AC 2011-1729: UNDERSTANDING THE TECHNICAL ENTREPRENEURSHIP LANDSCAPE IN ENGINEERING EDUCATION

Mary Besterfield-Sacre, University of Pittsburgh

Mary Besterfield-Sacre is an Associate Professor and Fulton C. Noss Faculty Fellow in Department of Industrial Engineering, a Center Associate for the Learning Research and Development Center, and the Director for the Engineering Education Research Center at the University of Pittsburgh. Her principal research is in engineering education assessment, which has been funded by the NSF, Department of Education, Sloan Foundation, Engineering Information Foundation, and the NCIIA. Mary's current research focuses on three distinct but highly correlated areas innovative product design, entrepreneurship, and modeling. She has served as an associate editor for the JEE and is currently associate editor for the AEE Journal.

Nur Ozge Ozaltin, University of Pittsburgh

Nur zge zaltin is a graduate student in the Industrial Engineering department at the University of Pittsburgh. She received her B.S. in Industrial Engineering at Bosphorus (Bogazici) University in Turkey, and her Masters degree in Industrial Engineering at the University of Pittsburgh respectively. Her research interest involves improving innovation through modeling the design process.

Angela Shartrand, National Collegiate Inventors & Innovators Alliance (NCIIA)
Larry J. Shuman, University of Pittsburgh

Larry J. Shuman is Senior Associate Dean for Academics and Professor of Industrial Engineering at the University of Pittsburgh. His research focuses on improving the engineering educational experience with an emphasis on assessment of design and problem solving, and the study of the ethical behavior of engineers and engineering managers. A former senior editor of the Journal of Engineering Education, Dr. Shuman is the founding editor of Advances in Engineering Education. He has published widely in the engineering education literature, and is co-author of Engineering Ethics: Balancing Cost, Schedule and Risk - Lessons Learned from the Space Shuttle (Cambridge University Press). He received his Ph.D. from The Johns Hopkins University in Operations Research and the BSEE from the University of Cincinnati. He is an ASEE Fellow.

Mr. Phil Weilerstein, National Collegiate Inventors & Innovators Alliance (NCIIA)

Understanding the Technical Entrepreneurship Landscape in Engineering Education (CCLI-Phase 2)

Authors andAffiliations

Abstract

Over the past decade, entrepreneurship has emerged as a critical aspect of engineering education. Driven by changes in the global economy, entrepreneurship is one of the fastest growing areas of course development. Across the U.S., literally hundreds of entrepreneurship courses, programs and certificates are offered for engineering students, yet little has been done to define what constitutes appropriate content or to assess the degree to which these educational experiences have resulted in student learning of entrepreneurial knowledge, skills and attitudes. Under funding from the National Science Foundation, CCLI – Phase II, we are conducting a nationwide study to determine the status of entrepreneurship education across the U.S. As a subset of this larger study we are investigating the variety of entrepreneurship opportunities available on U.S. engineering campuses. To do this we examined institutional websites to collect information on: a) programs and courses in entrepreneurship that are offered to engineering students, b) where these programs and courses are located within the university, and c) extracurricular learning opportunities and resources for entrepreneurship (e.g., centers, incubators, entrepreneurship contests, funding in entrepreneurship, etc.). To achieve completeness, data collection and verification was accomplished by three researchers. Cluster analysis was conducted using PASW Modeler to group institutions into like categories. Several algorithms were tested with the two-step algorithm yielding the best results in terms of cluster quality; and we were able to identify important cluster predictors. In this paper, we provide two types of clusters related to engineering schools. First we clustered schools according to variables depicting opportunities offered within engineering schools, as well as by creating a surrogate variable to emphasize the degree to which engineering schools are involved in entrepreneurship. For those engineering schools that offer coursework, course offerings were coded and a second set of clusters was created to determine the 'perspective' by which entrepreneurship was taught. This paper reports on this analysis and discusses the different types of models implemented at institutions to deliver entrepreneurial education in engineering schools, as well as providing exemplars from various clusters. When complete, this work will provide faculty with essential models, actionable information about institutional factors, and common curricular and extracurricular practices.

1. Introduction

Driven by changes in the global economy, entrepreneurship is one of the fastest growing academic areas within the nation's 335 engineering schools. As a result, literally hundreds of courses and programs in entrepreneurship for engineering students are now offered; yet little has been done to define what constitutes appropriate content or to assess the degree to which these educational experiences have resulted in their intended purpose: student learning of enabling entrepreneurship knowledge, skills and attitudes. Building on previous work, we are investigating the teaching of entrepreneurship across the nation.

