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# The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes

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## ABSTRACT

Entrepreneurship education is being delivered to greater numbers of engineering students through a variety of courses, programs, and experiential learning activities. Some of these opportunities are designed primarily to serve engineering students in their departments and colleges, while others are cross-campus, university-wide efforts to serve students from many disciplines. To date, few researchers have examined to what extent differing program models and experiential activities impact students' perceptions of their entrepreneurial knowledge, skills, and self-efficacy. This paper examines these issues based on the results of a survey of 501 senior level engineering students enrolled in three institutions that offered three different models of entrepreneurship education. Findings indicate that higher perceptions of entrepreneurial knowledge were associated with the number of entrepreneurship courses taken and involvement in experiential learning activities. Further, students who were enrolled at an institution with a multidisciplinary program tended to rate their entrepreneurial abilities higher than those at two institutions with programs more embedded in engineering departments. This research provides faculty and administrators with valuable insight that can inform the development of entrepreneurship programs targeting engineers, and suggests areas for future research.

**Key Words**: Entrepreneurship, Innovation, Engineering Education, Pedagogy

## INTRODUCTION

Engineering students are being exposed to entrepreneurship coursework and experiential learning opportunities more than ever before, both within and outside their engineering programs. Several trends in engineering have influenced this growth, including the expansion of engineers' roles and responsibilities within work organizations (Rover, 2005; Yurtseven, 2002), changes in accreditation standards that emphasize a wider range of skills pertinent to engineers (Shuman, Besterfield-Sacre, & McGourty, 2005), and greater interest in and funding for entrepreneurship programs targeting engineering students (National Science Foundation, 2011). These trends reflect broader economic conditions affecting all contemporary college graduates, in particular, fewer professional opportunities in large companies and increased global competition for jobs. Other important factors are increasing demand for accountability from universities in an economic environment where budgets are tightening and where there is increasing pressure for universities to be more responsive to community, the private sector, and education stakeholders in terms of workforce preparedness and economic development (Etzkowitz, Webster, Gebhardt, & Terra, 2000; Farrell, 2008; "Florida governor wants job-placement data from state universities," 2011).

In the context of U.S. engineering education, courses and programs that deliver entrepreneurial skills, knowledge, and experiences to students are very diverse in terms of target audience and key objectives. Some approaches target engineering students specifically and are embedded within the engineering curriculum, while others target students in multiple majors and/or are offered campus-wide. Programs can also vary considerably in terms of their desired outcomes. Some focus more generally on generating awareness of entrepreneurship and/or creating an entrepreneurial mindset, while others focus on developing innovative products and technologies and/or new business models and ventures. On a more pragmatic level, program requirements differ as well. Many require a specific sequence of courses for credit, while others emphasize experiential learning and extra-curricular activities that may or may not be directly tied to coursework and course credit. In addition to the diversity in entrepreneurship offerings, many other engineering education initiatives now focus on preparing students to take on leadership positions in a new, global economy. In light of this context, as well as the constraints of academic programs, this paper will begin to answer some overarching questions that are critical to developing entrepreneurship programs accessible to engineers. These include: What program models are most effective for achieving learning or behavioral objectives? And, what type and how much entrepreneurship education do engineering students need to realize value from it?

## REVIEW OF THE LITERATURE

In response to contemporary economic and workforce trends, entrepreneurship education is viewed increasingly as a "panacea for stagnating or declining economic activity in both developed and developing countries" (Matlay, 2006, p. 704). Historically, entrepreneurship education was primarily offered to business school students, but over the past 20 years it has spread to virtually all academic disciplines (Streeter & Jacquette, 2004). The shift has emerged from economic conditions and a realization that all students can benefit from learning how to create commercial or social value from their knowledge and skills. Programs and funding from several key foundations have also bolstered this movement, particularly over the past decade. Specifically, the Kauffman Foundation, through its campus initiatives program, awarded multi-million dollar grants to universities to supportcross-campus entrepreneurship education and awareness (www.kauffman.org). The Coleman Foundation provides entrepreneurship training and resources to faculty from a wide range of disciplines (www.colemanfoundation.org). VentureWell (www.venturewell.org, formerly known as the National Collegiate Inventors and Innovators Alliance), with major support from The Lemelson Foundation, supports the development of hundreds of experiential programs, courses and multi-disciplinary student teams focused on technology innovation and entrepreneurship. More recently, the National Science Foundation (NSF) has encouraged greater participation in entrepreneurship education and activities through a number of its funding programs. An example is the funding in 2011 of the National Center for Engineering Pathways to Innovation (Epicenter) at Stanford University which addresses what is described as a critical need for entrepreneurship education within engineering programs (National Science Foundation, 2011). In July 2011, the NSF also launched the Innovation Corps program (I-Corps), which provides NSF-funded research teams with grants and entrepreneurial training to assess the commercialization potential of their research ("NSF I-Corps Celebrates First Year," 2012).

### General Entrepreneurship Education Program Models

The need to equip students with skills and knowledge that will be marketable and valuable in this new economic environment has led to a proliferation of entrepreneurship-related courses, majors, minors, certificate programs, and experiential learning opportunities being offered at an estimated 3,000 institutions in the United States (Kuratko, 2011). Across institutions, these educational offerings are diverse in structure, emphasis, administration, staffing, funding source, and target audience. Jones and Matlay (2011) highlighted the difficulties associated with standardizing entrepreneurship education and its outcomes based on these differences as well as the complex relationships among-students, educators, educational processes, institutions, and communities involved.

A number of features distinguish entrepreneurship education from other academic disciplines and influence program models and their outcomes. Entrepreneurship programs can be considered non-traditional in that they often involve multiple disciplines and may be administered, funded, and delivered by multiple academic departments or centers. Second, programs at many institutions rely heavily on non-tenure track faculty or practitioners in both teaching and/or administrative positions (Zappe, Hochstedt, & Kisenwether, 2012). Third, the entrepreneurial culture of an institution (i.e., extent to which entrepreneurship is valued and encouraged on a campus) as well as the infrastructure it provides, in the form of assistance with technology transfer and business incubation, can contribute greatly to the buy-in and support for academic programs by stakeholders (Standish-Kuon, Colarelli O'Connor, & Rice, 2009). Finally, the entrepreneurial ecosystem, or environment in which an institution operates, can also play an important role in the ability to leverage important resources such as mentors, internships, funding, and the talent necessary to start and grow new ventures (Neck, Meyer, Cohen, & Corbett, 2004). Some of the factors influencing entrepreneurship program models are represented in Figure 1.

The relative newness and non-traditional nature of entrepreneurship education can lead to programs and courses that vary widely in their content and a situation where "each discipline views entrepreneurship from its own perspective without taking cognizance of approaches in other disciplines" (Henry, Hill, & Leitch, 2005, p. 99). A typical entrepreneurship curriculum can encompass a spectrum of knowledge and skills including creativity, product development, feasibility analysis, catalyzing change, seizing opportunity, and honing skills in communication, leadership and teamwork. The lack of a common core of knowledge leads to assessment challenges due to the lack of reliable instruments that are valid across programs or contexts (Duval-Couetil, Reed-Rhoads, & Haghighi, 2010; Duval-Couetil, 2013). Fayolle and colleagues (2006) described two key challenges associated

