collegiate Inventors and Innovators Alliance

Kate Golding is an Associate for Research and Evaluation at the National Collegiate Inventors and Innovators Alliance. She has worked as a consultant to small startups, as well as being office manager and project coordinator to established small businesses. She earned her B.F.A in painting at the University of Delaware.

TECHNOLOGY ENTREPRENEURSHIP PROGRAMS IN U.S. ENGINEERING SCHOOLS: COURSE AND PROGRAM CHARACTERISTICS AT THE UNDERGRADUATE LEVEL

Abstract

This paper examines and characterizes current approaches to entrepreneurship education among undergraduate engineering programs based on initial data from two research studies and over a decade of grant-making and faculty development by the NCIIA to support new courses and programs in technology-based entrepreneurship education in the U.S. To understand the current status of entrepreneurship education in engineering, we have been examining programs and courses offered at 340 ASEE member schools in the U.S. Our analysis identifies entrepreneurship education opportunities that are available, and will provide a framework to understand and characterize diverse approaches to offering curricular and extracurricular experiences to undergraduate engineering students. The data gathered so far illustrates the growth of entrepreneurship education and its increasing accessibility to engineering students. Over half of the ASEE listed engineering programs provided entrepreneurship options with ~25% having more substantive programs such as minors, Centers and other such structured programs based in the engineering school. This finding illustrates clearly that entrepreneurship education has becoming a widespread offering for engineering students. In our initial review of U.S. ASEE member institutions in 2008, we identified 47 programs that focused explicitly on engineering and technology entrepreneurship at the undergraduate level. In addition, we identified interdisciplinary and university-wide approaches that, while not exclusively focused on technology or engineering entrepreneurship, provide opportunities for students to acquire entrepreneurial skills to complement their undergraduate engineering major. This paper describes our approach to the analysis of the technical entrepreneurship programs and shares findings from this effort thus far. Specifically, we examined the topic areas of core and elective courses, identified where programs are administered at the university, and developed an initial framework for analyzing curricular and extracurricular opportunities (e.g., field experiences, venture development activities, internships, competitions, networks, entrepreneurship centers, staffing, and funding). Based on the work to date we conclude with thoughts on directions for future research and practice in this area.

Introduction

Background/Context. Motivated by the key role that engineers play in bringing new discoveries and technologies to the market, universities have begun in the last two decades to offer entrepreneurship as part of engineering education in the U.S. This has produced a rich and diverse landscape of programs, courses and extracurricular opportunities for engineering and science students. Entrepreneurship is increasingly viewed as a necessary area of competency and a career path for engineering graduates who need to be equipped with an appropriate knowledge base, skill set and an entrepreneurial mindset. The National Collegiate Inventors and Innovators Alliance (NCIIA), an educational not for profit created in 1995 with support from The Lemelson

Foundation, has been contributing to this growth by providing grants and development opportunities to faculty who seek to develop new courses, programs, and extracurricular activities that encourage and support technology-focused entrepreneurship among students[1]. To that end, NCIIA has awarded over 300 grants totaling over \$6 million to roughly 200 universities and colleges, leading to the creation of hundreds of new and/or modified entrepreneurship-related courses, programs, and other educational activities. Given the substantial number of programs established, there is value in understanding and categorizing the range of program characteristics, strategies, challenges that have been created and their impacts to date.

A significant number of large research universities in the U.S. (e.g., Georgia Institute of Technology, Stanford, Massachusetts Institute of Technology, etc.) have an established history of successful high-tech ventures and commercialization emerging from academic research programs. These accomplishments have made substantial economic impacts. For example, a well-known BankBoston study reported that over one million people were employed by about 4,000 MIT-related companies, collectively resulting in annual sales of \$232 billion world-wide [2]. These potential economic and social benefits have led other colleges and universities to provide opportunities for students to learn about and participate in entrepreneurial activities, not just in business and management fields, but also for students in the STEM fields, especially engineering. This article presents our efforts to better understand the extent to which entrepreneurship education is accessible to engineering students, and to understand the characteristics of the programs, courses, and extracurricular activities that are typically offered in these schools.

