International Journal of Engineering Education Vol. 28, No. 2, pp. 425–435, 2012
Printed in Great Britain

0949-149X/91 $3.00+0.00

Engineering Students and Entrepreneurship Education: Involvement, Attitudes and Outcomes*

NATHALIE DUVAL-COUETIL
Burton D. Morgan Center for Entrepreneurship, Purdue University, 1201 State Street, West Lafayette, IN 47907, USA.
E-mail: natduval@purdue.edu

TERI REED-RHOADS
School of Engineering Education, Purdue University, 701 West Stadium Avenue, West Lafayette, IN 47907, USA.
E-mail: trhoads@purdue.edu

SHIVA HAGHIGHI
School of Civil Engineering, Purdue University, 701 West Stadium Avenue, West Lafayette, IN 47907, USA.
E-mail: shaghigh@purdue.edu

Changes in the economy and workforce needs have driven many engineering schools to consider offering entrepreneurship education to their students. Although entrepreneurship education is believed to be complementary to an engineering education, little is known about the degree to which it plays a role in contemporary students' academic programs. The purpose of this study was to explore a broad array of attitudes toward and outcomes of entrepreneurship education on engineering students in order to understand the characteristics of students participating in related courses and activities, the nature and extent of their involvement, entrepreneurship's role in their career plans, and its impact on entrepreneurial self-efficacy. Survey data were collected from 501 engineering students enrolled in senior-level capstone design courses at three institutions with established entrepreneurship programs. The study found that while two-thirds or more of engineering students intended to work for medium or large size companies after graduation, a similar number felt that entrepreneurship education could broaden their career prospects and choices. Less than one third of those surveyed felt that entrepreneurship was being addressed within their engineering programs or by engineering faculty. Students who had taken one or more entrepreneurship courses showed significantly higher levels of entrepreneurial self-efficacy on a number of measures. Students in certain engineering disciplines such as electrical and mechanical engineering were found to participate in entrepreneurship education at higher rates than others. The results of this study provide valuable baseline data that can be useful for program development and evaluation.

Keywords: entrepreneurship; engineering education; assessment

1. Introduction

Economic trends and changes in the way employers organize and make decisions have led to an increased awareness of the potential value of entrepreneurship education to engineering students. In an article about de-industrialization and its effect on engineering education, Wei (2005) states that, 'research and development in manufacturing companies used to be viewed as a glamorous career for the brightest engineering graduates, but the number of attractive job offers has been declining for many years' (1, p.130). Today, a glamorous job for an engineer might be to work in a smaller, more entrepreneurial company, which requires 'a broad range of skills and knowledge beyond a strong science and engineering background' [2, p. 185]. To prepare students for this new reality, universities are increasingly aware that they must graduate engineers who not only understand science and technology, but who are also able to identify opportunities, understand market forces, commercialize new products, and have the leadership and communication skills to advocate for them. This has prompted a significant increase in the delivery of entrepreneurship education to engineering students through new courses, programs, and experiential learning opportunities, a movement that has garnered support from influential publications and professional organizations such as the National Academy of Engineering (NAE) and the American Society for Engineering Education (ASEE) [3]. Further evidence of this trend is the National Science Foundation's recent $10 million award to launch a national STEP Center at Stanford University which will address what is described as a critical need for entrepreneurial engineers across the United States. The center is intended to 'catalyze major changes in undergraduate engineering programs by developing an education, research and outreach hub for the creation, collection and sharing of innovation and entrepreneurship resources among the almost 350 engineering schools in the U.S.' [4].

* Accepted 20 August 2011.

Engineering students appear to be very well suited to become entrepreneurs. A study of the economic impact of the Massachusetts Institute of Technology (MIT) found that of their alumni, 50 to 100 percent more engineering than science alumni eventually became company founders. The study also discovered that engineering students were at least as inclined as management students to become entrepreneurs, and that more than 20 percent of total founders came from MIT's electrical engineering and computer science department (one department at the institution) [5]. As Wei (2005) states, engineering graduates who go on to become successful CEOs and senior officers of companies 'are often vocal in praise of the virtues and benefits of their engineering education, and they believe they acquired a number of positive attributes that are useful outside of a career in manufacturing and construction, such as rigorous discipline, a general knowledge of science and technology, the habit of collecting relevant information followed by quantitative analysis of data to construct conclusions and recommendations, teamwork, and strong oral and written communication skills' [1, p. 131].