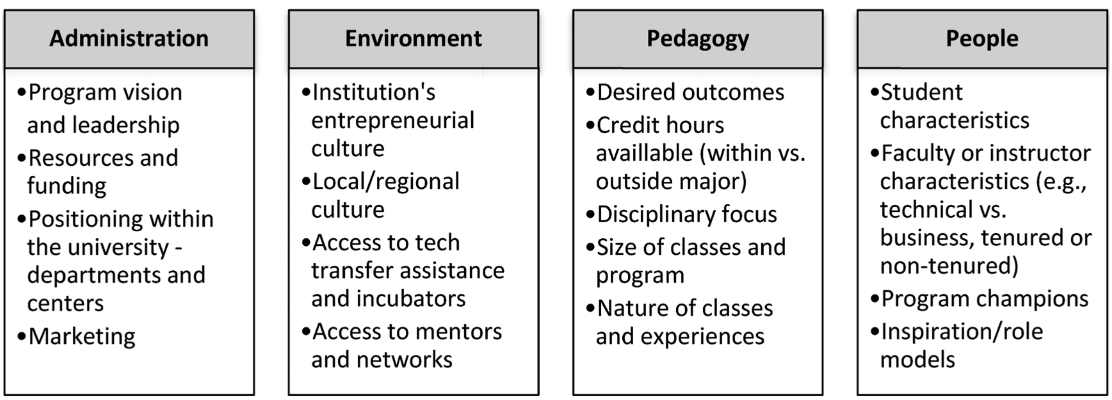


***Figure 1. Factors that influence university entrepreneurship program models.***

with the assessment of entrepreneurship education: (1) the selection of evaluation criteria and their effective measurement, particularly regarding the effect of time and (2) contextual variables. Other challenges associated with the assessment of entrepreneurship education include a dependence on samples of individuals who self-select into entrepreneurship programs and how to control for the nature of the education received (Van Der Sluis & Van Praag, 2008).

In a study of entrepreneurship program models, Streeter & Jacquette (2004) examined 38 ranked entrepreneurship programs and confirmed that the trend toward multidisciplinary campus-wide entrepreneurship was strong and growing. To characterize the models in their sample, the authors developed a conceptual framework for categorizing university-wide entrepreneurship programs comprised of: 1) *magnet programs* which drew students into entrepreneurship programs offered in business schools, and 2) *radiant programs*, which featured entrepreneurship programs outside a business school and which emphasized content tailored for non-business students. They concluded that while the radiant model was extremely appealing to students, parents, and alumni, the magnet model was easier to administer given that the locus for funding, students, and activities were in one place. They also concluded that while the magnet model can be easier to implement, in the long-term, it could lead to conflicts because each unit involved may require an independent source of funding, faculty, and activities, and benefits may not be shared equally across a university.

**Engineering Entrepreneurship Program Models**

In many cases, entrepreneurship programs that primarily target engineering or science students are known as "technology entrepreneurship" or "engineering entrepreneurship" programs. Standish-Kuon & Rice (2002) examined entrepreneurship program models that specifically served engineering and science students (Standish-Kuon & Rice, 2002). They organized the six programs in their sample into three categories: 1) business schools that offered formal technology entrepreneurship curriculum developed through collaboration with engineering or science or courses serving engineering/science students; 2) engineering school programs that offered formal technological entrepreneurship curriculum that co-existed with curriculum offered by the business school; and 3) multi-school programs that offered formal technological entrepreneurship curriculum developed with active collaboration of a business school and one or more technical schools (Figure 2). They indicated that the origin of programs targeting engineering or science students tended to be single individuals or a small group of "champions" rather than college or university administrators who advocated for institutional acceptance, the structure of the program, its financing or a combination of the three.

A study related to the research reported in this paper examined entrepreneurship education programs directed at engineering students and identified some key characteristics (Shartrand et al., 2010). The analysis, which focused on entrepreneurship programs offered at 341 American

| Model | Location/qualifiers | Approach to science and engineering students |
|---|---|---|
| **Business School** | Formal technological entrepreneurship curriculum developed through active collaboration with engineering/science school or courses serving engineering students | Students are encouraged or actively recruited |
| **Engineering School** | Formal technological entrepreneurship curriculum co-exists with curriculum offered by the business school: cross-pollination between schools | Students are actively recruited |
| **Multi-School** | Formal technological entrepreneurship curriculum formed with active collaboration of business school and one more technical school | Students are encouraged or actively recruited |

***Figure 2. Three models for introducing entrepreneurship to engineering and science students (Source: Standish-Kuon & Rice, 2002).***

Society for Engineering Education (ASEE) member schools in the U.S., found that despite the overall growth in entrepreneurship education opportunities, delivery to undergraduate engineers was not yet widespread or institutionalized. While over half of the institutions provided at least some entrepreneurship offerings to students, only 12% offered formal programs that targeted undergraduate engineering students. The remainder offered either business-school based or university-wide and multidisciplinary programs that were generally available to students of any major. Academic minors and certificate programs comprised about three-quarters of the sample; the other programs were categorized as fellows or scholars programs, residential programs, concentrations, specializations, and tracks. It should also be noted that some engineering schools, rather than offer a stand-alone course in entrepreneurship, integrate entrepreneurship throughout and/or embed modules or single courses in the engineering curriculum. Olin College offers one example of an integrated approach, whereby “entrepreneurship is interwoven with mainstream engineering disciplines” (Fredholm et al., 2002, p. 1).

Within the context of engineering or technology-oriented programs, entrepreneurship education is often closely connected to innovation education either in name or in practice. The degree to which innovation and entrepreneurship are distinguished, distinctly addressed, or overlap is difficult to assess given the variety of models that exist. Generally speaking, entrepreneurship education can be considered part of an innovation education continuum that ranges from the topic of creativity on one end, to new venture development and enterprise management on the other (Duval-Couetil & Dyrenfurth, 2012; Figure 3). Using this very basic framework, creativity and product development

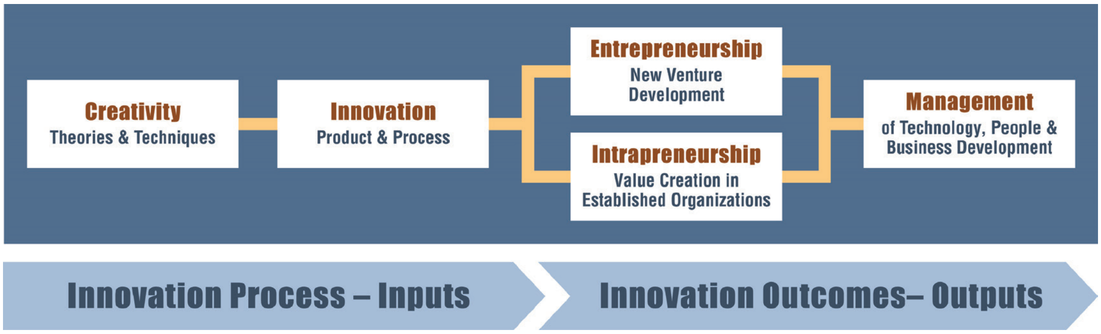


***Figure 3. The Innovation Education Continuum Framework (Duval-Couetil & Dyrenfurth, 2012).***

are considered the "innovation process" and the consequences of innovation, including entrepreneurship, intrapreneurship, and business/technology management are "innovation outcomes."

An instrument developed to encompass the body of knowledge is the Entrepreneurship Knowledge Inventory (EKI), a 105–item survey that is designed to measure students' self-assessed familiarity with terms and concepts addressed in technology entrepreneurship courses (Besterfield-Sacre, et al., 2013; Shartrand, Weilerstein, Besterfield-Sacre, & Olds, 2008). A factor analysis of these items resulted in 12 factors that were grouped into several categories and used to code types of courses. The category codes and corresponding percentage of survey items included: becoming and being an entrepreneur (34%); finance and accounting (11%); people and human resources (7%); sales and marketing (9%); product ideation and development (13%), with a substantial group not fitting readily into these categories (22%). Analysis showed that while about one-third of coursework was explicitly on the core topic of entrepreneurship, more than one-fifth of courses addressed areas such as fundamental business and technology innovation areas, communications skills, and other diverse topics.