Literature Review. Several empirical studies have examined entrepreneurship education in colleges and universities. To examine the extent of program offerings in business and management schools world-wide, Vesper and Gartner [3] surveyed 1,253 business schools in the U.S., Canada, and abroad. Of the schools that responded, 50 reported offering a entrepreneurial program of study (defined as at least four courses in the area of entrepreneurship). Levie [4] conducted a similar inventory of entrepreneurship education in the UK. To examine the institutionalization of entrepreneurship, Katz [5] conducted a survey examining the extent of endowed chairs and professorships of entrepreneurship, finding that between 1999 and 2003, the number of these positions grew by 71 percent. While these studies reflect foundational work on offerings of entrepreneurship in higher education, and document the growth of offerings, none have paid particular attention to entrepreneurship education within the STEM fields, focusing instead mostly on business and management based programs serving students in those disciplines. Because NCIIA has been focused on supporting the growth of technology innovation and entrepreneurship in higher education and has therefore worked extensively with schools of engineering, we sought to look more carefully at the extent to which entrepreneurship education is available to engineering students.

Several in-depth descriptions of specific programs and courses in technology-focused entrepreneurship have been written [6, 7, 8, 9, 10, 11]. However, to date there has been no comprehensive or systematic effort to identify, document, and characterize these initiatives broadly or in a way that allows comparison of the multiplicity of programs.

Despite this expansion in educational opportunities, we still do not know precisely the extent of offerings, both within and beyond the membership of NCIIA and ASEE. Nor do we understand what they consist of in terms of program structure, content, and teaching methods. Understanding these educational efforts in a meaningful way calls for a systematic investigation to provide a consistent knowledge base that can serve as a foundation for future research. This study examines engineering- and technology-focused entrepreneurship education as the primary focus.

Research goals:

The goal of this work is over the course of this research program, to methodically define and identify a coherent framework that can be used to distinguish approaches, study their efficacy, and promote future research on this topic.

- How many technology entrepreneurship programs exist, and which serve engineering students at the undergraduate and graduate levels;
- What are the key characteristics of these programs? How are these programs organized and what intra-university collaborations, infrastructure, and extracurricular activities support these initiatives?
- Is there a coherent body of knowledge covered in these programs? Are there important differences among programs?

Methods

Sample. In this study, we conducted a comprehensive search of entrepreneurship education programs at U.S. colleges and universities that were ASEE members in 2008. Though this list does not include every engineering school in the U.S., the ASEE membership list captured the majority of programs serving engineering students in the U.S. It also ensured the future possibility of utilizing data on the engineering programs and the students served (i.e., number of degrees offered, characteristics of the engineering student body). This yielded 341 schools for examination. We focused our efforts on identifying educational activities in entrepreneurship -- in particular, programs of study designed to serve undergraduate engineers as a target group. Some university-wide entrepreneurship programs, particularly at large schools, have a growing proportion of participating engineering students. For the purposes of this article we did not include such programs because it can be challenging to identify how many engineering students actually participate. However, we acknowledge that this is an important and growing area for future study and one that we intend to address in future work.

Key Informant Interviews. Of the total group of institutions, a subset of 20 schools was examined in more detail via phone interviews. These schools were asked to identify a key informant to help provide details of the entrepreneurial ecosystem at their particular institution. Prior to the interview, informants were provided key informants with data gathered about programs, courses, and other supporting activities and structures at their institutions. The informant reviewed the list to make corrections and additions to the

document. A series of open-ended questions about successes, collaborative relationships on and off campus, challenges, and strategies in implementing curricular and extracurricular activities that serve engineering undergraduates in the area of entrepreneurship were then asked. In most cases, the informants were either faculty members who taught and/or advise engineering students or were program directors of the entrepreneurial programs. Phone interviews conducted by a team lasted between 30-60 minutes; extensive notes were taken.

Program Review. Programs were defined as any set of courses or experiential activities that are sponsored by the university to promote student awareness of and competence in entrepreneurial thinking and practice. To identify relevant programs, school websites were systematically searched using keywords related to entrepreneurship and innovation. Course catalogues were also searched for the same keywords to identify specific programs of study and associated course requirements. Where relevant, NCIIA documents describing proposed and/or funded entrepreneurship initiatives were examined, since this information often clarified program structure, objectives, and targeted students; and provided rich descriptions of program history, infrastructure, curriculum, intra-university relationships, and student accomplishments. From this rich dataset, a relational database was created to store details about the school, entrepreneurship program, and to a lesser extent, associated courses. Following this, the programs were categorized in the following manner:

- undergraduate or graduate focused
- program type: certificate, concentration, major, minor, other
- administrative home
- area(s) of focus: engineering/technology/science, medical, sustainability, social entrepreneurship, other.

When available and applicable, the following program details were also noted:

- number of credits required to complete the program
- number of students enrolled annually
- number of engineering students enrolled annually.

Required and Elective Courses. Required and elective courses were categorized according to five topic areas that are included on the Entrepreneurship Knowledge Inventory [12], an 105 item survey instrument designed to assess students' exposure to entrepreneurial terms and concepts. These topic areas include:

- Becoming and Being an Entrepreneur ;
- Finance and Accounting;
- People and Human Resources;
- Sales and Marketing; and
- Product Ideation and Development

Courses that did not fit with the above categories were categorized as Miscellaneous.

