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A Comprehensive Review of Entrepreneurship Course Offerings in Engineering Programs

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Abstract

Entrepreneurship education is becoming increasingly important in engineering schools. This is a trend that started several years ago in the U.S. and is also spreading internationally. This trend appears to be due to the fact that engineers are responsible for providing solutions to enhance the quality of life for people worldwide and for facing the challenges related to that responsibility. As society develops we face new challenges, which call for varied and innovative approaches to solve these problems. This is further confirmed by the National Academy of Engineers' book titled "The Engineer of 2020", which the clearly discusses the changing role of the engineer in 2020 [7].

This process of evolving as a profession cannot be achieved unless an entrepreneurial mindset is created amongst the engineers of 2020 and beyond. To foster this entrepreneurial mindset, engineering programs are undertaking various initiatives. However, there is no clear agreement regarding the entrepreneurship content that should be included for engineers.

In this paper, the authors have done a comprehensive review of entrepreneurship course offerings in engineering programs. This includes analyzing whether the programs are offered by the engineering schools themselves or in partnership with a business school and what other offerings they have for their students in addition to course work. This enabled the authors to identify patterns about the required coursework that might be included in engineering programs. The authors make recommendations on how the current offerings can be improved to be able to create the entrepreneurial mindset for the engineering graduates.

Introduction

Encouraging creativity within engineering students is an apt concern for educators as modern 21st century living is fraught with considerations that require solutions that meet or exceed standards of sustainability for an environment already overburdened with problems like pollution, hazardous materials generation, global warming, etc. Every new engineering novelty designed to make life easier creates a new set of problems with respect to potential waste streams or other areas of long term sustainability. Additionally, in a business environment where consumers have changing needs, engineers need to be able to think creatively to meet those needs. Thus, it is both the goal and the challenge for engineering students and educators alike to build creativity into the front end of teaching endeavors, research endeavors, and professional endeavors.

Few engineering endeavors are done without the idea of a cost-benefit analysis, which businesses utilize to determine if they will make profits enough to start, innovate, and sustain production. Engineers of the 21st century thus need to realize that they need to think beyond just the technology involved in a product or service. They need to be able to provide this product or

service at a price/value that would be acceptable to a potential customer. In order to create a value perception based on the cost-benefit analysis, engineers need to hear the voice of the customer, understand the customer need and then think of innovative ways in which they can address this need.

Importance of Creativity, Innovation and Entrepreneurship for Engineers

Creativity has been a controversial issue due to different understandings of the concept. As Cropley [1] stipulates, creativity is defined as a process of creating and expanding upon new ideas. As society develops, we face new types of challenges. Of course, new challenges call for effective approaches. To draw a solution for new issues, creativity is a vital skill. Engineers are educated to solve well-defined, analytical problems and often little attention is given in engineering programs to the complimentary skills, attitudes, and abilities in creativity that are critical to developing effective and novel solutions.

Creativity, innovation, and leadership are among the vital attributes of forthcoming engineers as identified in the engineer 2020 report by the National Academy of Engineering [7]**.** It is critical for students to have the ability to identify new needs and opportunities for technological innovation in highly complex and interdisciplinary domains. Creativity relates to the ability to generate novel and effective solutions to an issue. Creativity can be an answer to either a question we faced a long time ago and came up with an efficient answer, or to a new question posed by modern society. Particularly, creativity plays a vital role in engineering schools. Students deal with a diverse set of problems every day, which requires creativity. Although, in the 1990's, the National Science Foundation (NSF) set forth an alliance between engineering schools to promote creativity, there is little support today for engineering students among schools in the United States to address the issue of creativity [1]. Similarly, it is also thought that some engineering degrees could possibly reduce creativity among the students due to the degree's rigidity [1]. Hence, it could be beneficial to offer creativity courses from the undergraduate level in engineering [1].