### Experiential Learning in Entrepreneurship Education

Similar to other fields, entrepreneurship education is considered more effective if it includes a strong experiential component, requiring students to intellectually and physically engage in the learning process and reflect on their experiences (Kolb, 1984). Therefore, many students are learning about entrepreneurship either through experiential activities embedded into course or program requirements or via extracurricular activities. A comprehensive analysis of general entrepreneurship education pedagogy found experiential learning in entrepreneurship education to be widespread and diverse (Solomon, Duffy, & Tarabishy, 2002). The types of learning activities described included: the development of business plans, startup companies created by students, consultation with practicing entrepreneurs, computer simulations, behavioral simulations, interviews with entrepreneurs, environmental scans, "live" cases, field trips, and the use of video. More recently, the development of smart phone apps, internships with startup companies, doing elevator pitches and investor presentations have become common elements of courses or programs.

Several researchers have characterized approaches to teaching entrepreneurship which emphasize its potential and desired applied outcomes, including product innovation, venture creation, and economic development. Laukkanen (2000) distinguished *education about entrepreneurship* from *education for entrepreneurship*. Rasmussen and Sorheim (2006) described learning about entrepreneurship as a phenomenon as opposed to learning useful skills to become an entrepreneur. Falk and Alberti (2000) attempted to address the differing emphases of entrepreneurship courses by characterizing them as fitting into two categories: 1) courses that explain entrepreneurship and its importance to the economy, where students examine the subject from a distance; and 2) courses with an experiential component, where students practice the skills necessary to develop their own businesses. Thompson, Scott and Gibson (2009) created a conceptual model of entrepreneurial learning and entrepreneurial impact, which demonstrates the range of knowledge-building capabilities associated with various learning activities (Figure 4).

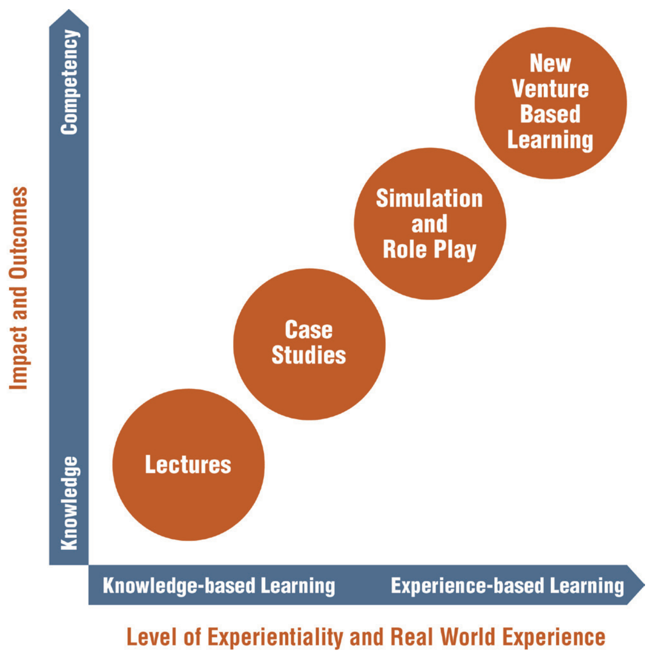


***Figure 4. Experiential learning and entrepreneurial impact (Adapted from Thompson Scott and Gibson, 2009).***

Within technology entrepreneurship programs specifically, experiential activities may involve collecting user and market data in the design of new products, conducting patent searches, writing invention disclosures, and participating in activities such as the VentureWell's E-Teams, which provide funding to, and are formed around, students and faculty involved in developing market-based technology inventions with commercial potential (http://venturewell.org/category/e-team-grants/). Engineering design and capstone courses can also offer opportunities for students to practice entrepreneurial skills in the engineering context. The goal of an entrepreneurial capstone is to prepare students to recognize, create, and act on entrepreneurial opportunities that are related to engineering products and solutions, which could be realized through the development of technologies with potential for commercialization, or the founding of a startup or non-profit venture (Shartrand & Weilerstein, 2012).

Although there is increased emphasis on entrepreneurship within engineering education, a major barrier to delivering entrepreneurship to students in engineering or the sciences is the time or space available for electives or extracurricular activities (Standish-Kuon & Rice, 2002). Limited credit hour availability and pressure to improve four-year graduation rates at many institutions further hamper students ability to participate in electives and experiential programs. Nevertheless, among engineering students, there appears to be strong interest in entrepreneurship. Analysis associated with this research, explored engineering students' involvement in and attitudes toward entrepreneurship education (Duval-Couetil, Reed-Rhoads, & Haghighi, 2012). The study found that most students (69%) felt that entrepreneurship education could broaden their career prospects and that approximately one half who had not yet taken an entrepreneurship course were interested in doing so. However, less than one-third of students felt that entrepreneurship was presented as a worthwhile career option within their engineering programs, that they were taught or encouraged to develop entrepreneurial skills, or that engineering faculty discussed entrepreneurship (Duval-Couetil et al., 2012). Students who did take an entrepreneurship course reported higher levels of entrepreneurial self-efficacy and were much more likely to have received hands-on experience related to market analysis, technology commercialization, business communication,or internships within start-up companies, all of which are considered to be in high demand by employers today.

## PURPOSE AND RESEARCH QUESTIONS

Given the interest and involvement of engineering schools in delivering entrepreneurship education to students, the purpose of this study was to begin to explore two important overarching questions pertinent to engineering students: What program models are most effective for achieving learning or behavioral objectives? And, what type and how much entrepreneurship education do engineering students need to realize value from it? This was accomplished by examining the effect of three different entrepreneurship education program models, and involvement in courses and experiential learning, on student outcomes. The three program models included: (1) embedded within engineering and composed of a course sequence; (2) originating within engineering and resulting in an academic minor; and (3) a university-wide, multidisciplinary program resulting in an academic certificate. Specifically, the following research questions were addressed:

- **Question 1**: How do engineering-based versus multi-school entrepreneurship program models compare in terms of their effects on student perceived knowledge and self-efficacy?
- **Question 2**: What is the incremental value of an engineering student taking more than one entrepreneurship course on their perceived knowledge and self-efficacy?
- **Question 3**: To what degree do experiential activities contribute to higher entrepreneurial self-efficacy?

## METHODS

The authors developed an assessment instrument to measure entrepreneurial attitudes, behaviors, knowledge, and self-efficacy that was administered at three public universities with entrepreneurship programs enrolling undergraduate engineering students (Duval-Couetil, Reed-Rhoads, & Haghighi, 2011). The 135-item online survey was administered to engineering students at three institutions enrolled in senior-level capstone design courses. Data analysis was based on survey items from the following categories:

- **Knowledge**: Thirty-seven items asked students to rate their familiarity with terms and concepts related to entrepreneurship. (Response scale: poor [1] to excellent [5])
- **Behaviors**: Twelve items 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. (Response scale: yes/no)
- **Self-efficacy**: Twenty-three items investigated students' perceptions of their ability to perform entrepreneurial tasks. Fifteen were taken with permission from Lucas, Cooper, Ward, & Cave's venturing and technology self-efficacy scale (2009) (Response scale: level of confidence, 0-10); other items in this category addressed self-perceptions of entrepreneurial ability (Response scale: poor [1] to excellent [5])

The sample, which has been described previously in the literature, was comprised of 501 senior level engineering students from three universities over a three semester period. These are large, land-grant institutions with well-ranked engineering programs that have entrepreneurship programs available to engineering undergraduates (Duval-Couetil et al., 2012). The three institutions also have many similarities based on their Carnegie Foundation classifications (2013); public, with a high undergraduate profile that is full-time, four-year, more selective, with lower transfer-in rates. All three have very high research activities and are primarily residential. University 1 is located in a region known for its entrepreneurial ecosystem. Universities 2 and 3 have significant initiatives in the areas of entrepreneurship and economic development; however, they are located in more rural areas. The characteristics of the three programs were as follows:

- **University 1**: This is an engineering-based model providing what is described as a "full immersion" experience designed to integrate the skills and knowledge that students have learned in their engineering studies with new technology products and startup business ideas. A sequence of engineering project-based courses culminating in the formation of entrepreneurship teams at the capstone level that can include students in science, business, industrial design, and the arts and humanities. Requirements include three core courses, and students are allowed to take one of the courses multiple times. At the time of the survey, the program enrolled 50-60 engineering students per year.
- **University 2**: This engineering-based model results in an academic minor. The program is designed to prepare students to be technology innovators and to acquire an entrepreneurial mindset. Students create their own in-class businesses. Four engineering-designated courses and two elective entrepreneurship courses are required. At the time of the study, approximately 450 students were enrolled in the program with engineering students accounting for 95% of participants.
- **University 3**: This multidisciplinary model results in an academic certificate. It is designed to complement a student's major by providing them with the mindset, knowledge, and skills necessary to analyze and develop new venture opportunities. A sequence of two required multidisciplinary core entrepreneurship courses, two elective courses, and one capstone course or experience are required. Select engineering courses can meet elective and capstone requirements. At the time of the study, approximately 1000 students were enrolled in the program with engineering students accounting for 15% of participants.

Of the 501 engineering students surveyed, 29% had some exposure to entrepreneurship education during their academic programs (Table 1). Senior-level students were selected in order to provide sample homogeneity across institutions across institutions and to capture exposure to entrepreneurship education, which might have occurred at different points during the students' academic programs. Also, many entrepreneurship-related activities, such as developing an idea for a product/business, developing prototypes, researching markets, and preparing business plans or pitches, often

| Variable | No e-ship courses | | One or more e-ship courses | | Total | |
|---|---|---|---|---|---|---|
| | 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) |
| 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) |

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

***Table 1. Demographics of Participating Engineering Students.***

occur at the capstone level (Dabbagh & Menasce, 2006). It was assumed that student involvement in entrepreneurship education, whether it was one or multiple courses, occurred primarily through the formal entrepreneurship programs offered at each institution.

Institutional Review Board approval was obtained at each institution before initiating research activities. Students received the survey via faculty members teaching capstone courses at each institution. Faculty members were identified through appropriate department heads or decision makers at each institution. They were sent an email describing the intent of the study and what would be required. If they agreed to participate, they were sent an email to be forwarded to their students, which included a brief explanation and the survey URL. Since participation was voluntary, over the course of the month following its release, instructors were asked to remind students to complete the survey. 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%, with a mean of 21%.

ANOVA was used to determine the effects of entrepreneurship programs and courses on entrepreneurial knowledge and self-efficacy. Specifically, the following analyses were conducted: (a) program model by institution for students who had taken at least one entrepreneurship course and (b) the number of entrepreneurship courses taken while in college (0, 1, 2, 3 or more). Student knowledge items (n=37) were analyzed individually and grouped into six categories based on content and face validity: General Entrepreneurship (n=6), Engineering (n=7), Business (n=6), Finance (n=6), Marketing (n=7), and Professional Skills (n=5). Averages for each category were computed and ANOVA was used to compare differences in scores among institutions. The potential interactions between the number of courses taken by students at each institution and knowledge level were evaluated by two-way ANOVA. Post-hoc tests using Tukey-Kramer's method were conducted when indicated by a significant F test. The effect of specific experiential learning or extracurricular activities on self-efficacy was evaluated using t-tests. The level of significance was set at $p < 0.01$ to account for the multiple comparisons conducted. Line graphs, instead of bar charts, are used to illustrate trends across survey items.

Normality of survey responses was assessed using the Shapiro Wilk test and most were found to not be normally distributed. Given controversy related to whether it is appropriate to treat Likert-type scale data as interval data as opposed to ordinal data, the analyses listed above were repeated using appropriate non-parametric statistics (Mann-Whitney and Kruskal-Wallis tests) and similar results were found as with parametric tests. The decision was made to present parametric statistical analyses using Likert-type scale data as interval data because these tests are more sensitive and powerful than non-parametric tests (Carifio & Perla, 2007).

## RESULTS

***Question 1. How do engineering-based versus multi-school entrepreneurship program models compare in terms of their effects on student perceived knowledge and self-efficacy?***

Students rated their knowledge of 37 terms and concepts related to entrepreneurship on a 5-point scale ranging from poor [1] to excellent [5]. Single item data are reported to show the range of topics that can be included in entrepreneurship programs. Student ratings at University 2 (engineering-based minor) and University 3 (multi-disciplinary certificate) showed significant differences on six items, and students at University 1 (engineering-based course sequence) and University 3 (multi-disciplinary certificate) showed significant differences on eight items (Table 2). Students taking

| | University 1 (Engineering-based) | University 2 (Engineering-based) | University 3 (Multidisciplinary) |
|---|---|---|---|
| **N** | **62** | **33** | **50** |
| 1. Characteristics of entrepreneurs | 3.39 ± 0.84 | 3.21 ± 0.86 | 3.76 ± 0.89 |
| 2. Role of entrepreneurs in the world economy | 3.23 ± 0.84 | 3.48 ± 0.91 | 3.66 ± 0.80 |
| 3. Business ethics | 3.52 ± 0.78 | 3.50 ± 0.67 | 3.78 ± 0.79 |
| 4. Risk management | 3.16 ± 0.93 | 2.94 ± 0.70 | 3.39 ± 0.86 |
| *5. Legal structures for ventures* | *2.52 ± 0.90[a]* | *2.58 ± 0.90* | *3.02 ± 0.89[a]* |
| 6. Intrapreneurship | 2.44 ± 0.96 | 2.47 ± 1.14 | 2.72 ± 0.93 |
| 7. Social entrepreneurship | 2.97 ± 0.97 | 2.76 ± 0.94 | 3.24 ± 0.85 |
| 8. Leadership | 3.84 ± 0.75 | 4.03 ± 0.73 | 4.18 ± 0.77 |
| 9. Managing teams | 3.71 ± 0.76 | 3.88 ± 0.70 | 3.92 ± 0.70 |
| 10. Project management | 3.69 ± 0.74 | 3.79 ± 0.70 | 3.98 ± 0.74 |
| 11. Negotiation | 3.37 ± 0.87 | 3.39 ± 0.79 | 3.50 ± 0.89 |
| 12. Product development | 3.60 ± 0.73 | 3.33 ± 0.69 | 3.62 ± 0.81 |
| *13. Product life cycle* | *3.26 ± 0.72* | *3.00 ± 0.71[a]* | *3.60 ± 0.64[b]* |
| *14. Economies of scale* | *2.84 ± 0.94[a]* | *2.76 ± 0.66[b]* | *3.42 ± 0.86[ab]* |
| 15. Feasibility study | 3.05 ± 0.91 | 3.03 ± 0.81 | 3.48 ± 0.93 |
| 16. Prototype | 3.58 ± 0.80 | 3.42 ± 0.87 | 3.54 ± 0.86 |
| 17. Intellectual property | 3.08 ± 0.80 | 3.18 ± 0.77 | 3.50 ± 0.76 |
| 18. Technology commercialization | 2.90 ± 0.82 | 2.90 ± 0.80 | 3.16 ± 0.58 |
| 19. Patents | 2.89 ± 0.73 | 3.12 ± 0.86 | 3.22 ± 0.76 |
| *20. Finance and accounting* | *2.82 ± 0.88[a]* | *2.73 ± 0.88b* | *3.34 ± 0.82[ab]* |
| 21. Venture capital | 2.75 ± 0.87 | 2.79 ± 0.89 | 3.04 ± 0.88 |
| *22. Equity* | *2.60 ± 0.93[a]* | *2.48 ± 0.87b* | *3.10 ± 0.84[ab]* |
| 23. Company valuation | 2.60 ± 0.90 | 2.52 ± 0.80 | 3.00 ± 0.83 |
| *24. Balance sheet* | *2.79 ± 0.89[a]* | *2.91 ± 0.88* | *3.42 ± 0.88[a]* |
| *25. Income statement* | *2.89 ± 0.91[a]* | *2.84 ± 0.88b* | *3.52 ± 0.74[ab]* |
| 26. Break even | 3.18 ± 0.80 | 3.13 ± 0.79 | 3.44 ± 0.88 |
| 27. Market research | 3.37 ± 0.75 | 3.13 ± 0.79 | 3.54 ± 0.81 |
| 28. Competitive analysis | 3.29 ± 0.86 | 2.94 ± 0.95 | 3.47 ± 0.71 |
| *29. Target market* | *3.35 ± 0.87* | *3.00 ± 0.80a* | *3.70 ± 0.65[a]* |
| 30. Product positioning | 3.19 ± 0.88 | 2.97 ± 0.90 | 3.48 ± 0.79 |
| 31. Product distribution | 3.10 ± 0.84 | 2.90 ± 0.91 | 3.18 ± 0.77 |
| 32. Advertising and promotion | 3.11 ± 0.89 | 2.97 ± 0.74 | 3.32 ± 0.82 |
| 33. Sales and selling | 3.16 ± 0.85 | 3.00 ± 0.79 | 3.34 ± 0.77 |
| *34. Executive summary* | *2.82 ± 0.84[a]* | *3.15 ± 0.83* | *3.64 ± .80[a]* |
| 35. Business plan | 3.15 ± 0.83 | 2.94 ± 0.90 | 3.35 ± .90 |
| *36. Business models* | *2.89 ± 0.90[a]* | *2.91 ± 0.91* | *3.46 ± .86[a]* |
| 37. Business incubator | 2.69 ± 0.90 | 2.52 ± 0.80 | 2.98 ± 0.89 |