Many experts agree that the U.S.'s technological leadership is highly dependent on its strong capacity for innovation and getting such innovations to market. According to political leaders, this strength "has continued to create jobs and raise living standards . . . However, the rising trend of outsourcing high technology manufacturing and high-end services jobs overseas presents a new and fundamentally different phenomenon. Key components of our innovation infrastructure such as knowledge and capital have become highly mobile. If our engineering, design, and research and development (R&D) capabilities continue to follow the manufacturing and services facilities going abroad, our competitiveness will be weakened, putting our economic prosperity and national security at risk" [1]. A National Academy of Engineering study drew a similar conclusion, declaring that "Leadership in innovation is essential to U.S. prosperity and security . . . U.S. leadership in technological innovation seems certain to be seriously eroded unless current trends are reversed" [2]. An NSF-commissioned study by the American Society of Engineering Education also concurred "U.S. engineers lead the world in innovation," but "this great national resource is at serious risk because America has an engineering deficit" [3]. Thomas Friedman's characterization of an increasingly flat world sounded a similar warning that "The Chinese and the Indians are not racing us to the bottom. They are racing us to the top. Young Indian and Chinese entrepreneurs are not content just to build our designs. They aspire to design the next wave of innovations and dominate those markets. Good jobs are being outsourced to them not simply because they'll work for less, but because they are better educated in the math and science skills required for 21st-century work" [4].

The role of engineers is changing in this new global context. They are being called upon to solve more complex problems in collaborative, interdisciplinary contexts. These roles call for ". . . a new type of engineer, an entrepreneurial engineer, who needs a broad range of skills and knowledge, above and beyond a strong science and engineering background . . . (p. 139)" [5].

In 2006, the U.S. government committed $5.9 million via the American Competitiveness Initiative (ACI), to support investment in research and development (R&D) and education. That initiative is aimed at ensuring U.S. economic strength in the midst of dramatic shifts in the global economy, by supporting technological innovation and entrepreneurship. Although the ACI is focused on technology transfer and commercialization, little attention has been placed on developing the human capital side of entrepreneurship. Yet, inventions do not proceed to the implementation and dissemination phase without knowledgeable and skilled people to get the technologies into the real world. Such knowledge and skill requires a hybridization of engineering with entrepreneurial/business competencies.

In summary, the U.S. is entering a time in which it is essential for our workforce not only to be technologically advanced and creatively innovative, but to be entrepreneurially minded as well. How do we best prepare technically sophisticated engineering students to engage in the innovation process through entrepreneurial activity? Though scientists and engineers have strong technical skills and knowledge to create and develop new technologies, that knowledge alone will not lead to the development of the needed new industries and markets that will benefit the U.S. economy.

The purpose of this Phase 2 CCLI research project is to understand how institutional, instructional and student variables influence student learning of technology-focused entrepreneurship. In order to enhance future engineers' abilities to incorporate entrepreneurship in their work, we need to better understand: (1) how entrepreneurship is taught within engineering schools, and (2) how the different pedagogical environments increase students' learning of entrepreneurship. This paper addresses the first overarching objective. Specifically, we have conducted a nationwide study to determine the status of entrepreneurship education in engineering schools across the U.S., and using this information, map and identify similar types of approaches and contexts using a clustering algorithm. We collected information on: a) programs and courses in entrepreneurship that are offered to engineering students, b) where these programs and courses are located within the university (e.g., engineering or business school, etc.), c) other extracurricular learning opportunities and resources for entrepreneurship (e.g., incubators, entrepreneurship centers, living learning centers, and business plan competitions), and d) key individuals or groups catalyzing entrepreneurship education in each context. This paper is the first of our dissemination of the results of this research.

2. Background

As stated, engineering schools are being called on to prepare "entrepreneurial engineers" who can identify opportunities, understand market forces, and successfully commercialize new technologies. This call has come from professional organizations such as the National Academy of Engineering, ASEE and ASME, and influential publications such as *The Engineer of 2020* [6-7]. As a result, the role of entrepreneurship in engineering, science and technology education is undergoing a transformation. Many engineering schools now expose students to commercially driven innovation and entrepreneurship programs. Studying entrepreneurship is increasingly viewed as a way to prepare students for the realities of the working world where they must contribute to the commercial success of any enterprise they join or create. Some of the most prominent U.S. universities including Stanford and MIT have well-established technology entrepreneurship initiatives that have successfully prepared students to not only invent new technologies, but to innovate and disseminate these technologies through successful commercialization, thus maximizing positive economic and social impact [8].

