AC 2012-4200: ESSENTIAL FACTORS RELATED TO ENTREPRENEURIAL KNOWLEDGE IN THE ENGINEERING CURRICULUM

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As an entrepreneur leading a not-for-profit organization, Phil Weilerstein has grown the NCIIA (http://www.nciia.org/), from founding as a grassroots group of enthusiastic university faculty to an internationally recognized resource supporting and promoting technology innovation and entrepreneurship to create experiential learning opportunities for university students, and successful science and technology-based socially impactful businesses. NCIIA does this by providing a linked sequence of programs that develop community and help move faculty and student entrepreneurs from innovative ideas to the launch of products and businesses. Weilerstein began his career as an entrepreneur as a student at the University of Massachusetts. He and a team including his advisor launched a start-up biotech company and took it to IPO. This experience, coupled with a lifelong passion for entrepreneurship, led to his work with the National Collegiate Inventors and Innovators Alliance. He is a founder of the Entrepreneurship Division of the American Society of Engineering Education and is the recipient of the 2008 Price Foundation Innovative Entrepreneurship Educators Award.

Factors Related To Entrepreneurial Knowledge in the Engineering Curriculum

Given changes in the global economy, innovative, entrepreneurial engineers are in high demand. As a result, entrepreneurship has become one of the fastest growing academic areas in engineering. Yet, we know little about what engineering students actually know regarding entrepreneurship in engineering. To address this issue, we devised a multi-institution pilot study using the Entrepreneurship Knowledge Inventory (EKI), a tool that measures students' familiarity with common technology entrepreneurship concepts and terms. The pilot study was conducted across six engineering schools investigating the differences between freshmen and senior engineers in their self-reported knowledge of technology entrepreneurship terms and concepts. The data from the EKI were analyzed to determine if significant differences in entrepreneurial knowledge existed between freshmen and senior engineering students, as well as between senior engineering students with and without past entrepreneurial experience. Results show some differences between freshmen and senior engineering students in certain content areas, as well as between engineering seniors with experience versus those students without any entrepreneurship experience. These findings identify gaps in engineering student knowledge, and suggest areas for improvement in specific areas of entrepreneurship education.

Index Terms ---Assessment, Engineering Education, Technology Entrepreneurship

I. Introduction

Innovation and technology-based entrepreneurship is a key to the United States' success in the global market. Although the United States has the innovative capabilities to lead the global market in design, it is beginning to wane as other countries progress. Therefore driven by the global economy and the current economic crisis in the U.S., there is a growing need for our "innovation infrastructure" and in particular, the human capital in engineering to be revitalized. The last decade has seen rapid increases in outsourcing of high technology manufacturing and high-end services jobs overseas.[1] This trend of outsourcing jobs is accelerating not only due to lower wages in countries overseas, but also because often, workers are better educated in the math and science skills needed for high technology work. In addition, young entrepreneurs overseas are becoming less satisfied with building what U.S. engineers have designed. Instead, these young entrepreneurs aspire to be the designers of the next wave of innovations. This trend will put increasing pressure on U.S. global leadership in innovation. In response, the United States needs to produce "a new type of engineer, an entrepreneurial engineer, with a broad range of skills and knowledge, above and beyond a strong science and engineering background."[1] As a result, 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. Herein lies the motivation for our work.

II. Objective

In light of the innovation driven knowledge economy and the key role that entrepreneurial activity plays in the global economy, entrepreneurship courses are now offered to engineering students in at least 335[2] institutions that have engineering schools and programs across the nation; and of this number roughly 12% offer entrepreneurship *within* their engineering schools. Despite the widespread need for entrepreneurship within engineering curricula, no formal research has been conducted on the body of knowledge for technological-based entrepreneurship.

Also few studies have examined the impact of a student's attainment of technological entrepreneurship-based knowledge and skills.