The degree to which entrepreneurship plays a role in contemporary engineering students' academic programs or career paths is largely unknown. Although more engineering students are being exposed to entrepreneurship education, minimal research has examined engineering student attitudes toward it, its impact on their learning, or professional competence. This is not surprising given that the integration of entrepreneurship in engineering is a relatively new effort, where definitions of what it means to be entrepreneurial within an engineering program as well as program models vary greatly [6]. Even within the field of management, entrepreneurship education is considered by some to be a relatively new field, still engaged in conceptual and methodological debates [7]. For example, there is a lack of consensus as to the degree to which entrepreneurship is a set of principles, terms, competencies, and skills that can be learned, versus a set of attributes that make one opportunistic, competitive, proactive, risk tolerant, autonomous and innovative [8–10]. The objectives and content of entrepreneurship programs also vary widely, leading Henry, Hill, and Leitch (2005) to state that the 'content of syllabi of courses developed by entrepreneurship scholars differs to such an extent that it is difficult to determine if they even have a common purpose' [9, p. 103].

Shartrand, Weilerstein, Besterfield-Sacre and Olds [11] described much of what has been documented by engineering faculty developing courses and programs in entrepreneurship as descriptive case studies, 'addressing the process of gaining administrative approval and student interest, describing content knowledge that is covered, pedagogical approaches utilized, challenges of implementation, and, in some cases, assessment plans' (p.2). A review of assessment instruments in the field of entrepreneurship education shows that there are few valid and reliable instruments being used widely in the field, and very few are intended specifically for engineering students [12]. Ohland, Frillman, Zhang, and Miller (2004) stated that, 'While much has been written recently about engineering entrepreneurship curricula, comparatively few investigators have provided hard evidence to substantiate their programs' successes' [13, p. 159].

There is evidence, however, that educational programs directed at engineers can influence and inspire students to be entrepreneurs. A study of over 500 engineering students at MIT, Lüthje and Franke (2004) found that personality had an indirect impact on the readiness to become self-employed, while perceived contextual factors had a direct impact. They concluded that public policy and universities would be 'well advised to intensify their activities to implement educational, research and resource programs on entrepreneurship' [14, p. 143]. Another study conducted with engineering and science students in Europe, examined which of the benefits of entrepreneurship programs, learning, resources, or inspiration, raised entrepreneurial attitudes and intention. The study found that inspiration proved to be most strongly associated with an increase in entrepreneurial intention, particularly among undergraduates who are very unlikely to start a business immediately after graduation [15]. The authors concluded that if the target is to increase the number of students who become entrepreneurs, then the inspirational aspect of the program must be purposeful. Course and program evaluation conducted as part of North Carolina State University's Engineering Entrepreneurs Program (EEP) provides evidence that entrepreneurship education can have a positive impact on the retention, GPAs, and entrepreneurial activity. Data collected from alumni found that relative to a control group, EEP alumni were 73 percent more likely to have started a new company, 23 percent more likely to have created new products or services, and 59 percent more likely to have high confidence in leading a start-up [16].

Given the potential value of entrepreneurship education to engineers, this paper will investigate a broad array of attitudes toward, and outcomes of, entrepreneurship education on engineering students in an effort to understand the characteristics of engineering students participating in entrepreneurship programs, the extent to which entrepreneurship plays a role in their academic programs and career

aspirations, and the impact of entrepreneurship education on their entrepreneurial self-efficacy. This research is a component of a larger NSF-funded study, *Entrepreneurship Education and its Impact on Engineering Student Outcomes: The Role of Program Characteristics and Faculty Beliefs*. The intent of the larger study is to clarify the relationship between engineering student outcomes, program characteristics, and faculty beliefs and practices in order to help faculty and administrators create programs, improve educational experiences, and evaluate their success.

2. Purpose and research questions

Given the interest and involvement of engineering schools in creating entrepreneurship curricula, the purpose of this study was to investigate student attitudes toward entrepreneurship and examine how entrepreneurship education impacts a variety of engineering student outcomes. The research questions addressed are:

- What are the characteristics of engineering students participating in entrepreneurship programs?
- To what extent does entrepreneurship play a role in engineering students' academic programs?
- To what extent does entrepreneurship play a role in engineering students' career plans?
- What are engineering student perceptions of their entrepreneurship-related abilities?

3. Methods

A new assessment instrument was developed by the authors to be administered at universities that have entrepreneurship courses available to engineering students [12]. The 135-item web-based survey was administered to engineering students enrolled in senior-level capstone design courses. Attitude and self-efficacy scales showed high reliability (Coefficient Alpha range = 0.83– 0.96). This paper presents results from the following categories of items in the survey.