Although entrepreneurship has stimulated innovation and transformation in many engineering curricula, we still know little about the educational practices and outcomes of this emerging field. Standish-Kuon and Rice [8] state, "introducing engineering and science students to entrepreneurship principles and practices is poorly understood (p. 33) ". Several important questions remain unanswered. First, and most basic - where and how is entrepreneurship education being offered to undergraduate engineering students? What types of institutions offer these learning opportunities, and what additional resources and infrastructure exist at these institutions to support entrepreneurial learning? Second, what is the essential body of knowledge comprising engineering entrepreneurship? What topics and concepts are typically taught and what distinguishes this field from traditional entrepreneurship education? At present, these questions have not been adequately answered.

No comprehensive analysis of engineering or technology entrepreneurship courses and programs exists. Faculty who are engaged in course and program development have documented the process of course or program creation, describing content, pedagogy, implementation issues, and assessment plans [9-11], although much of this literature is limited to a particular program or institution. One exception is Standish-Kuon and Rice's [8] study which analyzed approaches to teaching entrepreneurship to engineering and science students at six institutions using a multiple-case study approach. They found important differences among programs, such as location within the university, organizational structure, and the extent to which teaching, research, or new venture creation was emphasized. The small numbers of schools selected for this study were based on a convenience sample, and thus are not necessarily representative of entrepreneurship education in engineering. Several more comprehensive analyses of general entrepreneurship education in business and management departments have been conducted [12-13]. These provide a basis on which to formulate our examination of engineering entrepreneurship curriculum.

While there has been considerable debate about the extent to which entrepreneurship is teachable, most have concluded that successful entrepreneurs have acquired specific knowledge and skills through both successful and failed new ventures. According to Dabbagh and Menasce [6] an entrepreneurial mindset for engineers and scientists includes skills in teamwork, leadership, and written and oral communication, as well as contextual awareness such as understanding market forces, recognizing opportunities and needs for new technologies, and knowing how to garner the human, financial and technical resources in order to bring new technologies to the market. Thus, our assumption is that students can increase professional competence in this area through well-designed curricular and extracurricular experiences that provide such skills [14].

Okudan and Rzaza [15] conducted a review of the literature on entrepreneurship education and summarized recommendations for both content and teaching methods. They identified four key areas that informed curricular design: a) "affective socialization," such as values and attitudes associated with entrepreneurship; b) making decisions with "insufficient information" or risk taking; c) a "learning style" that addresses active experimentation; and d) "adoption of entrepreneurial behavior[s]" such as independent action, competitive aggressiveness, proactiveness, and innovativeness [16]. Kussmaul and colleagues [17] also developed a framework for a body of knowledge for entrepreneurship education intended primarily for undergraduates. This body of knowledge was based on "collective research about terms, definitions, concepts, resources, and skills useful to the entrepreneur as well as existing entrepreneurial course topics and categories . . . (p. 221)" and was linked to instructional materials and specific disciplines of study. We have built upon this work by developing an inventory to assess students' familiarity with many of the terms and concepts in this body of knowledge.

3. Methodology

Universities in general and engineering schools in particular deliver entrepreneurship education differently. These variations may have significant effects on student outcomes. Thus, it is important to first determine the "density" of entrepreneurship experiences offered at various schools of engineering. As discussed, studies have been conducted on entrepreneurship, particular by business school faculty, both in the U.S. and Europe [18-20]. Often the purpose of these studies is to provide a ranking of the entrepreneurship programs. Vesper and Gartner [12](1997) highlight the variables used in such studies as well as indicate additional variables based on the Malcolm Baldrige National Quality Award. Unlike the studies conducted in the business field, the purpose of this survey is to characterize technical entrepreneurship in U.S. engineering schools. Drawing upon these studies, we developed a set of variables, as shown in Table 1, to describe the state of technical entrepreneurship within engineering schools.

Table 1. Variables Used to Investigate Entrepreneurship Across the U.S.

Overarching Category	***Variables***
Institution characteristics	• Carnegie classification of institutions of higher education • Centers focused on entrepreneurship • Business school
School of engineering characteristics	• Size of engineering school • Program offerings (i.e. minor or certificate) • Number and types of courses with a focused on technical entrepreneurship (within engineering, cross-listed with business, business offered) • Engineering centers focused in the area of technical entrepreneurship or product realization • Extra-curricular activities (e.g. entrepreneur societies and clubs, product design and business plan competitions, invited speakers) • Faculty chairs or professorships in entrepreneurship
Leadership/ Management	• Degree of involvement from: program director, engineering dean, business dean, university administration, advisory board members, faculty, student representatives, entrepreneurial mentors, associations with entrepreneurial-based societies • Management housed (e.g., existing department, standalone center, etc.)
Community impact	• Alumni exploits and start-ups • Innovations • Employment of students in start-ups
School performance	• Engineering faculty publications in technical entrepreneurship • Average number of students enrolled in classes compared to School of Engineering enrollment • Tenure of courses • Frequency of courses offered
Strategic planning	• Internal resources • External grant/funds (i.e. Coleman, Kauffman, Lowe, Kellogg, other) • Faculty (e.g. faculty full-time, tenure, contract, visiting, part-time adjuncts) • Staff (i.e. number of positions, full or part-time) • Research in technical entrepreneurship and/or product realization