The objective of this particular research is to study what engineering students know about entrepreneurship. Specifically, we intend to identify what aspects of the educational setting relate to student learning related to entrepreneurial knowledge, skills, and thinking. To achieve this objective, two tools[3] have been created to measure students' familiarity with key entrepreneurial terms and concepts, and to examine students' "entrepreneurial mindset" as reflected in a written response to a hypothetical technology-based company scenario. The first tool, which is the focus of this paper, is the Entrepreneurship Knowledge Inventory (EKI). This inventory was initially designed to measure self-assessed entrepreneurial knowledge of students enrolled in entrepreneurship-based engineering courses and programs at six engineering schools located in the Midwest. The items were initially based on a taxonomy being developed under funding by the NCIIA entitled, *Institutionalizing Entrepreneurship at Primarily Undergraduate Institutions (PUIs)*[4]. The survey asks engineering students to indicate their level of familiarity with technology entrepreneurship terms and concepts at both the beginning of an entrepreneurial course or program and toward the end of their educational experience(s). The inventory takes approximately 20 minutes to complete.

A second tool, which is used in the larger research study, is the Entrepreneurial Mindset Rubric. We believe that "entrepreneurial mindset" is different than "entrepreneurial content knowledge and skills." Much has been articulated about the meaning of "mindset"; and certainly there is a fine line between what is "teachable" and what is inherent to a student's personality. Considering those characteristics unique to "technical entrepreneurship" that can be *influenced* in engineering education, we adopted three constructs from the "Entrepreneurial Orientation Scale" by Covin and Slevin.[5] This highly researched questionnaire includes eight items that load to the following constructs[6]: product market innovation, proactiveness of decision making, and risk taking.

Although the focus of this paper is on the EKI, data collected from both instruments highlight important aspects of entrepreneurial knowledge that can be used by engineering educators to measure and evaluate the impact of entrepreneurial programs and courses on students.

III. Methodology

The Entrepreneurship Knowledge Inventory (EKI) was developed and piloted with engineering students enrolled in entrepreneurship courses at ten engineering schools as a tool to assess students' familiarity with entrepreneurial terms. The participating students were undergraduate engineering students, all from various engineering majors. The inventory contains 105 items, divided into five subject headings: 1) Becoming and Being an Entrepreneur, 2) Finance and Accounting, 3) People and Human Resources, 4) Sales and Marketing, and 5) Product Ideation and Development. For each item, students were asked to rate their familiarity with the particular term associated with the item, based on a 5-point categorical scale, as shown in Table 1.

Table 1. Level of Familiarity

NONE	LOW	MODERATE	HIGH	VERY HIGH
Never heard of it	Heard of but not sure what it means	Can explain it partially	Can explain in depth but not sure how to apply it	Can explain in depth and can apply it

Using this initial pilot data, a factor and reliability analysis was conducted and applied to the data for verification. This analysis consisted of three necessary steps: a principal components extraction method, Varimax rotation, and Kaiser normalization[8]; hence, the 105 items were clustered into twelve factors, as shown in Table 2.

Table 2. Subject Area Identified Factors

Subject Areas	Identified Factors
Becoming an Entrepreneur	1. Strategic Thinking & Presentation
	2. Process & Context
	3. Structure & Approach
	4. Entrepreneurship
Financing & Accounting	5. Core finance
	6. Venture Launch/ Funding
	7. Reporting
People & Human Resources	8. People and Human Resources
Sales &Marketing	9. Sales and Marketing
Product Ideation & Development	10. Intellectual Property
	11. Meeting a need
	12. Protecting an Idea

During the fall and spring 2008-09 academic year a second pilot was conducted with 196 engineering students from the engineering institutions (98 freshmen, 95 seniors and 3 null – that is, the students did not indicate their level). After compiling descriptive statistics, hypothesis testing was conducted. Using Minitab version 15 statistical analysis software, two-sample independent t-tests were conducted on the latent variables comparing freshmen to seniors to determine which identified factors (if any) were statistically different. Additional two-sample t-tests were conducted to identify which individual items caused the statistical differences between factors. All of the two-sample t-tests help to show how entrepreneurial knowledge grows over an undergraduate career and identifies the items or topic areas that could be emphasized further.

In addition to the freshman-senior engineering comparison, we compared differences between senior engineering students with and without entrepreneurial experience. In addition to the EKI items, survey respondents completed a series of questions about their background, including demographics and experience with entrepreneurship. Questions about entrepreneurship experience addressed prior business ownership, participation in entrepreneurship courses, certificates and minors, participation in other campus resources to support entrepreneurial learning, including entrepreneurship centers, student clubs, mentoring programs, internships, and workshops. Table 3 presents students' reported levels of participation in each type of entrepreneurship experience. While the table shows general types of experiences, actual surveys were customized for each institution and presented the actual names of programs.