- *Demographics*: Fourteen items in this category collected data related to sex, race/ethnicity, residency, family background related to entrepreneurship, university affiliation, major, and minors. These were selected to investigate differences across groups.
- *Attitudes*: Of the 40 items in this category, 14 related to students' level of interest in entrepreneurship, the nature of the interest, and the attractiveness of entrepreneurship as a career choice. Twenty-six items asked students to identify reasons why they are or are not interested in entrepreneurship. These were taken with permission from a study by Shinnar, Pruett, and Toney [17] and modified slightly.
- *Behaviors*: Twelve items in this category measured students' level of participation in entrepreneurship-related activities, such as owning a business, interning for a start-up company, developing a product for a real customer, writing a business plan, or participating in an entrepreneurship-related competition.
- *Self-efficacy*: Twenty-three items in this category investigated student perceptions of their ability to perform entrepreneurial tasks. Fifteen were taken with permission from Lucas, Cooper, Ward, & Cave's [18] venturing and technology self-efficacy scale, an instrument found to be valid and reliable. Other items in this category address self-perceptions of analytical, communication, and presentation skills, as well as risk tolerance.
- *Perceptions of programs and faculty*: Nine items asked students to rate the level of involvement with, or encouragement of, entrepreneurship in their engineering programs and by engineering faculty.

Surveys were distributed to engineering students at three large public universities with established entrepreneurship programs available to engineering students. Two of the entrepreneurship programs are embedded within the colleges of engineering and primarily offered to engineering students. The other is a multidisciplinary program administered at the central university level, whereby engineering students take 'core' entrepreneurship courses with students in a variety of majors and complement these with approved engineering courses to complete program requirements. Senior-level students were selected in order to provide sample homogeneity across institutions and to capture exposure to entrepreneurship education, which could have occurred at any point during the students' academic programs. Moreover, many entrepreneurship and innovation-related activities, such as formulating an idea for a product/business, developing prototypes, presenting, researching markets, and preparing business plans, typically occur at the capstone level [19].

Students at each institution received the survey via faculty members teaching capstone design courses. Initial contacts with faculty were made either through personal connections at each institution, or through internet searches to identify department heads and other appropriate decision-makers. Faculty members were sent an email describing the intent of the study and what would be required of

them and their students. If faculty agreed to participate, they were sent an email to be forwarded to students, which included a brief explanation and the survey URL. Since the survey was voluntary, over the course of the month following its release, faculty were asked to remind students to take it.

The sample was comprised of 501 engineering students. Over three semesters, the survey was distributed to approximately 30 courses across the three institutions involved in the study. Response rates per course ranged from 3 to 58 percent, with a mean of 21 percent. To evaluate the self-selection bias resulting from this methodology, the sample was compared to the 2008 ASEE Online Profiles of undergraduate engineering degrees by discipline and gender for the three institutions involved in the study [20]. Over-represented disciplines in the sample were agricultural and biological engineering (4.1 times larger), construction engineering (4.5x), and chemical engineering (2.2x). A slightly under-represented discipline was mechanical engineering (0.5 times smaller). Women were over-represented in the sample (22%) relative to the overall population of women engineering graduates (16%).

Statistical analyses focused primarily on examining differences between two groups of engineering students: 1) those who had never taken an entrepreneurship course, referred to in the text of this manuscript as 'no-entrepreneurship students,' and 2) those who had taken one or more entrepreneurship courses, referred to as 'entrepreneurship students.' Normality of survey responses was assessed using the Shapiro Wilk test and most were found to not be normally distributed. Based on this result, nonparametric Kruskal-Wallis and Mann-Whitney U post-hoc tests were used to examine statistical differences between groups. All assumptions of these nonparametric tests were met in the analysis. The majority of survey items used Likert-type, 5-point, ordinal responses that represented verbal statements, therefore, data are presented as frequencies or percentages of responses in each category. To simplify the reporting of the data, 5-point response scales were collapsed into three by grouping responses. For example, the responses 'strongly agree and agree' were combined as were 'strongly disagree and disagree.' One exception is the analysis of responses to the fifteen items in the self-efficacy scale [18]; these items used an 11-point numerical scale (0-10) related to confidence and were analyzed using standard t-tests. The level of statistical significance was set at a p-value < 0.05. For multiple comparisons, the significance level was set at 0.05 divided by the number of comparisons.

4. Results

Question 1: What are the characteristics of engineering students participating in entrepreneurship programs?