Our approach was the following. First we collected those data which were readily available from each engineering school's website. For those schools that had formal programs in their engineering school, we conducted a structured phone interview with an appropriate contact(s) using the variables described in Table 1. We then re-examined the data for inconsistencies and missing information which were resolved by a second follow-up discussion with the institution. The websites and data were then analyzed *twice* more by two additional persons to verify and validate their content. Once complete, two types of cluster sets were developed.

For our first type, we clustered schools according to variables depicting opportunities offered within engineering schools. To do this we created a surrogate variable to emphasize the degree to which engineering schools are involved in entrepreneurship (or density), as shown in Table 2. Each engineering school received a rating (nothing to very high) according to the level of involvement offering coursework, extra-curricular activities, minors/certificates and concentrations, as well as majors in entrepreneurship. For example, an engineering school may receive a high rating if it offered a major in entrepreneurship; or if it offered four to seven activities and a minor, certificate or concentration. An additional set of clusters was also created to include variables related to business school involvement. This was done to determine how the engineering school clusters potentially morphed given exposure to a business school. For this paper, we provide results for programs offered only through engineering, which consisted of 38 institutions.

Table 2. Rubric to Classify Degree of Involvement in Entrepreneurship (Density)

	Individual Courses Extra-curricular Activities	***Granting Minor Granting Certificate Concentration***	***Granting Major***
Nothing	0	0	0
Low	1 to 3	0	0
Moderate	0	1	0
Moderate	4 to 7	0	0
Moderate	1 to 3	1	0
High	4 to 7	1	0
High	1 or more	2 or more	0
High	8 to 11	0	0
High	0	0	1
High	1 to 3	0	1
High	0	2 to 3	0
Very High	12 or more	0	0
Very High	2 or more	0	1 or more
Very High	0	0	1 or more
Very High	0	1 or more	1 or more
Very High	1 or more	1 or more	1 or more
Very High	0	4 or more	0

Our second type of clusters is specific to the course offerings of each engineering school. These course offerings were coded to determine a 'perspective' by which entrepreneurship was taught at the particular school. We coded each of the courses (core or elective) into one of several groupings according to their course title and course descriptions, as shown in Table 3. The categories were based on a taxonomy developed under a project entitled, *Institutionalizing Entrepreneurship at Primarily Undergraduate Institutions (PUIs)* (see http://www.pui-eship.org/ for details) and have been subsequently used in the development of the Entrepreneurship

Inventory [20]. Four additional categories were added: Engineering Coursework, Business Coursework, New Venture Planning Launch and Management, as well as other or unknown.

Table 3. Groupings for the Classes

Course Category	*Characteristics of the Category*
Becoming an Entrepreneur	• Strategic Thinking and Presentation • Process and Context • Structure and Approach • Entrepreneurship
Finance & Accounting	• Core Finance • Venture Launch/Funding • Reporting
People & Human Resources	• People & Human Resources
Sales & Marketing	• Sales & Marketing
Product Ideation & Development	• Intellectual Property • Meeting a Need • Protecting an Idea

For simplification, these categories were subsequently collapsed into our five final categories, specifically: Becoming and Being an Entrepreneur, Business and Management Skills, Engineering Coursework, Product Ideation and Development, and Other/Unknown. The other/Unknown category contained a small set of courses.

For both types, a clustering procedure was used to identify groups of similar entrepreneurship education by characterizing the nature or typology of the various program and course offerings, respectively. Cluster analysis allowed us to determine the composition and characteristics of each grouping, including critical variables in each cluster. In this way, differences among the clusters were assessed, and the distinguishing variables identified. Further, the importance of each variable in segmenting the dataset was determined [21].

We clustered the universities by using PASW Modeler. Because the data were attribute, we applied Two-step, Kohonen and K-means algorithms to segment programs into groupings. To determine the number of clusters in our data set, we used the following rule of thumb as a baseline: $k \approx$ *squareroot (n/2)*, where k = number of clusters and n = the number of data points. Given the number of universities, the rule of thumb gave us roughly five clusters. Further, we wanted a minimum of three members per cluster. For both types of clusters, we started the analysis with five clusters and increased the number of clusters to obtain the best cluster quality (i.e., a silhouette measure of cohesion and separation). We found eight clusters with the two-step algorithm (using log-linear distances) provided the best results for our first type of clusters (engineering programs); and eight clusters with the two-step algorithm for the second type of clusters (course offerings). In reporting our data, we have removed the names of the institutions until we have discussed the results with each institution.