Results

Courses. These categories were applied to analyze and group the approximately 230 courses. It was determined that the largest group of courses focused on introductory

knowledge and concepts in the category Becoming and Being and Entrepreneur (34%). Less prevalent were courses on Product Ideation and Development (13%), Finance and Accounting (11%); People and Human Resources (7%); and Sales and Marketing (9%); More than One Topic (6%). A substantial group of courses did not fit readily into any of the above categories (22%).

Programs. More than 500 entrepreneurship programs were identified among the 341 schools examined; 250 of these were at the undergraduate level. The study was then further narrowed to programs that had an explicit focus on technology or engineering. This was determined this in several ways:

- type of institution (institutes of technology or other engineering focused colleges)
- the program's administrative home (e.g., engineering school; technology commercialization or innovation center),
- program titles or descriptions that included phrases such as "engineering entrepreneurship" or "technology entrepreneurship"
- pathways for engineering students to participate; for university-wide entrepreneurship programs that are interdisciplinary, we included those that explicitly described a pathway for engineering students to participate (e.g., specific courses of study that allow the entrepreneurship courses to integrate with the engineering major).

This approach resulted in 47 programs at 45 schools for further examination (note that one school offered two undergraduate programs that met the criteria). In most cases, the initiatives selected were structured programs of study, in which the university defines a series of educational requirements that must be met for the student to receive a special designation on the academic transcript.

More than half of the ASEE programs in the sample offer some type of undergraduate entrepreneurship program. Of these programs, approximately 25% are focused explicitly on technology or engineering-focused entrepreneurship, while others incorporate pathways for engineering students to participate as well. This paper examines this smaller group of programs in an attempt to more clearly define program characteristics and curricular models.

The vast majority of programs were labeled as minors, concentrations, or certificates. Figure 1 shows the breakdown of program types in our sample, and Figure 2 shows the administrative affiliations of the programs in our sample.

Type of Program Offering

(N=47)

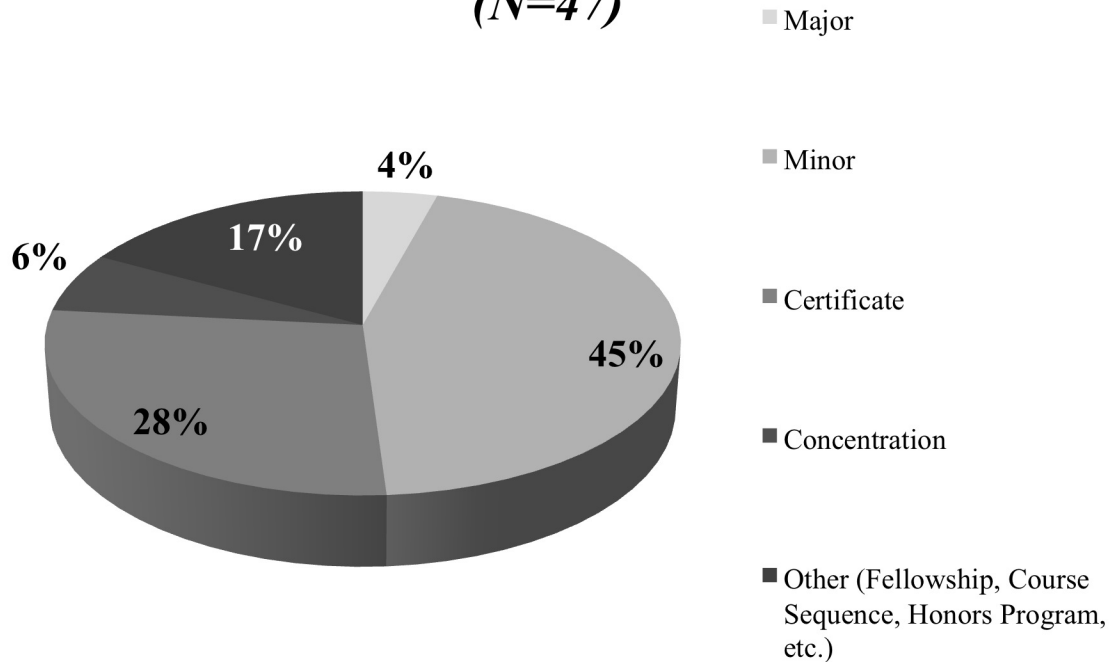


Figure 1: Classification of Programs by type of certification or for-credit offering (Major, Minor, Certificate, Concentration and Other)

About 25% of the programs were certificate programs. These are designed to supplement a student's major area of study and generally require between 4 and 20 credit hours of core courses and electives. There were a small number of programs that included additional requirements either through coursework or through extracurricular activities (e.g., participation in a business plan competition, creating a written business plan, giving an elevator pitch to an audience, or completing an internship in a start-up company).