Table 3. Levels of the Entrepreneurship Academic Experiences

Experiences	None	Low	Moderate	High
Coursework	Never heard of it	Heard of it but not interested in taking it	Heard of it and interested in taking it	Have taken the class
Program/Minors Certificates	Never heard of it	Heard of it but not interested in pursuing minor	Heard of it and interested in pursuing minor	Enrolled in this program
Innovation Competitions	Never heard of it	Heard of it but not interested	Heard of it and interested in it	Have entered the competition
Incubators and Centers	Never heard of it	Heard of it but not interested	Heard of it and interested in using it	Have utilized it
Clubs	Never heard of it	Heard of it but not interested	Heard of it and interested in joining	Am a member
Mentors/ Alumni Networks	Never heard of it	Heard of it but not interested	Heard of it and interested in finding one	Have a mentor entrepreneur
Boot-camps and Workshops	Listing provided			
Internships and Field Experiences	Listing provided			

The degree of entrepreneurship experience was determined as follows. Students with business ownership experience were categorized as "experienced." Students with two "High" responses (according to Table 3) were also categorized as "experienced." Based on the pilot sample, 19 of the 95 senior engineering students who took the EKI were categorized as "experienced"; the remaining 76 were categorized as "inexperienced." After categorization was completed, hypothesis testing was applied to each individual item (i.e., familiarity with terms) as well as to the factors delineated in Table 2. This analysis determined whether significant differences existed between experienced and inexperienced senior students.

IV. Results

A. Comparing Freshman Engineering and Senior Engineering Students: Factor and Item Analysis

Given the clustering of twelve identified factors into the five subject areas, shown in Table 2, a second set of hypotheses were tested on the twelve factors. Six factors were found to be significant ($\alpha=0.05$), as shown in Table 4.

Table 4. Significant Identified Factors

Subject Area	Significant Identified Factor	P-value
Becoming an Entrepreneur	Process & Context	.039
Financing & Accounting	Core Finance	.008
	Venture Launch/Funding	.014
	Reporting	.002
Sales & Marketing	Sale & Marketing	.029
Product Ideation & Development	Intellectual Property	.042

For each of these factors a Bonferroni adjustment for multiple comparisons was applied to the number of items in that particular factor (α=0.05). The purpose of the application of the Bonferroni α is to "protect against Type I error when conducting a series of statistical tests"[8]. This resulted in a list of items considered significant within each of these factors (i.e., those significant items had a p-value smaller than the Bonferonni α), as indicated in Table 5.

Table 5. Significant Item Statistics For Significant Identified Factors

Subject Area	Significant Factor	Bonferonni Alpha	Significant Item(s)	Item P-value
Becoming an Entrepreneur	Process & Context	.0042	Stakeholder Identification	.002
Financing & Accounting	Core Finance	.0042	Projections & Forecasts	.002
			Risk Analysis	.002
			Fixed Costs vs. Variable Costs	.000
			Overhead	.000
	Venture Launch/Funding	.0050	Venture Capital	.003
			Due Diligence	.001
			Overhead	.000
	Reporting	.0050	Equity	.003
			Cash Flow Statements	.000
			Payables/Receivables	.000
			Risk Analysis	.002
Sales & Marketing	Sales & Marketing	.0033	Product Life Cycle	.000
			Economies of scale	.003
			SWOT Analysis	.002
Product Ideation & Development	Intellectual Property	.0045	Concept Selection	.003

As noted, the subject area of "Financing & Accounting" has substantially more items, implying that engineering students do acquire this knowledge and/or gain experiences during their undergraduate career such that they have a better understanding of this topic area. In fact, on average 40% of the freshman indicated "None" (Never heard of it) or "Low" (Heard of but not sure what it means) for the terms in the finance and accounting category. In addition, engineering students are gaining more understanding stakeholder identification, product life cycle and economies of scale, as well as SWOT analysis and concept selection. Hence, albeit the engineering curriculum or their experience, engineering students are graduating with some basic knowledge of entrepreneurship.