4. Results: Cluster Type 1 – Technical Entrepreneurship Engineering Programs

As mentioned, our best model yielded good cluster quality with three inputs: density (as shown in Table 2), the number of "physical spaces", and the Carnegie classification (2000, see classifications.carnegiefoundation.org). Note the "physical space" variable encompasses the following: 1) incubators or business accelerators, 2) web-portals providing a mechanism for pointing people to resources on campus, 3) research institutes focused on entrepreneurship, and 4) studio like spaces to work on designs and prototypes. The density variable had the highest importance predictor, followed by the physical space variable, and then Carnegie classification variable.

Figure 1 provides an overview of the various engineering programs and how they clustered as organized by degree of density and number of centers. Here we present the schools in terms of their public or private status (i.e., Pb – public vs. Pr – private), their location in the U.S., Carnegie classification, and whether or not they are one of the top 50 engineering schools in terms of awarding bachelor's degrees (i.e., Yes – on the Top 50 list vs. No – not on the Top 50 list) [22]. As shown in Figure 1, eight clusters that were formed had striking characteristics. The cluster at the upper right of the figure contains those schools where the density is very high in their engineering school and they also have at least two physical spaces on their campus associated with entrepreneurship. These schools are also considered research one Carnegie classification.

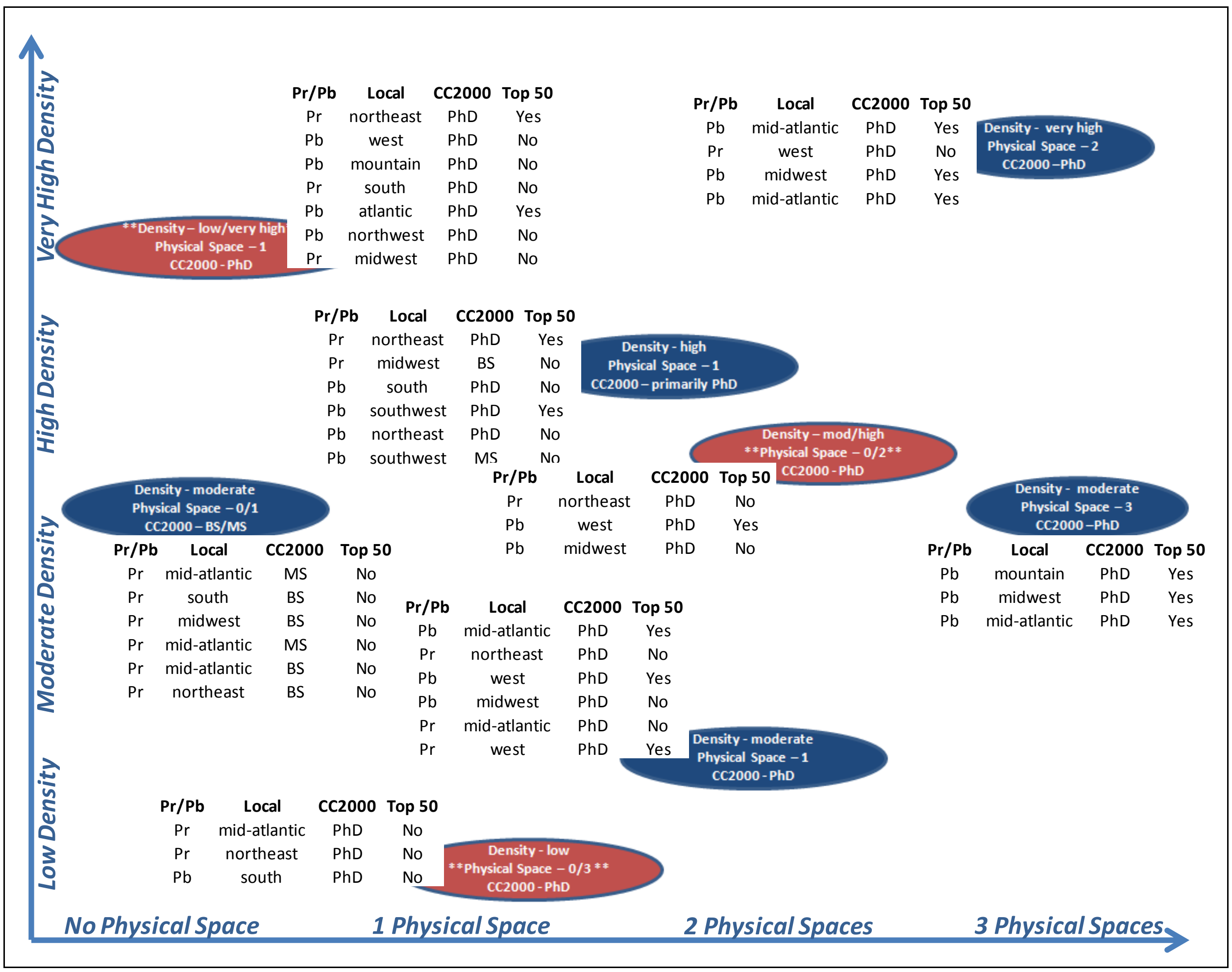

Figure 1. Technical Entrepreneurship Clusters in Engineering Schools

The cluster more centrally located also contains engineering schools with high density of technical entrepreneurship and host a physical space to carry out entrepreneurship activities. For the most part location does not seem to be a factor for the clustering; however, one cluster is made up entirely of private smaller schools with moderate density of entrepreneurship (lower left corner). Three red clusters have a variable that deviates more than one level of the variable. The variable is denoted with asterisk. The other clusters are self-explanatory; however, one cluster is worth further discussion. On the far right of the figure is a small cluster of large public engineering schools with moderate density; and these three programs all have three physical locations on their campus devoted to entrepreneurship.