Modules and Extracurricular Experiences. While the approach described here focused on examining the more visible and formal entrepreneurship learning experiences such as courses and programs, many students gain experiences in other ways. Some engineering schools, rather than offer a stand alone course in entrepreneurship, integrate modules in one or more existing engineering courses. This approach allows entrepreneurship to be introduced repeatedly and in the context of a specific engineering topic area. Other approaches at larger research universities, such as Stanford and MIT, have many extracurricular opportunities for students to connect their engineering coursework to entrepreneurial activities, such as business plan competition or entrepreneurs in residence who mentor and guide students who are working on projects with entrepreneurial potential. Though students in these environments may not be enrolled in stand alone

entrepreneurship courses or programs, they can still gain meaningful exposure to entrepreneurship. These type of opportunities will be examined in future work.

Program Administrative Home (N=47)

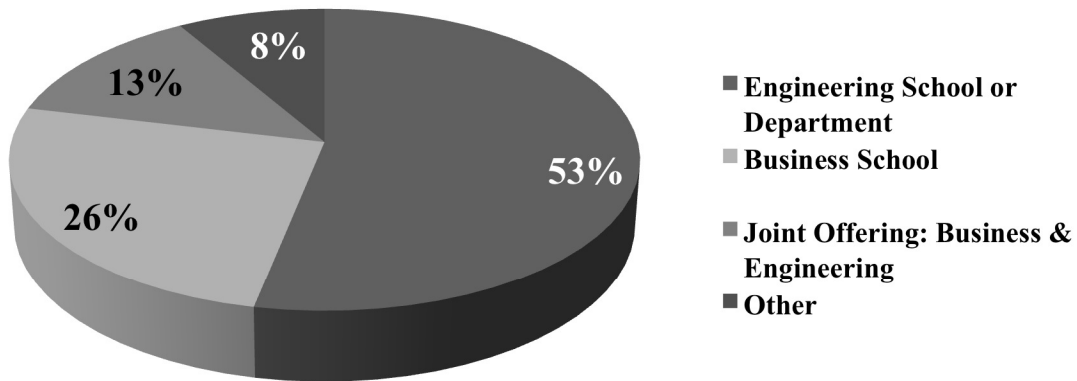


Figure 2: Administrative affiliation of entrepreneurship programs studied

Conclusions

This study provides a foundation from which to understand curricular innovations in engineering, using entrepreneurship education as the model. The initial results of our study show that entrepreneurship education is available in at least half of the engineering programs examined and has been integrated within the engineering program in approximately 25% of these programs. To date, there has not been a comprehensive catalog of programs that serve undergraduate engineers and thus our understanding of similarities and differences in curricular content and design, pedagogy, and administrative structures has been limited.

The work described here is preliminary and does not include analysis of the many university-wide programs that are now engaging engineering students. Ongoing work now in process will determine the extent to which engineering students take part in these programs, and provide a clearer understanding of approaches that enable additional or different coursework to fit into the tightly packed engineering curriculum. Another important area for further work is the university contexts in which programs operate.. Issues such as program sustainability, administrative policies and academic practices that

support or impede entrepreneurship education are critical and warrant further study. Finally, although we have begun to identify the extracurricular activities and university resources that are assumed to have a dramatic impact on entrepreneurship education outcomes a framework and catalog of those programs has yet to be completed.

The work completed to date is intended as a first step to understanding basic program characteristics in a way that allows for drawing comparisons between programs. Additional study of program features is needed. Issues such as student eligibility requirements; learning objectives and desired program impact; program evolution, strategies for integrating entrepreneurship with engineering; program sustainability, faculty hiring and evaluation practices; assessment practices, and interdisciplinary collaboration all provide rich areas for future examination. Though the analysis of courses has just begun, the work so far has centered on the topics emphasized rather than the teaching methods used. How entrepreneurship is taught within these courses, defining approaches that are experiential, interdisciplinary, and/or venture focused is important to enabling the identification of effective practices.

Given the emergence and widespread availability of entrepreneurship in the engineering curriculum, this work begins to provide the foundation from which to objectively compare program and curricular models, begin asking new questions, provide information on innovative strategies to overcome challenges, and in the longer term, provide evidence for effective practice and the growth of the field.

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