*Note.* Students included in the analysis reported taking at least one entrepreneurship course (n=145). Statistical differences in ratings ($p < 0.05$) between institutions are indicated by shaded rows and data with identical superscripts. Data shown is mean ± standard deviation.

***Table 2. Comparisons of Students' Self-rated Knowledge of Entrepreneurship-related Terms and Concepts by Institution and Program Model.***

courses from the multidisciplinary program (University 3) reported higher levels of entrepreneurial knowledge than those from the engineering-based programs (Universities 1 & 2) for all but one item (item 16: prototype). No significant differences in self-ratings of entrepreneurial knowledge were found between the two engineering-based programs. Comparisons of students from different institutions who had taken at least one entrepreneurship course showed the largest differences for the following terms: *executive summary, target market, income statement, economies of scale, balance sheet, equity, finance and accounting, product life cycle, and legal structures for ventures.*

Terms and concepts were grouped by category and program comparisons were made for students who had taken at least one entrepreneurship course. This analysis shows that in 4 out of 6 categories (General Entrepreneurship, Business, Finance, and Marketing; Figure 5), students at University 3 (multidisciplinary certificate) rated themselves significantly higher than those at Universities 1 and 2 (engineering-based programs). Interestingly, no significant differences were found in the categories Engineering and Professional. No significant interactions were found between the number of entrepreneurship courses taken by students and the three institutions ($p$ = 0.64) indicating that differences in student ratings of entrepreneurial knowledge were not confounded by potential differences in the number of courses taken by students at those institutions.

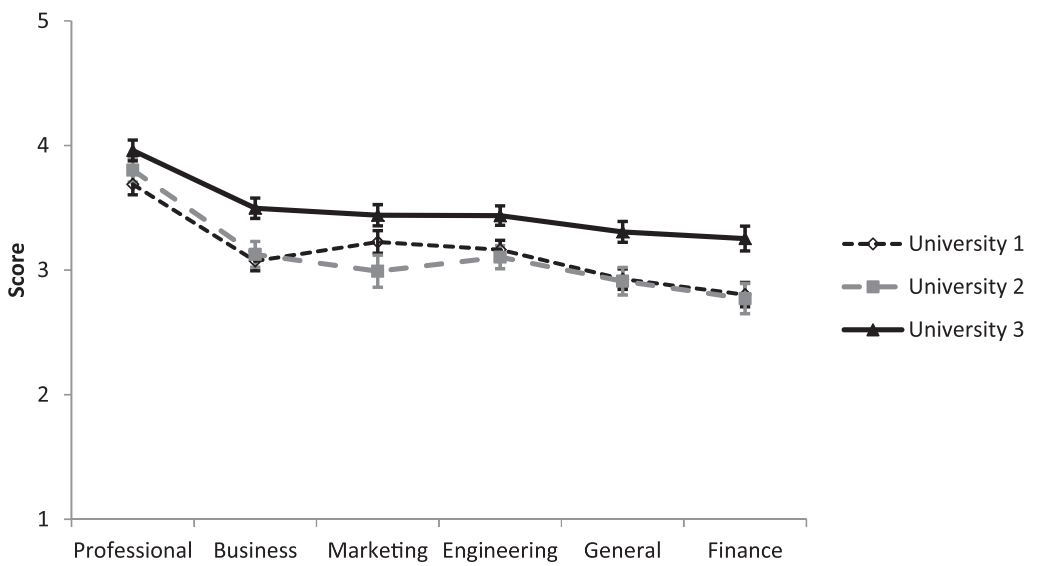


***Figure 5. Comparison of students' self-rated knowledge of 37 terms and concepts grouped by category. Students included in the analysis had taken at least one entrepreneurship course (n=145). *University 3 scores are significantly higher than University 2 (p<0.01). †University 3 scores are significantly higher than University 1 (p<0.01).***

Students from each institution were also asked to rate their level of confidence on a scale from zero to ten in performing 15 tasks that were derived from a venturing and technology self-efficacy scale (Lucas et al., 2009). Overall, the average confidence level ranged between 5.05 (medium) and 8.19 (high). Students expressed the lowest confidence levels for business and financial tasks, and the highest for technological and scientific tasks (Table 3). Students in the multidisciplinary program rated their confidence significantly higher than engineering-based programs on four business related tasks: *estimating financial value of a new venture*, *picking a marketing approach for a new service*, *cost estimation of a new project*, and *writing a business plan*.

***Question 2. What is the incremental value of an engineering student taking more than one entrepreneurship course?***

Analysis examined the effect of the number of entrepreneurship courses on student confidence levels for 15 items that comprise the venturing and technology self-efficacy scale (Lucas et al.,