Creativity also enters into the equation when considering that 21st century engineering students must face the changing landscape of global sustainability, most notably typified by modern issues like global warming, the drive to use more easily recyclable products, increasing manufacturing costs, and a labor force capable of producing high quality products in countries that are still developing technologically.

Creativity also has a hand in forcing emerging process technologies to match business models that address evolving product life cycles. For this, some young engineers might find themselves within the interdisciplinary realm of working with other scientists and technicians in the modeling and simulation phase of product development or process development using visualization. Sicard, Shariatzadeh & Lindberg [2] find that the use of visualization in project

teams during the development of new processes or products stimulates the possibility of common coincidental images of a future product or process. This then is the very essence of creativity as applied to engineering processes both at the student level as well as at the seasoned professional level as well.

Defining Innovation

Innovation can be considered as the output of creativity and thus innovation cannot happen unless there is creativity. As mentioned earlier, since engineers need to incorporate innovative solutions to meet growing customer needs, both creativity and innovation are increasingly becoming a necessity for the 21st century engineer to not only be aware of but know how to implement. The National Science Foundation (NSF) defined the process of innovation as the introduction of new or significantly improved products, processes, organizational methods, and marketing methods in internal business practices or the marketplace and described it as complex and conceptualized in different ways [3]. Technological Innovation is a subset of innovation that draws heavily on the scientific and engineering knowledge to create value for society. Technical Innovation involves the following stages [3]:

- Research
- Proof of Concept
- Early Stage Technology Development
- Product Development
- Commercialization

It is clear from the above steps that engineers are a critical catalyst in making technical innovation happen. However, the Innovation Ecosystem (shown in Figure 1), of which technical innovation is a small piece, is extremely complex and creates a number of intricacies.