The sample of engineering students was fairly well distributed across the universities involved in the study (Table 1). Women represented 22 percent of the engineering students surveyed and 18 percent of the entrepreneurship students, however, the difference in female and male participation was found to be not statistically significant. Although a higher proportion of entrepreneurship students had parents who were entrepreneurs (51% versus 38%) this difference was not found to be statistically significant. Similarly, although international students appeared to participate in entrepreneurship courses at a higher rate than both in-state and out-of-state domestic students (38% versus 29% and 26%) this difference was not statistically significant. In terms of race and ethnicity, differences in the rate of participation in entrepreneurship education of Caucasian (26%) and Asian (35%) students was not statistically significant. Sample sizes were too small to make conclusive statements about other groups. Significant differences in participation were found for the top four majors represented in the sample ($n > 50$) ($p < 0.05$). Electrical (54%) and mechanical (47%) engineering students had significantly higher levels of involvement than chemical (22%) and civil (18%).

Significant differences were found when examining the characteristics of students who participated in a multi-course entrepreneurship program. Students whose parents were entrepreneurs were twice as likely (13%) to participate in a multi-course program than students whose parents were not. Similarly, both domestic out-of-state (14%) and international students (19%) were two to three times as likely to participate in a multi-course program, than were in-state students (6%).

Question 2: What role does entrepreneurship play in students' engineering programs?

Of the entrepreneurship students, 73 percent reported that they had taken an entrepreneurship course through their colleges of engineering, which is reflective of programs offered by the institutions involved in the study. Several survey items asked students about the degree to which entrepreneurship was being addressed within their engineering programs or by their engineering professors (Table 2). Significant differences ($p < 0.05$) in the responses for both groups were found for four out of nine items. Entrepreneurship students more strongly agreed that students should learn more

Table 1. Demographics of Participating Engineering Students

	No e-ship courses		One or more e-ship courses		Total	
Variable	**N**	**(%)**	**N**	**(%)**	**N**	**(%)**
Total Participants	354	(100)	147	(100)	501	(100)
University 1	96	(27)	62	(42)	158	(32)
University 2	106	(30)	33	(22)	139	(28)
University 3	152	(43)	52	(35)	204	(41)
Sex						
Male	272	(77)	120	(82)	392	(78)
Female	82	(23)	27	(18)	109	(22)
Ethnicity						
White	291	(82)	100	(68)	391	(78)
Asian	28	(08)	15	(10)	43	(09)
Black/African American	6	(02)	7	(05)	13	(03)
Hispanic/Latino	10	(03)	2	(01)	12	(02)
Other	18	(05)	23	(16)	41	(08)
Entrepreneurial Parent(s)						
Yes	88	(25)	45	(31)	133	(27)
No	259	(73)	98	(67)	357	(71)
Unsure	6	(02)	4	(03)	10	(02)
Residency						
In-State	256	(73)	107	(73)	363	(73)
Out-of State	77	(22)	27	(18)	104	(21)
International	20	(06)	12	(08)	32	(06)
Engineering Major						
Chemical	64	(18)	18	(12)	82	(16)
Civil	50	(14)	11	(07)	61	(12)
Mechanical	30	(08)	27	(18)	57	(11)
Electrical	23	(06)	27	(18)	50	(10)
Agricultural/Biological	35	(10)	11	(07)	46	(09)
Industrial	27	(08)	9	(06)	36	(07)
Computer	17	(05)	16	(11)	33	(07)
Materials	26	(07)	1	(01)	27	(05)
Construction	20	(06)	6	(04)	26	(05)
Aeronautics/Astronautics	19	(05)	5	(03)	24	(05)
Nuclear Engineering	18	(05)	2	(01)	20	(04)
Other	25	(07)	14	(10)	39	(08)

Percentages are given as total number of respondents/total valid.

Table 2. Student perceptions of the degree to which entrepreneurship is addressed within their engineering programs

	No e-ship courses	One or more e-ship courses	
Item	**Agree %**	**Agree %**	***p***
Students should learn more about entrepreneurship	61	74	0.000
There are opportunities to interact with entrepreneurs	35	44	0.022
Students are encouraged to develop entrepreneurial skills	28	35	0.298
Entrepreneurship is presented as a worthwhile career option	23	28	0.116
Faculty discuss entrepreneurship	19	27	0.146
Students are encouraged to take entrepreneurship courses	13	27	0.003
Students are taught entrepreneurial skills	18	26	0.028
Students are encouraged or required to participate in entrepreneurship-related activities	14	18	0.333
Students are encouraged to consider starting their own companies	13	18	0.270

about entrepreneurship. They also more strongly agreed that they were taught entrepreneurial skills, were encouraged to take entrepreneurship courses, and had opportunities to interact with entrepreneurs within their engineering programs. Overall, one third or less of all the students surveyed agreed or strongly agreed that entrepreneurship was presented as a worthwhile career option, that they were encouraged to develop entrepreneurial skills, that engineering faculty discussed entrepreneurship or that they were taught entrepreneurial skills as part of their engineering programs. Less than 15 percent of no-entrepreneurship students felt they were encouraged to take entrepreneurship courses, to participate in entrepreneurship-related activities, or consider starting their own companies. Overall, a majority of both groups felt that students should learn more about entrepreneurship.