| | University 1 | University 2 | University 3 |
|---|---|---|---|
| N | 62 | 33 | 50 |
| Know the steps needed to place a financial value on a new business venture | 5.05 ± 2.38[a] | 5.30 ± 2.10 | 6.50 ± 2.31[a] |
| Pick the right marketing approach for the introduction of a new service | 5.67 ± 2.52[a] | 5.82 ± 2.19 | 7.00 ± 2.37[a] |
| Work with a supplier to get better prices to help a venture become successful | 6.33 ± 2.43 | 6.18 ± 2.07 | 7.38 ± 2.30 |
| Estimate accurately the costs of running a new project | 5.75 ± 2.54[a] | 6.13 ± 2.11[b] | 7.46 ± 2.09[ab] |
| Recognize when an idea is good enough to support a major business venture | 6.75 ± 2.77 | 6.94 ± 2.52 | 7.42 ± 2.09 |
| Recruit the right employees for a new project or venture | 6.68 ± 2.38 | 7.42 ± 2.36 | 7.40 ± 2.04 |
| Convince a customer or client to try a new product for the first time | 7.10 ± 2.28 | 7.24 ± 2.45 | 7.60 ± 2.09 |
| Write a clear and complete business plan | 5.90 ± 2.51[a] | 6.64 ± 2.36 | 7.60 ± 2.27[a] |
| Convert a useful scientific advance into a practical application | 6.93 ± 2.64 | 7.09 ± 2.16 | 7.69 ± 2.18 |
| Develop your own original hypothesis and a research plan to test it | 7.28 ± 2.42 | 7.03 ± 2.40 | 7.73 ± 2.38 |
| Grasp the concept and limits of a technology well enough to see the best ways to use it | 7.67 ± 2.29 | 7.27 ± 2.07 | 7.85 ± 2.05 |
| Design and build something new that performs very close to your design specifications | 7.70 ± 2.47 | 7.42 ± 2.29 | 8.06 ± 1.80 |
| Lead a technical team developing a new product to a successful result | 7.58 ± 2.44 | 7.76 ± 2.05 | 8.13 ± 1.91 |
| Understand exactly what is new and important in a groundbreaking theoretical article | 7.15 ± 2.24 | 7.00 ± 2.21 | 7.90 ± 1.98 |
| Translate user needs into requirements for a design so well that users will like the outcome | 7.75 ± 2.05 | 7.24 ± 1.90 | 8.19 ± 1.92 |

*Note*. Students included had taken at least one entrepreneurship course (n = 145). Statistical differences in ratings ($p < 0.05$) between institutions are indicated by shaded rows and data with identical superscripts.

***Table 3. Comparisons by Institution: Students' Self-reported Confidence Levels in Their Ability to Perform Different Tasks.***

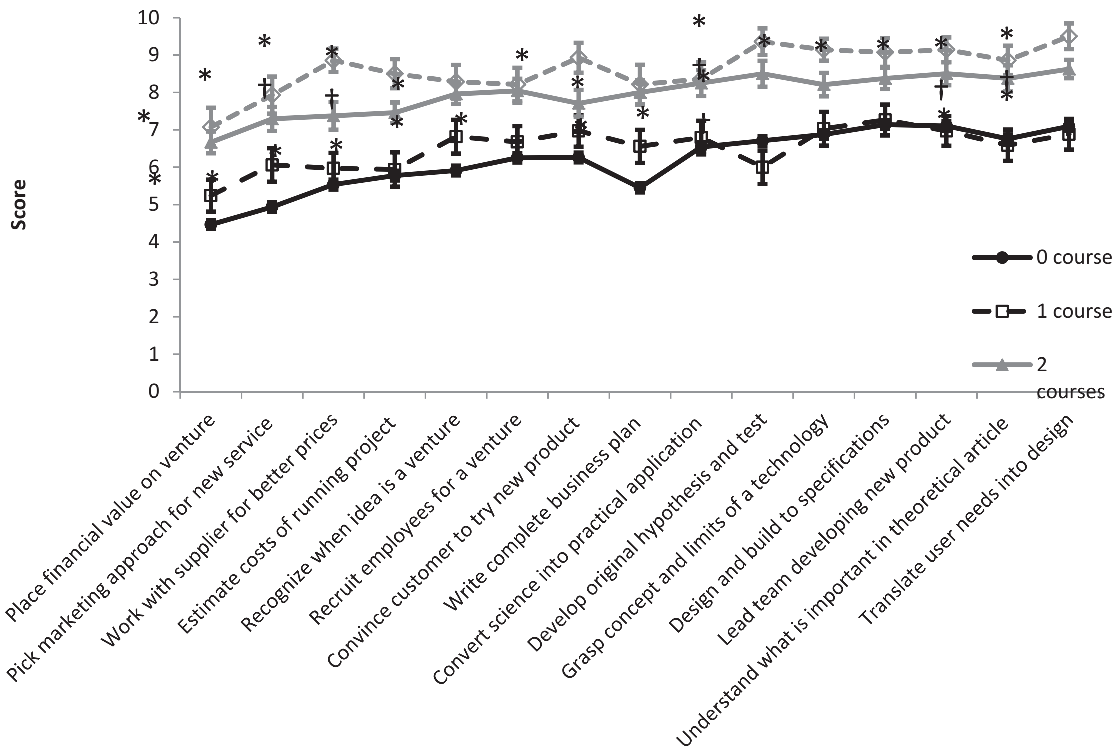


***Figure 6. Comparisons by number of entrepreneurship courses taken: Students' self-ratings on Lucas' venturing and technology self-efficacy scale (Lucas et al., 2009). *Indicates student self-efficacy is significantly higher compared with those who took no entrepreneurship courses (p<0.05). †Indicates student self-efficacy is significantly higher compared with those who took one entrepreneurship course (p<0.05).***

2009). Results showed that students who took three or more entrepreneurship courses were significantly more confident in their ability to complete 13 out of 15 tasks than students who took just one course ($p$<0.01; Figure 2). Similarly, students who took two courses were significantly more confident than those who took one or none on 11 out of 15 tasks ($p$<0.01). Also, students who took two entrepreneurship courses were more confident in their ability to develop their own original hypothesis and research plan to test it when compared to students who took only one entrepreneurship course ($p$<0.01). No significant difference was found between students taking one or no entrepreneurship courses.

Student ratings of their entrepreneurial knowledge or skills in six categories show that taking at least one entrepreneurship course raised their levels significantly in five of the six categories with the one exception being Professional ($p$<0.01; Figure 3). However, no significant difference

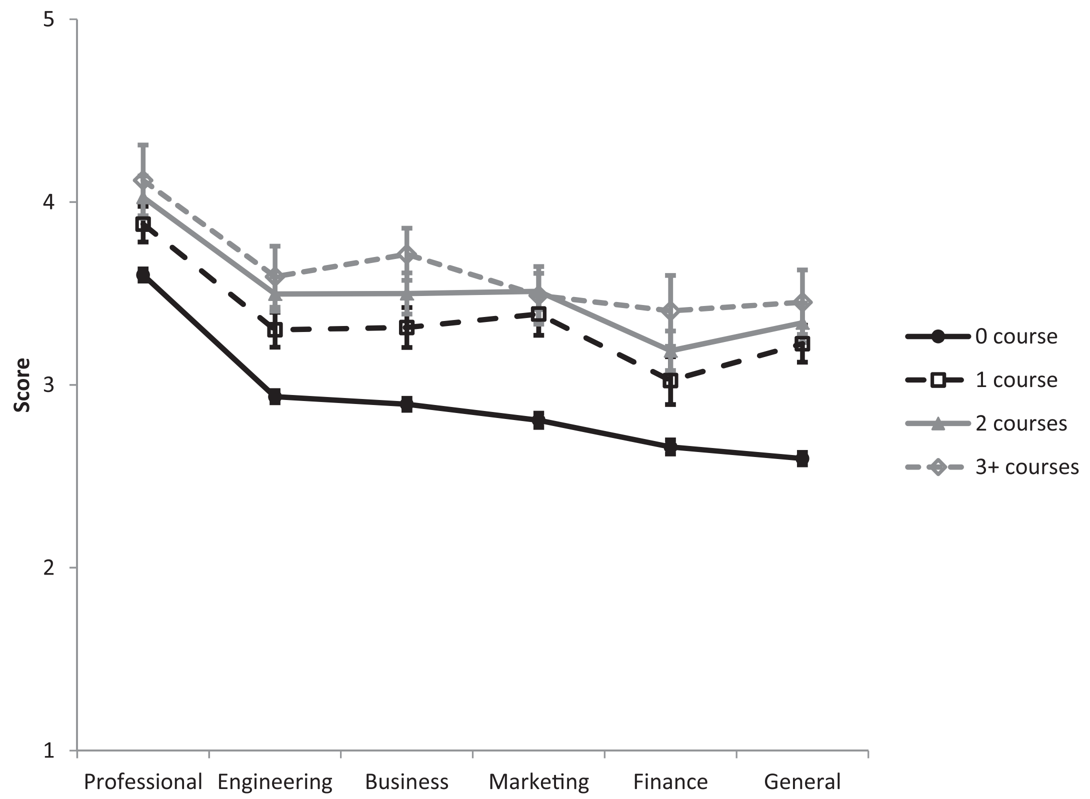


***Figure 7. Effect of number of entrepreneurship courses taken on knowledge or skill relative to categories of terms and concepts grouped into six general categories. *Significantly different from 1, 2, and 3+ courses (p<0.01).***

in self-ratings were found between students who took just one course and those who took two or more entrepreneurship courses.