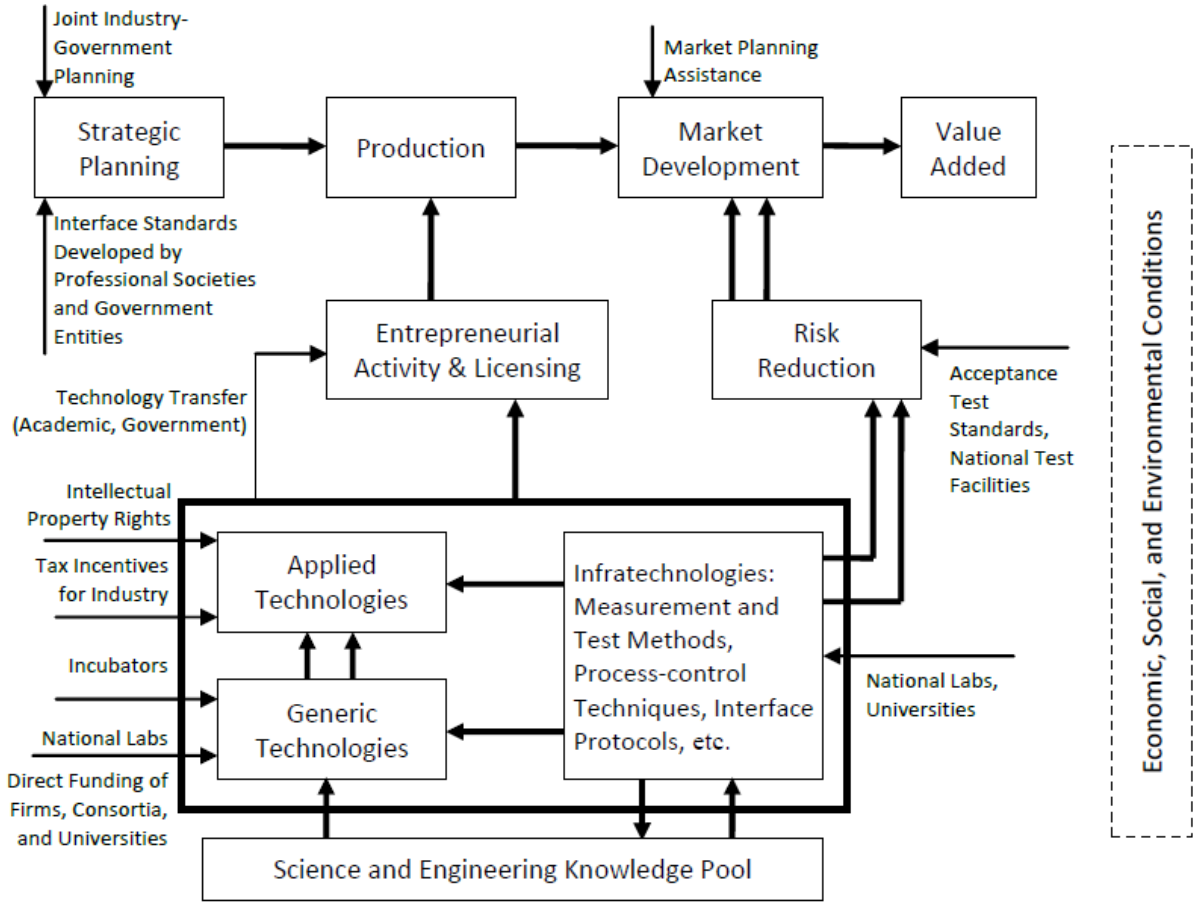

Figure 1: Representation of U.S. Innovation Ecosystem (adapted from [3, 4])

In the 21st century, engineers have to not only understand technical innovation but also understand how it would integrate into and be part of the larger Innovation Ecosystem. This is not a trivial task considering the complexity and interconnectedness of the Innovation Ecosystem. In order to be able to comprehend this mammoth task, engineers would be required to be able to "think outside the box" and far beyond just the technology piece that they are traditionally accustomed to doing. This requirement becomes far more pronounced as they transition from being engineers to engineering managers.

In order to be able to fulfill this requirement, engineering students should be exposed to ideas such as the innovation process based on design thinking as shown in Figure 2. This was developed by Osorio. [5]

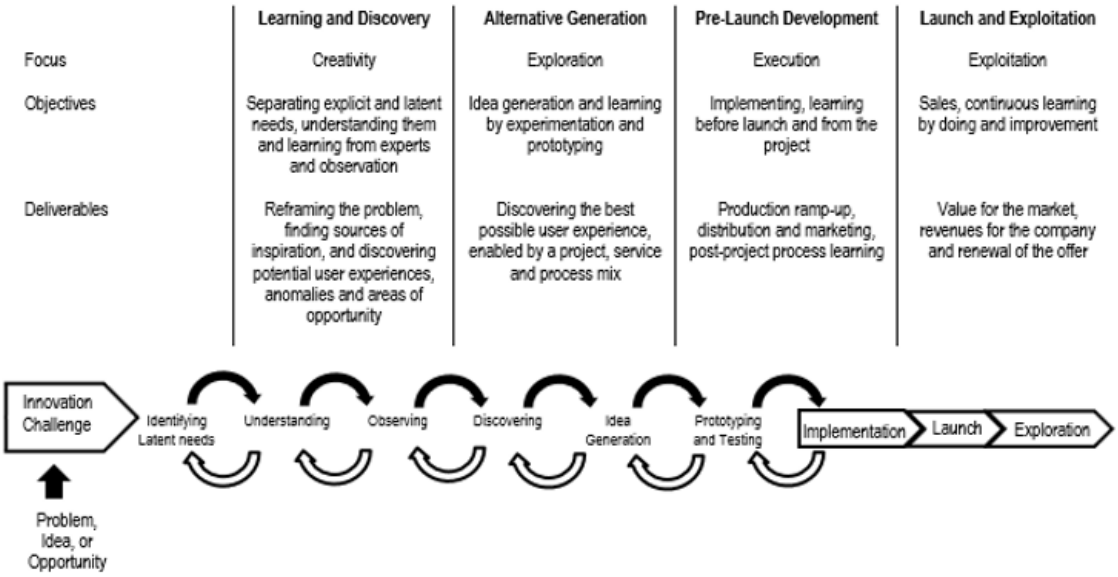

Figure 2: Innovation Process based on Design Thinking (adapted from [5])