Table 3. Comparison of general interest in entrepreneurship: 'Please rate your level of agreement with the following'

Item	No e-ship courses Agree %	One or more e-ship courses Agree %	*p*
Entrepreneurship education can broaden my career prospects and choices	69	82	0.000
I have a general interest in the subject of entrepreneurship	59	79	0.000
I would like to learn about entrepreneurship in my engineering courses	60	78	0.000
I am interested in taking entrepreneurship classes	47	71	0.000
I would like to know if I have what it takes to be an entrepreneur	57	65	0.023
I want to become an entrepreneur	34	59	0.000
I have an idea for a business product or technology	32	46	0.000

The reasons why engineering students are interested in entrepreneurship were investigated by asking students to rate their level of agreement with a number of statements (Table 3). Not surprisingly, students who had taken one or more courses in entrepreneurship reported more interest in the topic than those who had not. Significant differences were found for all items ($p < 0.05$). Students in both groups were very much in agreement with the statement 'entrepreneurship education can broaden my career prospects and choices.' Students who had not taken an entrepreneurship course had a relatively strong interest in doing so. Forty-seven percent were interested in taking an entrepreneurship course and 60 percent wanted to learn about entrepreneurship in their engineering courses.

To measure entrepreneurial behaviors, students were asked about the degree to which they participated in related activities while in college (Table 4). Approximately half or less of all of the engineering students surveyed reported participating in activities that could be considered related to entrepreneurship. However, significant differences were found in the responses of both groups ($p < 0.05$) for all but one activity. Moderate involvement for both entrepreneurship and no-entrepreneurship students was in the area of 'developed a product or technology for a real client or customer' (45% and 26%, respectively) and relatively low but similar levels of involvement in 'patenting a technology or protecting intellectual property' (18% and 13%, respectively). Entrepreneurship students were three or more times as likely to participate in activities such as conducting market research, giving elevator pitches, writing business plans, or interning in a startup company. Almost half of entrepreneurship students and 32 percent of those who had not taken a class reported having an idea for a business, product or technology.

Question 3: What are engineering students' attitudes about entrepreneurship as a career path?

To understand how entrepreneurship factored into career goals, students were asked to rate their level of interest in a number of post-graduation options. Students in both groups were most interested in working for a medium—or large-size business, followed by attending graduate school (Table 5). Significant differences between the two groups of students were found for careers that were related to entrepreneurship; 43 percent of entrepreneurship students agreed that they wanted to start their own business or work for a small business or startup, which was significantly higher than the

Table 4. Comparison of level of student involvement in entrepreneurship-related activities

Item	No e-ship courses %	One or more e-ship courses %	Total *n*	*p*
Conducted market research and analysis for a new product or technology	17	53	129	0.000
Given an 'elevator pitch' or presentation to a panel of judges about a product or business idea	13	47	107	0.000
Developed a product or technology for a real client/customer	26	45	154	0.000
Written a business plan	11	42	95	0.000
Participated in an entrepreneurship-related competition (e.g., product development, business plan)	6	39	72	0.000
Participated in entrepreneurship-related workshops (extra-curricular, non-credit)	4	29	52	0.000
Interned or worked for an entrepreneurial or start-up company	11	29	78	0.000
Been involved in entrepreneurship- or business-related student organizations	5	26	52	0.000
Been involved in patenting a technology or protecting intellectual property	13	18	68	0.153

Table 5. Comparison of interest in post-graduation options

Item	No e-ship courses Agree %	One or more e-ship courses Agree %	*p*
Work for a medium- or large-size business	72	66	0.311
Attend graduate/professional school	42	50	0.125
Start my own business or be self-employed	27	43	0.000
Work for a small business or start-up company	34	43	0.034
Work for the government	34	29	0.049
Work for a non-profit organization	13	11	0.371
Serve in the military	7	8	0.068