5. Results: Cluster Type 2 – Technical Entrepreneurship Course Offerings

Based on its title and course description, each course was coded according to Table 3. Given the nine variables, this cluster analysis was more involved, as it must consider not only the type of courses, but the number of courses taught and whether the courses are core or elective. Further, several different algorithms and size of clusters must be applied (i.e., Two-step, Kohonen, and K-means) to determine best fit. At this time we are still investigating proper combinations of courses, cluster algorithm and size. However, we provide here a preliminary set of eight clusters using Two-step analysis. The cluster quality rating is fair. For this particular cluster analysis, all the courses were considered (regardless whether the course are core or elective); and the number of courses per category were given the following rating:
Nothing (0 course offerings), Low (1 course offering), Moderate (2-3 course offerings), High (4-8 course offerings), and Very High (9 course offerings or more).

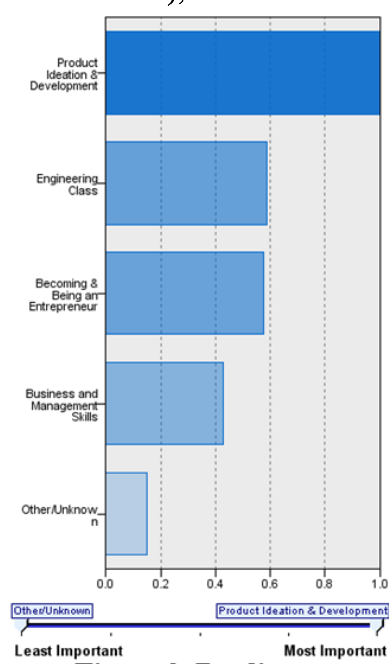

Figure 2. Predictor Importance for Courses

Figure 2 provides the list of variables and their predictor importance for this cluster analysis. As shown in Figure 2, Product Ideation and Development (PID) was the most important variable in determining cluster membership; followed by Engineering Classes and Becoming and Being an Entrepreneur. Figure 3 provides a general description of the cluster analysis of the types of programs offered by the various engineering schools. It is evident in Figure 3 that most schools offer moderate to high in the number of courses in the area of Product Ideation and Development, which is an intuitive result. What is a somewhat surprising result is the low to moderate number of course offerings in the area of Becoming and Being an Entrepreneur, as most of the clusters showed only low to moderate offerings for this category. One exception is the cluster on the far right containing four schools. For this particular cluster, there is both a high level of Product Ideation and Development coursework as well as high numbers of offerings in the area of Being an Entrepreneur.