B. Comparing Engineering Seniors with and without Entrepreneurship Experience

Given the relatively lower number of seniors (i.e., 19 with experience; and 76 without experience) in the pilot study, hypothesis testing was applied to each term using an $\alpha = 0.10$. Table 6 list items that show significant differences between students with and without experience and their corresponding p-values. In all cases, as expected, senior engineering students with entrepreneurship experience had higher scores on these items than those who did not.

Table 6. Hypothesis Testing Results for Each Term

Subject Area	Term	P-value
Becoming an Entrepreneur	Business Incubators	0.00
	Social Entrepreneurship	0.07

	Partnering	0.08
	Entrepreneur Role Models	0.09
Financing & Accounting	Venture Capital	0.03
	Bootstrapping	0.07
Sales &Marketing	Market Identification Target Market	0.09

As noted in Table 6, experienced seniors reported greater knowledge of several items related to "Becoming and Entrepreneur." Notably, they reported greater knowledge of business incubators, the term social entrepreneurship, partnering and role models in entrepreneurship. Additionally, seniors with entrepreneurship experience reported higher levels of familiarity with venture capital, bootstrapping and market identification target market, compared with their non-experienced counterparts.

In looking at the data it is worth noting that students, regardless of their level in school and experience, indicated low ratings for "Sales and Marketing" terms. Approximately 64% of all the students suggested they had "None" to "Moderate" knowledge of this area. It is particularly important as the literature indicates that marketing is a key aspect of innovation, a factor important in entrepreneurship.

V. Discussion

In coming decades, entrepreneurial engineers will be in even greater demand. Engineering educators and administrators will need to keep pace by offering opportunities to acquire entrepreneurial knowledge and experience. We believe that through the use of this simple tool, engineering educators can better assess engineering students' knowledge and skills related to technology entrepreneurship as they progress through their programs of study. Given the findings of this pilot study, we discuss potential ways this tool and the research can be used to help improve entrepreneurship education for engineers.

According to this pilot study and statistical analysis, differences exist between freshmen and senior engineering students, indicating that the general engineering curriculum may be helpful in introducing several important terms and concepts contained in the EKI. Certainly, the analysis shows that in the area of Financial and Accounting, several items were significantly higher for seniors than freshmen (i.e., core finance, funding and reporting). In some cases, these concepts may often be taught in existing courses and/or are easily attained over an undergraduate career. However, the comparison between senior engineering students with and without experience definitely indicates areas where specific entrepreneurial experience can impact an engineering student's knowledge.

Further, because the EKI tool is designed to measure student familiarity with technology entrepreneurship terms and concepts, it can be used to assess progress in engineering and technology focused entrepreneurship programs. Using this tool, educators can quantify familiarity with concepts and topics that students are familiar with both prior to and upon completion of their engineering programs. Notably, this tool measures students' self-assessed knowledge. It is not a direct measurement of the actual skills and knowledge a student might

exhibit in the work place. However, the results described here, though preliminary in nature, demonstrate a tool for tracking and assessing student knowledge in entrepreneurship.

The next step in this research is to investigate the relationship between engineering students' perceived acquisition of entrepreneurship knowledge and the teaching practices of entrepreneurship faculty who instruct these engineering students. This study is underway.

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1. 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

2. Shartrand, A., P. Weilerstein, M. Besterfield-Sacre, and K. Golding. *"Technology Entrepreneurship Programs in U.S. Engineering Schools: An Analysis of Programs at the Undergraduate Level*." 2010 ASEE Annual Conference, Louisville, KY, June 20-23, 2010.
3. 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.
4. see http://www.pui-eship.org/ for details
5. Covin, J. G., & Slevin, D. P. (1989). Strategic management of small firms in hostile and benign environments. *Strategic Management Journal, 10,* 75-87.
6. Kreiser, P., Marino, L., & Weaver, K. M. (2002). Assessing the psychometric properties of the Entrepreneurial Orientation Scale: A multi-country analysis, *Entrepreneurship Theory and Practice, 26*, 71-94.

7. see http://www.he-academy.ac.uk/ourwork/learning/employability/enterprise for more details.

8. Kim, Jae-On. *Factor Analysis; Statistical Methods and Practical Issues.* Beverly Hills: SAGE, 1978. Print
9. Rossi, Peter H., James D. Wright, and Andy B. Anderson. *Handbook of Survey Research*. New York: Academic, 1983. Print