Table 6. Reasons why students would start a company

Item	No e-ship courses Agree %	Rank	One or more e-ship courses Agree %	Rank	*p*
Satisfy a need in a market	75	2	86	1	0.001
Focus on a technology that interests me	75	3	82	2	0.017
Create something of my own	74	4	79	3	0.042
Have more flexibility and independence	76	1	76	4	0.120
Solve a social problem	63	5	69	5	0.011
Be at the head of an organization	55	8	60	6	0.205
Manage people	48	9	58	7	0.020
Make more money	59	6	58	8	0.790
Create jobs	55	7	56	9	0.325
Have more free time	43	10	36	10	0.021
Gain high social status	21	11	25	11	0.501
Follow a family tradition	17	12	21	12	0.987

Table 7. Reasons why students would not start a company

Item	No e-ship courses Agree %	Rank	One or more e-ship courses Agree %	Rank	*p*
Lack of initial capital for start-up	76	1	66	1	0.010
Excessively risky	63	4	59	2	0.324
Lack of legal assistance or counseling	65	3	56	3	0.043
Lack of ideas regarding what business to start	62	5	54	4	0.255
Lack of knowledge of the business world and the market	67	2	51	6	0.000
Lack of assistance available to assess business viability	55	8	51	5	0.083
Lack of experience in management and finance	62	6	43	7	0.000
Current economic situation	55	7	41	8	0.001
Irregular income	52	9	41	9	0.022
Having to work too many hours	30	11	26	10	0.052
Fear of failure	32	10	25	11	0.015
Lack of support from people around me (family, friends, etc)	21	13	23	12	0.704
Doubts about personal abilities	26	12	19	13	0.028
Problems with employees and colleagues	19	14	16	14	0.071

no-entrepreneurship students. No-entrepreneurship students were also significantly more interested in working for the government.

Students were also surveyed about reasons why they would and would not start a company. Rankings of responses were similar for students who had and who had not had exposure to entrepreneurship education (Table 6). There were, however, significant differences in the extent of their agreement. Top reasons for entrepreneurship students were to 'satisfy a need in a market,' 'focus on a technology that interests me,' and 'create something of my own.' A main difference for no-entrepreneurship students was that to 'have more flexibility and independence' was among their top reason to start a business.

Top ranked reasons that students would not start a company for both groups were 'lack of initial

Table 8. Comparison of perceptions of venturing and technology self-efficacy: 'For each statement indicate how confident you are that you could perform that skill or ability now'

Item	No e-ship courses		One or more e-ship courses		
	M	SD	M	SD	*p*
Lead a technical team developing a new product to a successful result	5.99	2.47	6.81	2.18	0.001
Translate user needs into requirements for a design so well that users will like the outcome	6.00	2.48	6.78	1.99	0.001
Design and build something new that performs very close to your design specifications	6.08	2.32	6.76	2.22	0.003
Grasp the concept and limits of a technology well enough to see the best ways to use it	5.77	2.27	6.64	2.16	0.000
Develop your own original hypothesis and a research plan to test it	5.61	2.54	6.38	2.40	0.002
Understand exactly what is new and important in a groundbreaking theoretical article	5.70	2.42	6.37	2.17	0.005
Convince a customer or client to try a new product for the first time	5.10	2.62	6.30	2.25	0.000
Convert a useful scientific advance into a practical application	5.47	2.52	6.23	2.39	0.003
Recruit the right employees for a new project or venture	5.13	2.53	6.10	2.28	0.000
Recognize when an idea is good enough to support a major business venture	4.78	2.53	6.02	2.50	0.000
Work with a supplier to get better prices to help a venture become successful	4.41	2.66	5.65	2.35	0.000
Write a clear and complete business plan	4.37	2.50	5.65	2.49	0.000
Estimate accurately the costs of running a new project	4.76	2.62	5.42	2.41	0.011
Pick the right marketing approach for the introduction of a new service	3.85	2.51	5.16	2.45	0.000
Know the steps needed to place a financial value on a new business venture	3.39	2.40	4.60	2.37	0.000

capital for startup,' 'lack of legal assistance or counseling,' 'excessively risky,' and a 'lack of ideas of what business to start' (Table 7). One area where the rankings differed between groups was that a 'lack of knowledge of the business world and the market' was ranked second for students who had not taken an entrepreneurship course and sixth among those who had.

Question 4: What are engineering student perceptions of their entrepreneurship-related abilities?