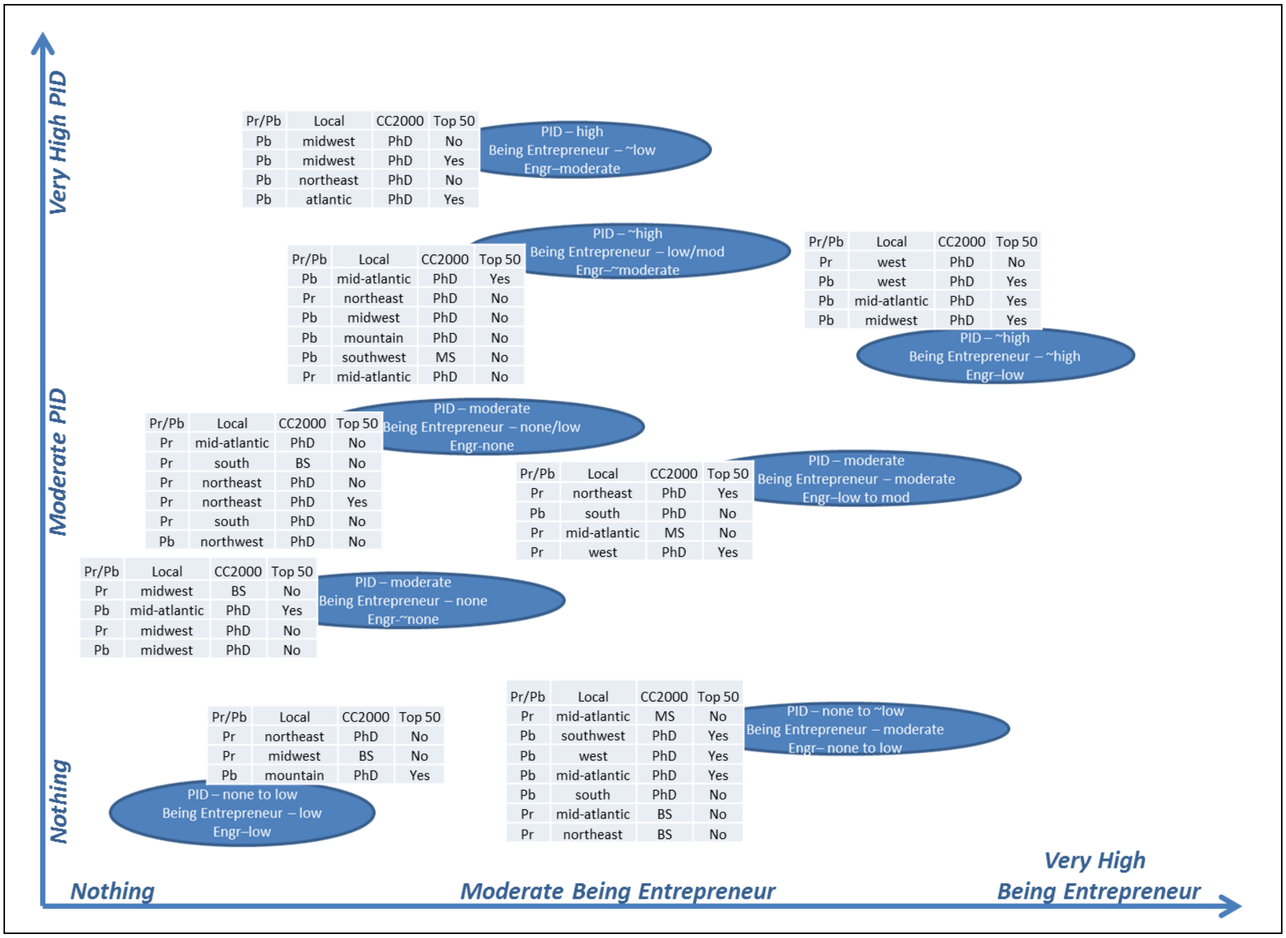

Figure 3. Clustering of Courses Offered by Engineering School

6. The Value of Clustering Technical Entrepreneurship

This portion of our CCLI Phase II research is primarily descriptive in nature. Prior to determining how learning is assessed, we first need to determine what institutions are engaging engineering students in entrepreneurship and how they are engaging them. Although our research investigates many more variables, this paper reports on two such cluster analyses that have been prepared. Even so, much can be gleaned from this analysis and used by engineering programs and faculty. For example, from Figure 1 consider a private engineering school who lies in lower left corner (i.e., Density – moderate; Center – none; CC2000 – BS and MS) and wishes to increase their visibility in entrepreneurship. From the results of this analysis, they may wish to investigate and emulate schools that lie in the cluster towards the top and middle of the figure (i.e., Density – high; Center - one; CC2000 – mixed). As a second example, from Figure 3 consider an engineering school that lies in a cluster that offers courses in the area Product Ideation and Development (PID) (e.g., moderate to high, or high to very high), but does not offer courses in the area of Being an Entrepreneur (e.g., offers nothing or low). Such engineering schools can investigate schools in the cluster to the right of the figure to determine what offerings in the area of Being an Entrepreneur might be conducive to their curriculum. When fully complete, this work will provide faculty with essential models, actionable information about institutional factors, and common curricular and extracurricular practices.

Much work is still to be done with regards to these 38 institutions, as well as the many more engineering schools that work collaboratively with their business schools to provide entrepreneurial experiences. These analyses will be reported on at a future date.