***Question 3: To what degree do experiential activities contribute to higher self-efficacy for entrepreneurship or the desire to be an entrepreneur?***

To examine the association of specific experiential learning or extracurricular activities to students' perceived ability for entrepreneurship, analyses were conducted to compare the differences in students who had and who had not participated in various experiential learning activities. Two survey items were used to assess overall entrepreneurship ability: "How do you rate your overall entrepreneurial ability?" and "How do you rate your ability to start a business now?" The results show that activities with the largest effect were *writing a business plan*, *participating in an entrepreneurial competition*, *pitching a business idea to a panel of judges*, *participating in* *entrepreneurship workshops* and *involvement in entrepreneurship-related student organizations* ($p$ < 0.001; Figures 8 & 9).

Participation in experiential learning activities increased the average self-rated ability score significantly (between 0.94, p<0.01) in all but one category, *protecting intellectual property*. Most students who did not participate in an activity rated their overall entrepreneurship ability below average (mean score = 2.3). Students who took at least one entrepreneurship course while in college rated their overall entrepreneurial ability (3.34 ± 0.91; n=141) and ability to start a business now (2.91 ± 1.15; n=142) significantly higher than students who did not take any entrepreneurship courses (2.68 ± 1.02, n=338 and 2.22 ± 1.05, n=337, respectively). However, there was no significant

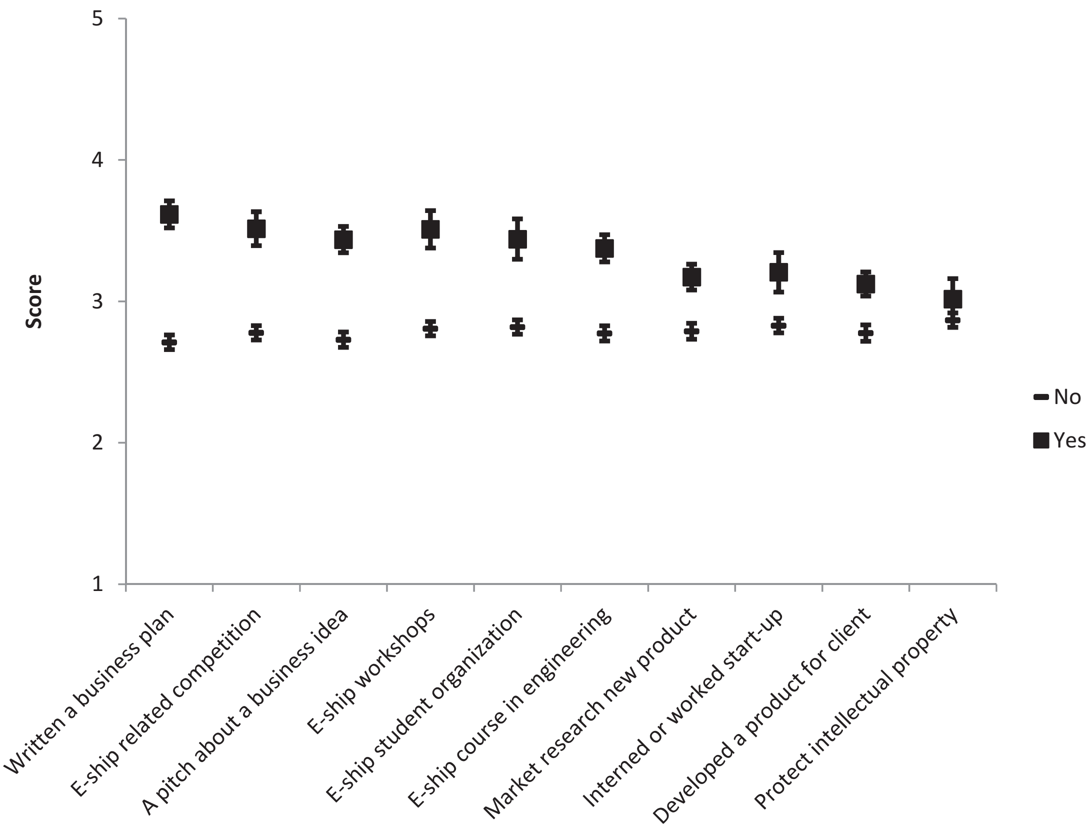


***Figure 8. Student ratings of their "overall entrepreneurial ability": Comparisons based on participation in entrepreneurship-related experiential learning or extracurricular activities during college. Yes=students who participated in the activity. No=students who did not participate in the activity.***

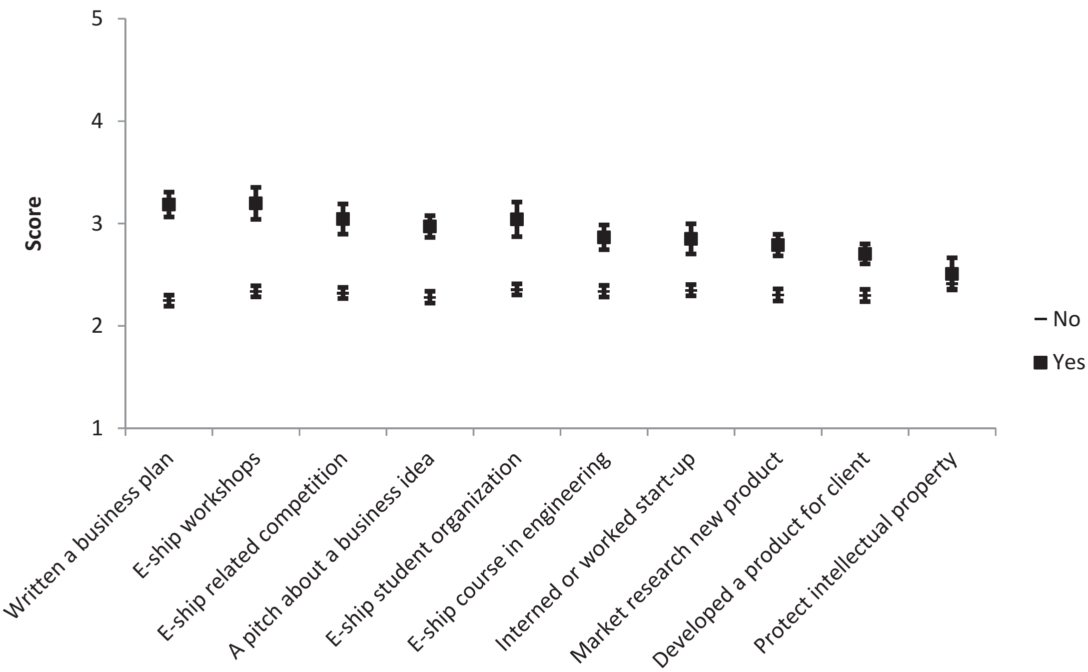


***Figure 9. Student self-ratings of their "ability to start a business now": Comparisons based on whether or not students participated in entrepreneurship-related experiential learning or extracurricular activities during college. Yes=students who participated in the activity. No=students who did not participate in the activity.***

interaction between experiential learning activities and entrepreneurship courses taken on perceived business ability.