A number of survey items evaluated student perceptions of their entrepreneurial ability. The first was a technology and venturing self-efficacy scale [18], which asked students to rate how confident they were, on an 11-point scale from 0 (not at all confident) to 10 (100 completely confident), to perform a set of fifteen skills related to venturing and technology self-efficacy. Since this used a numeric response scale without individual verbal statements representing each point, differences between students who had and who had not taken one or more entrepreneurship courses were calculated using standard t-tests (Table 8). A comparison of means showed that entrepreneurship students rated their level of confidence significantly higher than those who had not for all of the items ($p < 0.01$). Skills suggesting a need for business knowledge, such as 'pick the right marketing approach for the introduction of a new service,' 'write a clear and complete business plan,' 'work with a supplier to get better prices to help a venture become successful,' 'recognize when an idea is good enough to support a major business venture,' accounted for some of the largest differences between both groups. A few items included in the self-efficacy scale did not appear to be directly related to entrepreneurship, yet entrepreneurship students rated themselves significantly higher on these items as well. They included 'develop your own original hypothesis and a research plan to test it,' and 'understand exactly what is new and important in a groundbreaking theoretical article.'

Students were also asked to rate their ability from poor to excellent on more general skills and traits associated with entrepreneurship and entrepreneurs (Table 9). There were no significant differences between the groups in the areas of communication, presentation, analytical skills, and their ability to deal with uncertainty. However, when the categories above average and excellent are broken out, there were more 'excellent' than 'above average'

Table 9. Comparison of students' perceived aptitude for entrepreneurship skills and traits

Item	No e-ship courses Above average or excellent	One or more e-ship courses Above average or excellent	*p*
Analytical skills	83	90	0.191
Communication skills	67	75	0.274
Presentation skills	60	67	0.088
Ability to evaluate business ideas	35	60	0.000
Ability to deal with uncertainty	48	54	0.069
Level of risk tolerance	35	45	0.002

responses from entrepreneurship students. Their perceptions of their ability to evaluate business ideas and their level of risk tolerance, were found to be significantly higher than students who had not taken an entrepreneurship course ($p < 0.05$).

Finally, students were asked two overarching questions related to their entrepreneurial self-efficacy and significant differences in the responses for both groups were found ($p = 0.001$). The first was, 'Overall how would you rate your entrepreneurial ability?' to which 49 percent of entrepreneurship students versus 21 percent of no-entrepreneurship students rated their ability as above average or excellent. The second was 'How would you rate your ability to start a business now' to which 35 and 11 percent, respectively, responded above average or excellent ($p = 0.001$).

5. Discussion

The results of this study show that senior-level engineering students show considerable interest in learning more about entrepreneurship, however most do not expect to pursue entrepreneurial careers. Although, approximately 70 percent of students surveyed felt that that entrepreneurship education could broaden their career prospects and choices, approximately 70 percent of all engineering students reported that they were most interested in working for a medium to large size organization after graduation. Not surprisingly, students who had taken an entrepreneurship course were more interested in starting their own business or working for a startup than those who had not. They were also more likely to have an idea for a business, product, or technology. Nevertheless, 30 percent of no-entrepreneurship students also reported having an idea for a business, product, or technology. Less than one-third of all students surveyed felt that entrepreneurship was presented as a worthwhile career option in their engineering program or that it was being addressed by their engineering programs or engineering faculty. Both groups of students expressed a strong interest in taking an entrepreneurship course and even a greater percentage of entrepreneurship students were interested in learning more about entrepreneurship within their engineering courses (60 and 78, respectively). These data suggest that there is more demand than supply for entrepreneurship education among engineering students. However, whether this demand would translate into actual course enrollment is unknown.

Taking even one course in entrepreneurship appears to positively impact engineering students' perceptions of their entrepreneurial self-efficacy. The entrepreneurship students rated their abilities significantly higher on every measure of a venturing and technology self-efficacy scale. They also rated their ability to evaluate business ideas, and deal with risk and uncertainty significantly higher. Entrepreneurship students also reported to have higher perceived self-efficacy in areas that were more loosely tied to entrepreneurship (e.g., 'understand exactly what is new and important in a groundbreaking theoretical article'). A ranking of reasons why engineering students would and would not start a business were similar for both groups, however, fewer entrepreneurship students felt strongly about potential obstacles than no-entrepreneurship students, suggesting that entrepreneurship education may lessen perceived barriers to entrepreneurial careers. These findings pose some interesting questions such as: Is the knowledge gained in entrepreneurship courses making students more confident in a wide range of activities relevant to their majors? Or, are more confident students gravitating to entrepreneurship courses and programs? Additional research is necessary to examine which might be the case and the degree to which individual demographic and other factors contribute to entrepreneurial self-efficacy.

Engineering students with particular characteristics may participate in entrepreneurship courses and programs at higher rates than others. An examination of program participants by demographic group could be a useful exercise when making program development and recruiting decisions. The analyses of differences by engineering major are also interesting and warrant further investigation. Potential questions include: Is entrepreneurship more relevant to those engineering majors? Is it being addressed to a greater degree by those disciplines? Are students with particular characteristics more attracted to specific disciplines or universities? If so, what are these characteristics? How can entrepreneurial involvement or relevance be duplicated or translated across engineering majors? Larger sample sizes and additional research are necessary to answer these questions.