In considering the use of Osorio's General Model of Innovation Process based on Design Thinking, it is obvious that it could be applicable to engineering education and therefore incorporated into the engineering education curriculum. Similarly, Bhatti's model of frugal innovation, shown in Figure 3, demonstrated the interaction between engineering and business competencies.

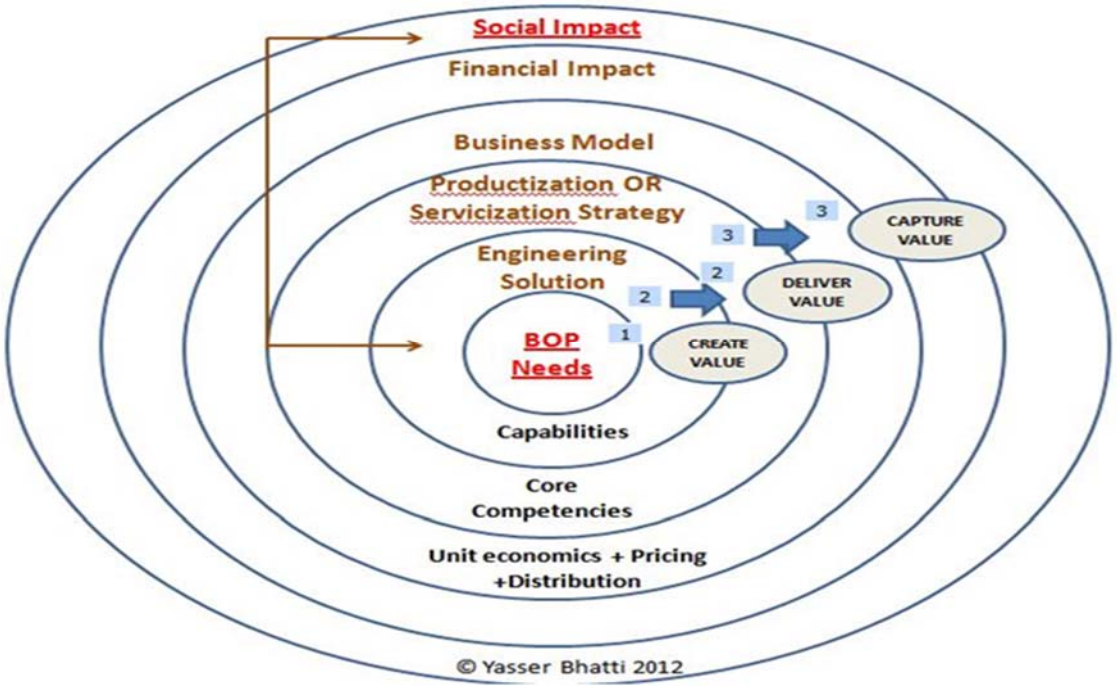

Figure 3: Bhatti's Model of Frugal Innovation (Adapted from [6])

Figure 3 shows that for an engineer to design a successful product that would add value to his/her organization it is important to understand both the engineering as well as the business aspects related to it. This model demonstrates the marriage of capabilities, core competencies, and business economics as they interact between engineering and business endeavors. This model correctly assumes that engineers must have a more than passing grasp of business acumen to make their products innovative, competitive, and conducive to a long term problem-solving lifespan**.**

The types of models described above are already in widespread use in the creation and production of new and emerging technologies. However, the downside is that relatively few engineering programs incorporate these kind of creativity and innovation models in their curriculum at the undergraduate or even the graduate level. Considering this challenge, the authors of this paper decided to embark upon an initial study to evaluate the offerings of innovation and entrepreneurship in Schools of Engineering versus in Business Schools.