## DISCUSSION

The purpose of this paper was to explore the characteristics of entrepreneurship program models that are most effective for engineering students in order to provide engineering faculty and administrators with factors to consider when developing entrepreneurship curricula or programs. It is based on research that examines how several aspects of entrepreneurship programs, including disciplinary focus, participation in experiential learning, and number of courses taken impact student perceptions of their entrepreneurial knowledge and self-efficacy. As highlighted, the heterogeneity of entrepreneurship education, as well as curricular constraints associated with engineering programs, make it difficult to prescribe a single "right" model that will suit all students and institutions. Nevertheless, the literature review and the analysis presented in this paper provide a useful foundation for conversations and additional research related to: (1) how entrepreneurship education programs for engineers should be structured and administered, (2) the extent to which content and pedagogy should be tailored specifically to engineers, and (3) the number of courses and/or experiential learning programs that may be involved in meeting outcomes.

Results from this study suggest that engineering students may benefit from being involved in multidisciplinary entrepreneurship courses. While differences were not all statistically significant, engineering students who took at least one course as part of a multidisciplinary program rated their knowledge of select entrepreneurial terms and concepts higher than those in engineering-based programs. These students also indicated more confidence in their ability to perform several business-related tasks that were part of a 15-item venturing and technology self-efficacy scale. They also had higher mean ratings for engineering-based tasks that were part of the scale. Therefore, it appears that integrating multidisciplinary entrepreneurship courses may be a way to provide engineering students with broader exposure to business concepts, without compromising engineering-related entrepreneurial knowledge. More research across a broader sample of programs is necessary to make definitive statements about whether multidisciplinary or discipline-specific programs are more effective.

It is also important to note that there are a number of factors beyond program models that could account for differences in student perceptions of their entrepreneurial self-efficacy that are not accounted for in this study. For example, individual universities may draw students with different levels of confidence or academic achievement which might influence perceptions of entrepreneurial self-efficacy. There may be differences in curriculum, pedagogy, activities, or faculty. The multidisciplinary learning environment could also influence engineering student perceptions of their own ability relative to non-engineers; for example, finance may come easy to engineering students given their strong quantitative and analytical backgrounds, as compared to students who have less confidence in these areas. Another possibility is that the university with the multidisciplinary program may have attracted more entrepreneurial students due to its reputation, culture, or marketing of programs. Further, the characteristics and expertise of faculty teaching in entrepreneurship programs can have a significant difference in outcomes based on their beliefs and instructional methods (Zappe et al., 2013). Non-engineering faculty may emphasize business and financial skills or *innovation outcomes* more heavily in their teaching than engineering professors, who are likely to emphasize the *innovation process*. Future research should explore and account for these factors.

In terms of "how much" entrepreneurship education is necessary, the data indicate that there are incremental benefits to engineering students taking more than one course. Previous analysis of this dataset found significant differences in many knowledge and self-efficacy items between students who had taken at least one entrepreneurship course and those who had taken none (Duval-Couetil et al., 2012). This more granular analysis focuses on the incremental benefits of each additional entrepreneurship course taken, and shows that there is a clear "dose effect." Students taking two and three or more entrepreneurship courses were significantly more confident in their ability to complete a broad range of tasks associated with the venturing and technology self-efficacy scale versus students who had taken fewer than two entrepreneurship courses. Interestingly, students taking one course in entrepreneurship rated their knowledge of entrepreneurial terms and concepts significantly higher than those who took no courses; however, the incremental benefit of taking two or more courses was largely insignificant. This suggests that these particular survey items and their corresponding 5-point response scale (poor to excellent) may have captured familiarity with terms, but not depth of knowledge. While more research, and in particular longitudinal research, is necessary to determine how much entrepreneurship education will result in an engineer behaving entrepreneurially or becoming an entrepreneur, it seems that student knowledge level increases readily after only one course but their ability to confidently perform entrepreneurial tasks increases after taking at least two courses.

Experiential activities commonly associated with entrepreneurship education appeared to increase students' perceptions of their entrepreneurial self-efficacy and should be integrated into courses and programs. No one particular activity stood out, however, students who had written a business plan, participated in a competition, presented a pitch, or participated in an entrepreneurship-related student organization rated their ability for entrepreneurship higher than those who did not. Participation in intellectual property protection was the one exception where there was no significant difference in perceived ability between students who had and had not participated in the activity. This may reflect the complex nature of intellectual property and the difficulty students have in determining if they are "good" at it. Future research should analyze the specific knowledge, skills and behaviors associated with experiential learning activities in entrepreneurship to arrive at a better understanding of the manner in which they impact competency, self-efficacy, and intention to be an entrepreneur. There are also new entrepreneurship-related experiential learning activities increasingly being integrated into engineering programs which have not yet been reported on extensively in the literature. Future research should examine the effectiveness of using experiential learning versus didactic approaches to teach entrepreneurship to engineers.

A limitation to this study is that it relies on self-report data, which is common in the field of entrepreneurship education. Additional research is necessary to determine the degree to which indirect assessments such as surveys, align with more direct methods of assessment that require students to demonstrate competency and mastery of knowledge and skills. Another limitation of this study is that it relies on a sample of engineering students that has a higher proportion of students who took entrepreneurship courses than might be found in the general population of engineering students across the three institutions. This occurred due to the purposive sampling procedures which were used to ensure adequate representation of students in each group, as well as the voluntary nature of participation. A challenge associated with this work includes defining the proper measures and outcomes for entrepreneurial engineers across diverse programs and time periods (e.g., post-graduation). Future research must attempt to address such limitations and challenges.

Categorizing contemporary entrepreneurship education programs for research purposes is another challenge as they are continually expanding and changing. For example, since the data for this research was collected, both engineering-based entrepreneurship programs in this study have begun to expand to university-wide programs. Also, the multidisciplinary program, which was comprised of 15% engineering students when the study was conducted, now has 27%. Even defining a program model is challenging; for example, the multidisciplinary program in this study could be considered a hybrid model because to meet program requirements, engineering students can choose to combine multidisciplinary foundational courses in entrepreneurship with engineering-based elective courses. Generally speaking, across the U.S., there is movement toward more multidisciplinary entrepreneurship programs based on an assumption that there is value in bringing students with different knowledge, skills, and perspectives together and these experiences better prepare them for the environments in which they will work (Pirrie, Hamilton, & Wilson, 1999).

From a program development and administration standpoint, a primary challenge for engineering programs is how to make entrepreneurship accessible to students given existing, very full academic programs and limited room for the integration of additional or optional credit hours. Another is how to make it a priority given other administrative and curricular priorities and constraints (e.g., budget and accreditation). While multidisciplinary entrepreneurship programs appear to have advantages, there can be challenges associated with implementation, including the administrative structures and funding models that support them. However, working across disciplines appears to result in benefits for students. To better understand why this is the case, more research into the curriculum, pedagogy and faculty behind these programs is necessary.

## CONCLUSION

The movement to integrate more entrepreneurial knowledge and skills into engineering education is growing. It is driven primarily by a belief that equipping engineers with a broader range of skills will help them create value in a new economy. Program models to deliver entrepreneurship education to engineering students can vary greatly based on the degree to which they are engineering-based or multidisciplinary and the type and number of courses and activities they encompass. This research suggests that: 1) multidisciplinary programs may be a way to provide students with broader exposure to business concepts that are pertinent to engineers; 2) participation in entrepreneurship-related experiential activities should be integrated into courses and programs directed at engineers; and 3) at least two courses are necessary for engineering students to feel confident about performing entrepreneurial tasks. Given the challenges associated with integrating new learning into very full academic programs, it is important that entrepreneurship education delivered to engineering students be impactful. This study provides a foundation for further research into the type and quantity of entrepreneurship education that is best suited to achieve this.

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