This study has several limitations. First, the overall sample of engineering students has a higher proportion of students who have enrolled in entrepreneurship courses than would be found in the general population of engineering students across the three institutions. This occurred for two reasons: 1) purposive sampling was necessary to ensure that there was an adequate representation of students who had exposure to entrepreneurship education in order to make comparisons between groups, and 2) since the study was voluntary, faculty and students who were interested in the topic of entrepreneurship were more likely to participate. Since the study was conducted at institutions with entrepreneurship

courses and programs that are available to engineers, there may also be increased awareness of entrepreneurship by engineers on these campuses. Also, certain engineering majors were over and underrepresented relative to general enrollment in these majors and the reasons why need to be examined more closely. Another limitation is that data related to learning outcomes relied on students' self-report of abilities and knowledge and future research should include additional measures to triangulate these findings.

Future analyses of this dataset will examine how engineering student attitudes and perceptions differ by university, entrepreneurship program model (within or outside of engineering), and/or engineering major. It will also examine the degree to which participating in a multi-course program impacts entrepreneurial self-efficacy, as compared to participation in a single course, and will examine differences in entrepreneurial self-efficacy based on demographic characteristics. Given the constraints of relatively full and structured engineering programs, additional research should also be conducted to understand where entrepreneurship education is situated relative to the other curricular priorities for engineering students, faculty, and administrators. Finally, the ultimate measure of the outcome of entrepreneurial education is the degree to which it impacts students' post-graduation careers, which requires longitudinal analysis.

6. Conclusion

This study summarizes data related to engineering student interest and involvement in entrepreneurship education, attitudes toward entrepreneurship as a career option, how this involvement relates to students' entrepreneurial self-efficacy, and the characteristics of students who participate in these courses and programs. Overall, engineering students expressed interest in learning more about entrepreneurship but relatively few reported being exposed to it even at institutions with formal entrepreneurship programs. Those who took one or more courses were found to have significantly higher entrepreneurial self-efficacy than those who did not. They were also much more likely to get hands-on skills related to market analysis, technology commercialization, business communication, or internships within start-up companies all of which are in demand by employers today. The results of this study provide valuable baseline data that can be useful for program development and evaluation. Additional research is necessary to validate learning outcomes and to explore the impact that entrepreneurship education ultimately plays in engineering students' careers.

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Nathalie Duval-Couetil is the director of the Certificate in Entrepreneurship and Innovation Program, associate professor in the College of Technology, and associate director of the Burton D. Morgan Center at Purdue University. She is responsible for the launch and development of the university's multi-disciplinary undergraduate entrepreneurship program. As part of the program, she has established entrepreneurship capstone, global entrepreneurship, and women and leadership courses and initiatives. Her research interests include entrepreneurship education, women and leadership, and program evaluation and assessment. She received her BA from the University of Massachusetts at Amherst, her MBA from Babson College, and Ph.D. from Purdue. Prior to her work in academia, Dr. Duval-Couetil spent several years in the field of market research and business strategy consulting in Europe and the United States with Booz Allen and Hamilton and Data and Strategies Group.

Teri Reed-Rhoads is assistant dean of engineering for undergraduate education, associate professor in the School of Engineering Education, and director of the First-Year Engineering Program at Purdue University. She received her BS in petroleum engineering from the University of Oklahoma and spent seven years in the petroleum industry, during which time she earned her MBA. She subsequently received her PhD in industrial engineering from Arizona State University. Dr. Reed-Rhoads' teaching interests include statistics, interdisciplinary and introductory engineering, diversity and leadership. Her research interests include statistics education, concept inventory development, assessment/evaluation of learning and programs, recruitment and retention, diversity, equity, and cultural humility. She has received funding from the National Science Foundation, Department of Education, various foundations, and industry. Professor Reed-Rhoads is a member of the American Society for Engineering Education, the Institute of Electronics and Electrical Engineers, and the Institute of Industrial Engineers. She serves as an ABET EAC evaluator for ASEE.

Shiva Haghighi Shiva Haghighi is a graduate research assistant in Engineering Education and Civil Engineering. She received her BS in civil engineering from Purdue University, and is continuing her studies in Civil Engineering in the area of architectural engineering and green building design. Her research interests include green building and urban planning and design. Shiva is a LEED Accredited Professional and an Engineer in Training (EIT).