Acknowledgements

This research is supported in part by the National Science Foundation through DUE-0817394: "*Collaborative Research: Assessing Technical Entrepreneurship Learning in Engineering Education*."

Bibliography

1. Lieberman, J. (2004, May 11). *Offshore outsourcing and America's competitive edge: Losing out in the high technology R&D and services sectors* [White paper]. Retrieved January 9, 2008, from http://lieberman.senate.gov/documents/whitepapers/Offshoring.pdf

2. National Academy of Engineering. (2004). *Assessing the capacity of the U.S. engineering research enterprise.* Washington, DC: Author. Retrieved January 8, 2008, from http://www.nae.edu/nae/engecocom.nsf/weblinks/MKEZ-68HQMA?OpenDocument

3. Douglas, J., Iverson, E., & Kalyandurg, C. (2004). *Engineering in the K12 classroom: An analysis of current practices and guidelines for the future.* Washington, DC: ASEE. Retrieved January 8, 2008, from http://www.engineeringk12.org/Engineering_in_the_K-12_Classroom.pdf

4. Friedman, T. (2004, October 17). Oops, I told the truth. *New York Times*. Retrieved January 9, 2008, from http://www.nytimes.com/2004/10/17/opinion/17friedman.html

5. Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education, 95*(2), 139-151.

6. Dabbagh, N., & Menascé, D. A. (2006). Student perceptions of engineering entrepreneurship: An exploratory study. *Journal of Engineering Education*, *95*(2), 153-163.

7. Rover, D. T. (2005). New economy, new engineer. *Journal of Engineering Education, 94*(3), 427-428.

8. Standish-Kuon, T., & Rice, M. P. (2002). Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *Journal of Engineering Education, 91*(1), 33-39.

9. Wang, E. L., & Kleppe, J. A., (2001). Teaching invention, innovation and entrepreneurship in engineering. *Journal of Engineering Education*, *90*(4), 565-570.

10. Carlson, L. E., & Sullivan, J. F. (2000, October). Engineers invent and innovate [Paper 1373]. *Proceedings IEEE Frontiers in Education Conference* [CD-ROM]. Kansas City, MO.

11. Sullivan, J. F., Carlson, L. E., & Carlson, D. W. (2001). Developing aspiring engineers into budding entrepreneurs: An invention and innovation course. *Journal of Engineering Education, 90*(4), 571-576.

12. Vesper, K. H., & Gartner, W. B. (1997). Measuring progress in entrepreneurship education. *Journal of Business Venturing, 12,* 403-421.

13. Solomon, G. T., Duffy, S., & Tarabishy, A. (2002). The state of entrepreneurship education in the United States: A nationwide survey and analysis [Electronic version]. *International Journal of Entrepreneurship Education, 1*(1), 65-86.

14. Gorman, G., Hanlon, D., & King, W. (1997). Some research perspectives on entrepreneurship education, enterprise education and education for small business management: A ten-year literature review. *International Small*

Business Journal, 15(3), 56-77.

15. Okudan, G. E., & Rzasa, S. (2004, October). *Teaching entrepreneurial leadership: A project-based approach.* Paper presented at the 34th ASEE/IEEE Frontiers in Education Conference, Savannah, GA.

16. Lumpkin, G. T., & Dess, G. G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *The Academy of Management Review, 21*(1), 135-172.

17. Kussmaul, C., Howe, S., Arion, D., Farris, J., Goodrich, J., Lane, P., et al. (2006, March). *Institutionalizing entrepreneurship at primarily undergraduate institutions.* Paper presented at the 10th Annual Conference of the National Collegiate Inventors and Innovators Alliance, Portland, Oregon.

18. Vesper, K. H. (1993). *Entrepreneurship education – 1993*. Los Angeles: University of California, Los Angeles, Center for Entrepreneurial Studies.

19. Callan, K., & Warshaw, M. (1995). The 25 best business schools for entrepreneurs. *SUCCESS, 42*(7), 37-49.

20. Shartrand, A., P. Weilerstein, M. Besterfield-Sacre, and B. Olds. “Two Tools for Assessing Student Learning in Technology Entrepreneurship.” *38th* at the ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY, October 22-25, 2008.

21. Norusis, M. J. (2005). *SPSS 14.0 statistical procedures companion* (pp. 357-384). Upper Saddle River, NJ: Prentice Hall.

22. Gibbons, M.T. (2010, June), Engineering by the Numbers, *The 2009 Edition of the Profiles of Engineering and Engineering Technology Colleges*, ASEE publications. .http://www.asee.org/papers-and-publications/publications/college-profiles/2009-profile-engineering-statistics.pdf