Analyzing Trends of Innovation and Entrepreneurship Course offerings in Engineering Programs versus Business Programs

During an initial evaluation of the top 10 engineering schools, as identified by the US News & World Report in 2015, it was observed that many more universities offer programs in innovation and entrepreneurship (I&E) in their College of Business versus in their College of Engineering. This was judged based on an evaluation of both the engineering and business school curriculums at top schools such as Stanford University, Duke University as well as others. Table 1 shows in the top 10 universities [8], where the innovation and entrepreneurship programs were offered.

Table 1: Offerings of I&E programs in Engineering and Business Schools at the top 10 universities

Ranking	Name of University	Engineering School offering I & E Courses/ Program	Business School offering I & E Courses/ Program
1	Massachusetts Institute of Technology	NO	YES
2	Stanford University	YES	YES
3	University of California—Berkeley	NO	YES
4	Carnegie Mellon University	YES	YES
5	California Institute of Technology [9]	YES	NO
6	Georgia Institute of Technology	NO	YES
7	Purdue University—West Lafayette	NO	YES
8	University of Illinois—Urbana-Champaign	YES	YES

9	University of Michigan—Ann Arbor	NO	YES
10	University of Southern California (Viterbi)	NO	YES

From the universities listed in Table 1, only 4 out of the top 10 universities offered I & E courses or programs in their Colleges of Engineering. However, all schools, with the exception of California Institute of Technology [9], offered I & E courses in the business school. This shows some indication of the increased importance schools of business give to I&E education versus schools of engineering. Considering the importance of I&E to engineers that the authors have discussed in this paper, this is indeed an alarming trend. The only engineering school from the top 10 that does give considerable entrepreneurship resources to its engineering students, from varied sources is California Institute of Technology [9] where they are provided by The Office of Technology Transfer & Corporate Partnerships (OTTCP). The authors felt that this was a unique approach and should be looked into further.

As a result, of this trend, the authors decided to look at the I&E curriculum offered by the top 50 universities [8]. The top 50 schools were selected on the basis of U.S. News Rankings. Evaluating the I&E curriculum included searching for any courses or minors, as well as checking if these courses/minors/programs were offered by the College of Engineering, College of Business, or by another school of the university. This was done by extensive research on the university websites – for the college of engineering, college of business as well as searches for any independent centers run by the university, viz, centers of innovation and entrepreneurship that might be independent of any college on the university campus. Attempts were made to reach contact people at various universities via phone and email but the responses were extremely slow and hence it was decided to use the information that was collected from the respective websites. However, in the future research section of this paper, the authors have talked about comparing I&E course offerings in Engineering versus Business and for that purpose phone interviews will have to be conducted. The findings of the extensive search done for the purpose of this paper are provided in Table 2 and helped the authors get an initial insight into the research question they posed which was, “Considering the increasing importance being given to innovation and entrepreneurship in engineering education, how would we rate the current offerings of these courses to engineering majors at the undergraduate level?” The findings from the data collected show that only 18 out of the 50 schools evaluated offer I&E courses for undergraduate students in the college of engineering. This suggests that only about a third of engineering schools consider it necessary to offer stand-alone courses in the engineering college versus just relying on entrepreneurship courses offered by the college of business. The authors consider this an important distinction as they feel that entrepreneurship taught in the college of engineering may different significantly from entrepreneurship taught in the college of business; specifically, there may be more focus on experiential learning with tasks such as making and building prototypes integrated into the entrepreneurship curriculum within the engineering school vs. the business

school. This focus on innovation and entrepreneurship through colleges of engineering would fill a void to promote manufacturing and potentially bring back many lost jobs to the U.S. as well as increase the competitiveness of the existing manufacturing that is still flourishing in the U.S. [10]

Table 2: Analysis of I&E offerings at top 50 universities in the US.

Name of university	I&E offered in Engineering school	I&E offered in Business school
Massachusetts Institute of Technology	NO	YES
Stanford University	YES	YES
University of California—Berkeley	NO	YES
Carnegie Mellon University	YES	YES
California Institute of Technology	YES	NO
Georgia Institute of Technology	NO	YES
Purdue University—West Lafayette	NO	YES
University of Illinois—Urbana-Champaign	YES	YES
University of Michigan—Ann Arbor	NO	YES
University of Southern California (Viterbi)	NO	YES
University of Texas—Austin	NO	YES
Texas A&M University—College Station	NO	YES
Cornell University	NO	YES

Name of university	I&E offered in Engineering school	I&E offered in Business school
Columbia University (Fu Foundation)	NO	YES
University of California—Los Angeles (Samueli)	NO	YES
University of Wisconsin—Madison	NO	YES
University of California—San Diego (Jacobs)	NO	YES
Princeton University	YES	NO
University of Pennsylvania	YES	YES
Harvard University	YES	YES
Northwestern University (McCormick)	YES	YES
Virginia Tech	NO	YES
University of California—Santa Barbara	YES	NO
University of Maryland—College Park (Clark)	NO	YES
Johns Hopkins University (Whiting)	YES	NO
Pennsylvania State University—University Park	YES	YES
University of Washington	YES	YES
Duke University (Pratt)		YES
North Carolina State University	NO	YES
University of Minnesota—Twin Cities	NO	YES

Name of university	I&E offered in Engineering school	I&E offered in Business school
Rice University (Brown)	YES	YES
Ohio State University	NO	YES
University of California—Davis	NO	YES
University of Colorado—Boulder	NO	YES
Vanderbilt University	YES	YES
Yale University	NO	YES
Boston University	NO	YES
University of California—Irvine (Samueli)	NO	YES
Arizona State University (Fulton)	NO	YES
Iowa State University	NO	YES
Northeastern University	NO	YES
University of Florida	NO	YES
University of Pittsburgh	NO	YES
Case Western Reserve University	NO	YES
New York University	YES	YES
Brown University	YES	YES

Conclusions and Future Work

This is an initial exploratory study to get a high level understanding of the current offerings in entrepreneurship courses through colleges of engineering as well as colleges of business throughout the country. For the most part, engineering colleges allow their students to take

innovation and entrepreneurship courses as electives in the college of business. This could be because of resource constraints and a mentality of "not needing to reinvent the wheel," as well as curriculum expertise that faculty have within the respective colleges.

However, as a result of this approach, for the most part, the courses in innovation and entrepreneurship taken by the engineering students do not necessarily focus on the goal of promoting innovation and entrepreneurship within the engineering domain, particularly in manufacturing for which there has been a strong push from the US government since 2014. For this purpose, the authors will continue this study and will investigate in more detail the actual course offerings in the programs mentioned in Table 2. The future investigation will include a differentiation of the courses offered in innovation and entrepreneurship in the business school versus courses offered in I& E in the engineering schools? The important research question to be asked here is, "How do the offerings of I&E courses in Engineering Schools and Business Schools vary?" This detailed investigation can be seen as an opportunity for engineering schools to possibly collaborate closer with business schools and will be used to analyze those offerings and to develop guidelines on how technical innovation and entrepreneurship curricula can be implemented in engineering schools across the country. This will include the investigation of unique entrepreneurship course offerings and other resources at schools such as Cal Tech. The goal will be to identify a set of courses or other curricula approaches that strike a balance between the technical and business aspects of innovation and entrepreneurship. The ultimate goal of such a curriculum is to enable engineers to understand the technical and business aspects of entrepreneurship that are required in order to bring value to their organizations and thus make the engineers more valuable assets to their organizations.

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